EFFECTS OF CANNABIS ON COMPLEX INTELLECTUAL FUNCTIONING

by Neville A. Taylor

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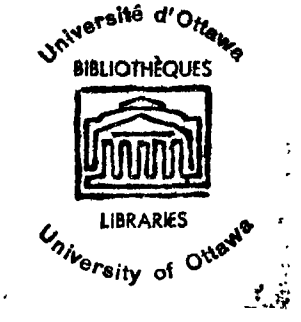

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ABSTRACT OF

Effects of Cannabis on Complex Intellectual Functioning[1]

In the present study an attempt was made to examine possible differential effects of smoked marijuana on tests representing each of the five operations categories of J. P. Guilford's Structure of Intellect model. The study also sought to examine the effects of the drug on attention, and to resolve arguments in the literature concerning its effects on memory.

The Digit Span test and six Structure of Intellect tests were administered to 40 male cannabis users, under placebo, low dose, high dose, and control (no drug) conditions. Ten subjects were retested under a very high dose condition. All tests were administered under double blind conditions, using a repeated measures design in which the order of treatment conditions, the order of tests on each testing occasion, the order of test forms across conditions, and the times of testing were fully counterbalanced. The Otis SA, Test of Mental Ability was also administered under control and high dose conditions.

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1 Neville A. Taylor, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1974, xiii-233 p.

On the basis of recordings of heart-pulse rate changes, subjects' verbal comments, and self ratings on a 0 to 100 scale, it was demonstrated that subjects had actually ingested and had been affected by socially relevant doses of Δ^1THC. Despite this evidence of intoxication, no significant differences were found in the mean scores obtained under the five treatment conditions on any of the measures of intellectual functioning used in this study.

It has been suggested that cannabis does not, in fact, impair performance on any test of any type of intellectual functioning, provided that the test items are clearly circumscribed and of short duration. However, it may impair the capacity of subjects to solve multi-stage goal-directed problems in which they are required to employ a number of intellectual abilities in rapid succession. Finally, it has been suggested that cannabis does affect attention and concentration, but this effect can be controlled if subjects are sufficiently well motivated.

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Preparation of the thesis was carried out under the supervision of Henry P. Edwards, Ph.D., Dean of the Faculty of Psychology, University of Ottawa. The writer is very grateful to Dr. Edwards for his guidance, support and patience. Gratitude is also expressed to George Ling, Ph.D., Chairman, Department of Pharmacology, Faculty of Medicine, University of Ottawa, and to Dr. Michael MacConaill, Assistant Professor at the University of Ottawa, for their advice concerning the pharmacological aspects of this thesis, and for the preparation of the marijuana used in the study.

The writer is also indebted to Mrs. Ouida Kleniewski, R.N., Walter Noe, M.A., and Marc-André Paquette, the three experimenter-assistants in the study, and to Clay Bagwell, laboratory assistant at the Department of Pharmacology, for his work on the quantification of marijuana dosages.

CURRICULUM STUDIORUM

Neville A. Taylor was born in Kingston, Jamaica, on September 10, 1933. He received the Bachelor of Arts degree in Liberal Arts from Sir George Williams University, Montreal, Quebec, in November 1963. He received the Master of Arts degree in Psychology from the University of Ottawa, Ottawa, Ontario, in June 1966.

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INTRODUCTION

It is generally agreed, by those concerned with the history of cannabis, that the first detailed description of this plant is to be found in a Chinese compendium of medicines believed to have been written in the twenty-eighth century B.C. Since that time, references to cannabis drugs, in their various forms, have appeared in the writings of one or more cultures in every period of history, and on every continent of the globe. Until the late 1930s (1923 in Canada), the possession and use of cannabis drugs were legal, if not approved, in many countries of Europe and the Western hemisphere, including the United States.

Although the recreational use of cannabis did not become generally popular in the West until quite recently, its psychotropic properties have long been known. There exists a substantial body of literature, composed of naturalistic observations and personal accounts of the drug's various effects. In addition, a number of good clinical reports and officially sponsored surveys have been written concerning possible mental and physical effects related to its chronic use. While a number of these accounts have subsequently proved to be of real value, many have been extremely biased and inaccurate.

With the notable exception of the "LaGuardia Report" of 1944, it was not until quite recently that a concerted

effort was made to verify these earlier findings by means of scientifically controlled studies. With regard to the behavioral effects of cannabis, laboratory research dates back only as far as 1968. Regrettably, in the approaches taken by various authors to this work, there has been very little in the way of a common system or underlying theoretical rationale. In addition, in many studies, insufficient attention has been paid to a number of important variables which can influence the outcome and interpretation of cannabis research. As a consequence of these failings, there is still remarkably little which can be concluded with certainty regarding the behavioral effects of cannabis; and, in particular, with regard to its effects on intellectual functioning.

The present study is intended to be a first step in a more thorough and systematic investigation of the effects of cannabis on all aspects of intellectual functioning. First, in order that such an investigation may yield meaningful results, it is considered essential that it be carried out within the framework of a comprehensive theory which can serve as a basis for comparing and interpreting findings concerned with the many different types of intellectual functioning. It is felt that J. P. Guilford's Structure of Intellect theory is ideally suited to this purpose. A portion of chapter one will be devoted to a

discussion of this theory and its application in the present study. Secondly, it is considered essential that attention be given to the problem of creating an experimental design which will permit greater control of the relevant variables which are of particular importance in cannabis research. To this end, the first four sections of chapter one will be devoted to a consideration of these variables.

Section six of chapter one contains a review of the literature concerned with the effects of cannabis on intellectual functioning. Particular attention will be paid to the three main questions with which this study is most concerned, namely, (1) What particular intellectual functions are most affected by cannabis? (2) Does cannabis impair the input or the recall processes of memory? (3) Does cannabis actually affect any particular form of intellectual functioning as such, or does it impair the underlying ability to focus attention on the task in hand, irrespective of the nature of that task? In the final sections of the chapter these general questions are rephrased in the form of experimental hypotheses, using the terminology of Guilford's Structure of Intellect theory.

Chapter two presents the experimental design and procedures used to test these hypotheses, and describes the statistical methods used in analyzing the obtained data.

In chapter three the findings of the study are presented and discussed and suggestions are offered concerning possible directions for future research in this area.

CHAPTER I

REVIEW OF THE LITERATURE

This study is primarily concerned with the effects of cannabis on intellectual functioning. However, the effects of cannabis (particularly its psychological effects) are influenced by a great number of variables which must be taken into account when doing any research with this drug. The Interim Report of the Commission of Inquiry into the Non-medical Use of Drugs[1] states the problem as follows:

> The psychological effects of cannabis vary greatly with a number of factors and are often difficult to predict. The dose, type of preparation, rate and mode of administration can greatly influence the response, even if the effective doses and peak responses are made comparable. Furthermore, the psychological effects depend to a considerable degree on the personality of the user, his past experience with cannabis or other drugs, his attitudes, and the setting in which the drug is used (p. 77).

The extent to which these variables, either singly or collectively, determine the effects of cannabis is still a matter of much controversy. It will be necessary, therefore, to devote a portion of this review to their consideration.

Accordingly, the first four sections of this chapter are concerned with problems which directly affect the design,

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1 Hereafter, in the interests of brevity, this commission will be referred to by its unofficial name, the Le Dain Commission.

outcome and interpretation of research into the behavioral effects of cannabis drugs. These sections are entitled (1) Cannabis Sativa--General Description; (2) Chemistry--Problems Related to the Quantification of Dosages; (3) Effects--General Outline; (4) Variables Which Influence the Effects of Cannabis: (a) Dose Magnitude, (b) Route of Administration, (c) Subject's Previous Cannabis Experience, (d) Set, Setting and Personality.

Section 5 discusses the use of dose-related changes in heart-pulse rate as bio-assay technique, for estimating the size of doses actually delivered to subjects, in the smoke from marijuana cigarettes.

Section 6 provides a review of studies concerned with the behavioral effects of cannabis preparations, with particular reference to effects on intellectual functioning. This section will close with a summary of trends and conclusions derived from the preceding review.

The next section gives a brief description of J. P. Guilford's Structure of Intellect model, presented in the context of his theory of intelligence. This is followed by a discussion of the basic rationale underlying the experimental design. This discussion leads to the formulation of the hypotheses of the experiment. The ninth and final section of the chapter presents the null hypotheses which are to be tested.

1. Cannabis Sativa--General Description

Cannabis Sativa, or Indian Hemp as it is sometimes known, is an annual plant which grows in temperate climates throughout the world, including the United States and Canada. It is classified as a dioecious plant, which is to say that it has separate male and female forms. These can be readily distinguished by the different appearances of their flowering parts. It is a hardy weed which requires little or no cultivation and, under favorable climatic and soil conditions, it can grow to heights of over 15 feet.

The chemical compounds responsible for the pharmacological action of cannabis may be obtained from both the male and female varieties. These compounds are contained in the resin which permeates all parts of the plants, but are most concentrated in the flowering tops and adjacent leaves of the unfertilized female plant (Le Dain Commission, 1972, pp. 22-24).

A variety of drug preparations may be derived from the same plant, the relative potencies of which will depend upon the portion of the plant from which they were obtained. Grinspoon (1969) classifies cannabis drug preparations into three grades which he refers to by their Indian names. The least potent preparation, known as bhang, is derived from the cut tops and leaves of uncultivated plants, and frequently

contains seeds and twigs. Ganja is similar to bhang, but is obtained only from the flowering tops of carefully selected and cultivated female plants and is considerably more potent. In North America both of these preparations usually are classified together as marijuana (also called "grass" or "pot"), though according to Grinspoon (1969) most North American marijuana is of the poorer or bhang variety. Charas, also called hashish or "hash" in North America, is composed of the pure resin which is scraped from the tops of mature female plants and then dried and compressed into solid cakes. It is five to ten times more potent than good quality marijuana. All of these preparations may be ingested as drinks when boiled or mixed with milk, or eaten in food such as candies or cookies. On this continent, however, cannabis preparations are usually smoked, either in ordinary pipes, hookas, or in other specially made devices or, in the case of marijuana, in hand-rolled cigarettes commonly called "joints."

It also should be noted that the potencies of cannabis drug preparations depend not only on the portion of the plant used but also vary with the plant strain, methods of cultivation and harvesting, and the climatic and soil conditions prevailing at the time of growth. Waller (1971), in comparing the relative potencies of marijuana samples from around the world, found that a

sample from Thailand contained 120 times more Δ^1-THC (considered to be the principal active ingredient in cannabis --see Chapter I, Section 2) than did marijuana grown wild in Minnesota. The Le Dain Commission (1972) tested numerous samples of "home grown" marijuana obtained in Canada. THC content ranged from 0.02% to 3.5%, the highest value being obtained from a plant grown indoors (p. 23). Because of these great differences in potency, it is essential that researchers using cannabis specify clearly the strength of the material used in their experiments. This requires some awareness of the chemistry of cannabis drugs.

2. Chemistry--Problems Related to the Quantification of Dosages

The chemical structure and actions of the various compounds contained in cannabis preparations is a subject of great complexity and one which is not yet fully understood. It is not the place of this paper to attempt a detailed discussion of this complex topic. However, in order to evaluate the experimental procedures used in other research, and also to decide upon the dosages to be used in this study, it is necessary to present certain basic facts concerning the chemistry of cannabis.

A number of chemical compounds, collectively known as cannabinoids, have been isolated from the resin of cannabis sativa. Principal among these are cannabidiol (CBD),

cannabinol (CBN), a number of cannabinoid acids, and a group of stereo isomers referred to as the tetrahydrocannabinols (THC). To date only two of these naturally occurring substances, Δ^1 tetrahydrocannabinol (Δ^1-THC) and $\Delta^{1(6)}$ tetrahydrocannabinol ($\Delta^{1(6)}$-THC),[2] have been shown conclusively to possess psychoactive properties (Mechoulam, 1970; Mechoulam, Shani, Edery & Grunfeld, 1970; Gaoni & Mechoulam, 1971).

In studies performed on a variety of animals, these two compounds have been shown to have similar pharmacological effects, and to be approximately equal in potency in terms of the dosages required to produce these effects (Scheckel, Boff, Dahlen & Smart, 1968; Dewey, Harris, Howes, Kennedy, Granchelli, Pars & Razdan, 1970). However, in most naturally derived cannabis preparations, the $\Delta^{1(6)}$ isomer constitutes a very small and, at times, undetectable portion of the total THC content. Mechoulam (1970) states:

> The $\Delta^{1(6)}$THC isomer is a minor active compound in marihuana (15). Though in some fresh marihuana samples $\Delta^{1(6)}$THC may represent up to 10 per cent of the combined THC content (15), usually the percentage is considerably lower. Analyses of

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2 Throughout this paper the Monoterpenoid numbering system will be used in preference to the Formal or Pyran system. Both are used in the literature, but the Monoterpenoid system is used exclusively in all publications by Mechoulam and his colleagues to whom frequent references are made below. The psychoactive compounds referred to as Δ^1-THC and $\Delta^{1(6)}$-THC under the Monoterpenoid system are called Δ^9-THC and Δ^8-THC in the Formal system.

> Lebanese hashish over a period of 5 years have shown that $\Delta^{1(6)}$THC did not exceed 0.5 to 1 percent of the amount of Δ^{1}THC (8). In 14 samples of Mexican marihuana (18) the range of the ratio of Δ^{1}THC to $\Delta^{1(6)}$THC varied from 99.9 : 0.1 to 98.6 : 1.2 (p. 1160).

Thus, while small quantities of $^{1(6)}$THC may be present, and the possible existence of other active compounds has not been finally ruled out, there appears to be general agreement throughout the recent literature that, for all practical purposes, the dosage level of a natural cannabis preparation may be calculated in terms of its Δ^{1}THC content (Le Dain Commission, 1972, p. 21).

It must be noted, however, that estimating the Δ^{1}THC content of a cannabis sample is by no means a straightforward process. As mentioned above, natural cannabis preparations contain a number of pharmacologically inactive acids, among which are Δ^{1} tetrahydrocannabinolic acid A (Δ^{1}THC acid A) and Δ^{1} tetrahydrocannabinolic acid B (Δ^{1}THC acid B). When heated to temperatures of 75°C or higher (Davis, Martin, Pitt, Wildes & Wall, 1970, p. 458), these acids are rapidly transformed by decarboxylation into the active compound Δ^{1}THC. When gas-liquid chromatography is used as the means of analyzing cannabis preparations, the high column temperatures (200°C+) (Beckstead & French, 1971, p. 147) employed in these instruments are more than sufficient to decarboxylate any THC acids present in the sample. Thus, for any given sample of cannabis, the Δ^{1}THC content, as shown by gas-liquid

chromatography, will be greater than that obtained from other analytic methods which do not require such high operating temperatures. Fehr and Kalant (1972) have reported the combustion temperature of hand-rolled cigarettes to be 600°C ± 40°C (p. 764). Since decarboxylation of cannaboid acids also occurs at these temperatures, it would appear that gas-liquid chromatography is the most suitable method of estimating the amount of Δ^1THC present in a sample of cannabis when it is consumed by smoking. Mechoulam (1970) states:

> All cannabinoid acids undergo decarboxylation at the high temperatures necessary (200° to 250°C). For a routine analysis this may be an advantage, for this reaction parallels the smoking process. Gas-liquid chromatographic analysis will thus give directly all the THC available to a smoker in a certain sample. When an exact determination of the content is required, decarboxylation can be prevented by esterification (p. 1164).

At the same time, if it may be assumed that THC acids are not decarboxylated when cannabis is ingested orally, then it follows from the above statements that gas-liquid chromatography will over-estimate the THC dosage level in a sample administered by this route. Unfortunately, the author has been unable to find any reference in the literature to studies which give a quantitative comparison between the Δ^1THC content of a given cannabis sample, as revealed by gas-liquid chromatography, and its Δ^1THC content as shown by an assay technique which does not cause the decarboxylation of

THC acids. Thus, in any study involving the oral administration of a crude extract of marijuana, the Δ^1THC content of which has been determined by gas-liquid chromatography, one can state with reasonable certainty that the dosage actually ingested will be less than reported; but exactly how much less remains unknown.

The estimation of dosage levels is further complicated by the fact that, when cannabis is smoked, the high combustion temperatures also destroy a large percentage of the THC available in the sample. Fehr and Kalant (1972) have conducted a very carefully controlled study on the amount of Δ^1THC recovered from smoked marijuana. A smoking machine was used to replicate closely actual in vivo smoking techniques. The authors conclude that ". . . under the smoking conditions usually employed by marihuana users, up to 62% of the initial content of THC may be delivered in the marihuana smoke (p. 767)." In fact, it is probable that this estimate is somewhat higher than would actually be obtained in a social context, because the marijuana cigarettes were enclosed in a pyrex smoking chamber which presumably reduced side stream loss, and ". . . were smoked until all leaf material was completely combusted (p. 763)." Truitt (1971), referring to unpublished work by Foltz et al., reported that 8% of the THC originally available in a cigarette is lost in the side stream, and 21% is retained

in the unsmoked butt or "roach." (The length of the butt is not specified.) Truitt (1971) is in agreement with Manno, Kiplinger, Haine, Bennett and Forney (1970) in saying that, provided the butt is fully consumed, 50% of the THC contained in the marijuana is delivered in the smoke to the user. An earlier finding, that over 90% of the available THC is destroyed during combustion, has not been supported by subsequent studies (Claussen & Korte, 1968). The figure of 50% THC recovery has been widely quoted and appears to be generally accepted by workers in the field (Le Dain Commission, 1972, p. 33).

The foregoing discussion has been concerned mainly with the chemistry of naturally occurring cannabis preparations. In addition to work with these substances, research has also been carried out using a number of synthetically produced analogues of THC such as Dimethyl Heptyl Pyran (DMHP), Synhexyl and Δ^3 tetrahydrocannabinol (Δ^3THC). Reports by Hardman, Domino and Seevers (1971) and Hollister (1971a) indicate that these substances are generally similar in their effects to each other and to Δ^1THC, but differ considerably in potency. Despite these reported similarities, it is felt that because of their differences in chemical structure, and the presence of some ambiguities in the comparative studies, it would be more prudent, for the purposes of this paper, to treat them as a separate

group of drugs and exclude them from this review of the literature.

On the other hand, synthetically produced Δ^1THC is chemically identical with the same substance found in natural drug preparations (Mechoulam & Gaoni, 1965; Waller, 1971). Furthermore, according to Mechoulam (1970), ". . . it can apparently reproduce fully the effects of the crude drug in animals and humans (p. 1160)." A possible challenge to this conclusion is to be found in a paper by Jones and Pertwee (1972) in which the authors claim that pretreatment of experimental animals with cannabidiol (which is present in natural cannabis), has an inhibiting effect on the metabolism of Δ^1THC. However, the authors themselves admit that these findings cannot be generalized to the natural situation in which both compounds are administered together. Pending further work in this area, there appears to be little basis on which to reject Mechoulam's (1970) statement that the inactive cannabinoids ". . . do not seem to exert potentiating or other effects (p. 1161)." Therefore it would appear to be reasonably certain that direct comparisons may be made between the results of studies in which synthetic Δ^1THC is administered orally and those in which crude drug preparations are given by the same route. However, when pure Δ^1THC is smoked, the situation may be somewhat different. Fehr and Kalant (1972) report that when

pure Δ^1THC was injected into the middle of tobacco cigarettes, the recovery from the smoke was only 32.2% ± 1.7%, as compared with a recovery of 53% ± 6% from natural marijuana cigarettes burned at the same air flow rate. They state that ". . . the recovery was lower, possibly because the higher and less even concentration of THC reduced the efficiency of distillation and permitted more pyrolysis (pp. 765 & 766)." Whatever the reason, the relative inefficiency of this method cannot be ignored.

Finally, considerable controversy exists concerning changes in the potency of both synthetic and natural cannabis products over time (Le Dain Commission, 1972, pp. 24-25). Turk, Manno, Jain and Forney (1971) have reported that when stored in light at room temperature under air, pure Δ^1THC is rapidly transformed into cannabinol (96% Δ^1THC loss in five months). Refrigeration and storage in darkness reduced this loss to less than 3%. Zunin (1969) and Caldwell, Myers, Domino and Merriam (1969) report similar deteriorations in the potency of natural marijuana over time. In direct contrast to these findings, Jones (1971) states that: "Repeated assays with a gas chromatograph were done throughout the experimental period which spanned almost 2 years. There was no significant change in the THC content (p. 360)." The apparent contradiction between these reports has not been satisfactorily explained. Until the question is

resolved it would seem that in order to be certain of their reported dosage levels, researchers using cannabis products of any kind should re-assay their material at the time of their investigations.

If all these factors are taken into account (and too often they are not), it is possible to quantify fairly accurately the amount of THC delivered to the subjects. The effects produced by these known quantities of Δ^1THC are influenced by a number of variables which are considered below.

3. Effects--General Outline

In general terms, the acute effects of cannabis have been well described in the Interim Report of the Le Dain Commission (1970). This report is based upon a very complete review of the literature up to 1969. Since that time a lot of research has been done which has elaborated and refined our knowledge of cannabis. Nevertheless, for an overall account of the effects of this drug, it is felt that the Le Dain Commission Interim Report has not been improved upon. It is therefore worth quoting at length:

> Physiological Effects. . . . The following effects have been established in adequately controlled studies: increase in heart rate, swelling of the minor conjunctival blood vessels in the membranes around the eye, and minor unspecific changes in the electroencephalogram (EEG). Also commonly noted, but less well documented, are: a slight drying of the eyes and nasal passages, initially stimulated salivation followed by dryness of the mouth, throat irritation

> and coughing during smoking, and increased urination. Less commonly, nausea, vomiting, diarrhea or constipation are reported. These gastrointestinal disturbances rarely occur with smoked cannabis, although nausea is not uncommon when large quantities are taken orally. Changes in blood sugar level and blood pressure have been inconsistently reported. Appetite is usually stimulated. Contrary to popular belief, there is little evidence of pupil dilatation. In some individuals, incoordination, ataxia and tremors have been observed and chest pains, dizziness and fainting have occasionally been noted, usually at high doses. Physiological hangover effects have been described but are rare even after considerable intoxication. . . . sleep is the usual somatic consequence of over-dose (p. 76).

It should be noted that it is highly unlikely that all of the above symptoms will appear during a single experience with the drug. Furthermore, there is a great deal of inter- and intra-individual variability in response from one occasion to the next. This is particularly true of the psychological effects which are described as follows:

> Psychological effects which are typically reported by users include: happiness, increased conviviality, a feeling of enhanced interpersonal rapport and communication, heightened sensitivity to humor, free play of the imagination, unusual cognitive and ideational associations, a sense of extraordinary reality, a tendency to notice aspects of the environment of which one is normally unaware, enhanced visual imagery, an altered sense of time in which minutes may seem like hours, changes in visually perceived spatial relations, enrichment of sensory experiences (subjective aspects of sound and taste perception are often particularly enhanced), increased personal understanding and religious insight, mild excitement and energy (or just the opposite), increased or decreased behavioral activity, increased or decreased verbal fluency and talkativeness, lessening of inhibitions, and at higher doses, a tendency to lose or digress from one's train of thought. Feelings of enhanced spontaneity and creativity are often described,

> although an actual increase in creativity is difficult to establish scientifically. While most experts agree that cannabis has little specific aphrodisiac (sex stimulating) effect, many users report increased enjoyment of sex and other intimate human contact while under the influence of the drug (Le Dain Commission, 1970, p. 79).

It should be emphasized that most of the physiological effects described above are derived from the subjective impressions of users. By no means all of these reports have been subjected to empirical investigation and, when this has been done, the results have not always agreed with the subjective reports given by the users.

On an *a priori* basis, it might be assumed that many of the symptoms described above, both physiological and psychological, would be more pronounced with higher doses of the drug. Certainly, it does seem that the so-called toxic reactions such as nausea, vomiting, acute anxiety and paranoid ideation are more likely to occur at higher doses. At the same time, these effects appear to be due in at least equal part to other variables such as set, setting, and personality factors, which will be discussed below. In general, however, it may be stated that for the majority of symptoms listed above, dose/response relationships have not been clearly established. Two possible exceptions may be heart-pulse rate and conjunctival injection, both of which increase in a fairly constant ratio with increasing doses of cannabis. Since heart-pulse rate increase appears to be a relatively sensitive

and stable response, it is hoped that this measure may be used as an additional method of determining the amount of Δ^1THC actually delivered to subjects in an experimental setting. This question will be dealt with in more detail in Section 5 of this chapter. Increases in conjunctival injection, as measured by observers using rating scales, have also been reported to be dose-dependent (Manno, Kiplinger, Scholz & Forney, 1971; Kiplinger, Manno, Rodda & Forney, 1971). However, this method yields at best only a rough indication of dosage size and is thus of little value in a study of this kind.

In discussing other variables which may influence the effects of cannabis, consideration will be given mainly to those studies which have attempted to demonstrate measurable changes in the objective rather than the subjective effects of the drug. These will be discussed in the following section.

4. Variables Which Influence the Effects of Cannabis

(a) Dose magnitude

Even though dose-response relationships have been clearly established for only a few variables, it is evident that dose magnitude is a factor which could potentially

influence the outcome of any cannabis experiment. It is therefore necessary that researchers have some basis for deciding what might be considered as a "relevant" dose for the variables which they wish to study. One such reference point is the average, or "social dose," taken by people who use cannabis for non-scientific purposes.

Jones (1971) has estimated that the marijuana commonly available in North America seldom contains more than 1% Δ^1THC (p. 360). Thus, a 1 gm cigarette, containing 1% Δ^1THC, will deliver approximately 5 mg Δ^1THC to an individual smoker (assuming 50% Δ^1THC delivered in the smoke). Most of the subjects in his experiment reported that they seldom smoked more than one or two such cigarettes in an entire evening, and that it was not uncommon for this amount to be shared among as many as five smokers, all of whom became acceptably "high." Jones believes that the dose of 4.5 mg (delivered in the smoke) which he used in his investigations is a realistic approximation of the amount consumed in a "typical" social situation (p. 360).

The literature on this topic has been extensively reviewed in the Le Dain Commission's (1972) report on cannabis. The authors of this report agree with Jones (1971) that, on the average, the potency of marijuana available in North America is about 1% Δ^1THC. However, they report that a "typical joint" contains only about 400 mg of marijuana,

and could therefore be expected to deliver in the smoke a dose of about 2 mg Δ^1THC. Thus, a user who smoked two "joints" by himself in an evening would receive a delivered dose of about 4 mg. These conclusions, based on a review of the literature, are supported by laboratory experiments carried out by the Le Dain Commission (1972) in which it was found that:

> . . . cigarettes containing 5 to 10 mg THC, completely smoked, produced effects which were beyond the range of cannabis experiences of some regular users who had been "turning on" several times a week for a number of years. . . . Subjects indicated that cigarettes containing about 6 mg THC produced effects generally comparable to those typically experienced when "high" or "stoned" (p. 41).

On the basis of the foregoing reports, it may be said with reasonable certainty that doses ranging from 1 mg to 4 mg Δ^1THC, delivered in the smoke from a marijuana cigarette, will produce effects similar to those commonly experienced by users in a social situation. Because, in North America, cannabis is usually consumed by smoking, there is no comparable data concerning the amount of orally igested THC needed to produce a "social high."

(b) Route of administration

When cannabis is smoked, effects are noticed almost immediately and persist for three or four hours, with the maximum response occurring between ten minutes and half an

an hour after smoking. With oral ingestion, the onset of symptoms is delayed for an hour or more and the "high" may last for as long as twelve hours (Le Dain Commission, 1970, p. 75). Thus, when testing subjects under the influence of cannabis the time interval between drug administration and testing can be an important variable affecting the results.

Smokers of cannabis tend to report mainly feelings of euphoria, relaxation, enhancement of sensory experiences and, finally, sedation. In contrast, the effects of oral ingestion are often reported as being more dramatic and may include, in addition to gastro-intestinal disturbances, the hallucinations and disorientation commonly associated with the more powerful psychedelic drugs such as LSD. Weil (1969) has suggested that "cannabis appears to be a different drug when ingested rather than smoked (p. 41)." As a possible explanation of this difference, he goes on to say that, "all this suggests that components of cannabis resin that are destroyed by the heat of smoking may get into the body when the drug is ingested (p. 41)." This theory, that the drug is qualitatively different when administered by different routes, is not supported by recent studies on the chemistry of cannabis (see Chapter I, Section 2). On the basis of extensive clinical observation, Smith and Mehl (1970) believe that

the rapid onset of effects during smoking permits the user to titrate the dose, so that he consumes only as much as is needed to achieve a desired level of intoxication. With oral ingestion no such control is possible and there is, therefore, a greater likelihood of overdose, and hence of toxic reactions. However, even if a qualitative difference may be ruled out, there remains the question of a quantitative difference in potency between the two routes of administration.

To date very little research has been done in which direct comparisons were made between the effects produced by smoking as opposed to oral administration. The study most frequently quoted is that by Isbell, Gorodetzsky and Jasinski (1967) in which purified Δ^1THC was administered, both orally and by smoking, to ten healthy opiate addicts (all of whom were in jail at the time and hence had not had access to drugs for some months prior to the experiment). All had used marijuana previously. For oral administration, the doses used were 120 μgm/kg and 480 μgm/kg (equivalent in a man weighing 70 kg, to 8.4 mg and 33.6 mg of Δ^1THC).[3]

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3 Some authors specify dosages on a microgram per kilogram basis. Others, perhaps feeling that in humans such dosage distinctions are unnecessarily precise, state the amount in milligrams of THC without reference to body weight. For convenience of comparison, all μgm/kg doses will be translated into the equivalent dose in milligrams for a 70 kg man; 70 kg being taken as the average weight of a North American male, as specified in P. O. Astrand and K. Rodahl, Textbook of Work Physiology, New York: McGraw-Hill, 1970, p. 104.

For smoking, the Δ^1THC was injected into the middle third of a tobacco cigarette. Dosages contained in the cigarettes were 50 μgm/kg and 200 μgm/kg (70 kg equivalents: 3.5 mg and 14 mg of Δ^1THC). Drug effects were measured by means of changes in pulse rate and a "special questionnaire" (not described) which was intended to assess subjective psychological reactions. The authors present no raw data in support of their conclusions, which read as follows:

> In the assay experiment, potency of Δ^9-THC after smoking calculated from changes in the peak pulse rate was 2.6 times that after oral ingestion (95% confidence limits, 1.3-5.1). In the case of responses on the questionnaire, Δ^9-THC was 3.0 times as potent when smoked as when taken orally (95% confidence limits, 1.8-5.1). Analysis of variance showed that the data in this experiment met requirements for parallelism and regression for a valid assay (Isbell et al., 1967, p. 186).

It is uncertain whether or not the authors were aware, at the time of writing, that a percentage of the original Δ^1THC dose is lost during the smoking process. If one assumes that they did not, and if one accepts the finding of Fehr and Kalant (1972) that only 32% of the THC injected into a tobacco cigarette is delivered in the smoke, then it may be concluded that, when smoked, Δ^1THC is actually between eight and ten times more powerful than it is when orally ingested. Kiplinger and Manno (1971) assume that Isbell et al. (1967) were not aware of THC loss during

smoking and, calculating on the basis of a 50% recovery rate, they conclude that ". . . THC may be actually five to six times as potent by inhalation when delivered dose rather than cigarette content is considered (Kiplinger & Manno, 1971, p. 340)." Hollister (1971b), in his review of the literature, also mentions the figure of 50% THC loss during smoking. Nevertheless, when referring to Isbell et al.'s (1967) study shortly afterwards, he appears to accept its findings without criticism, and states ". . . doses (oral) equivalent in effect to those from smoking are about threefold larger (p. 22)."

Jones and Stone (1970) compared the effects of ethanol with smoked and orally administered cannabis and placebos. The oral preparation was a crude extract of marijuana administered in capsule form. The smoked marijuana was in the form of hand-rolled cigarettes, containing 500 mg of the same plant material from which the oral extract had been derived. Both the extract and the plant material were assayed for THC content and both were found to contain 0.9% THC. The dosages reported were 90 mg of Δ^1THC administered orally and 4.5 mg Δ^1THC contained in the cigarette consumed during each smoking session. No significant differences were found between the effects produced by these oral and smoked doses on heart rate, EEG frequency, time judgments and scores on the Rod and Frame Test.

The authors state that "the subjects received approximately 20 times as much marijuana orally as was smoked . . . The difference in potency between the two dose routes is far greater than Isbell (1967) reports with THC, but in the same direction (p. 116)." Had they allowed for the estimated 50% THC loss during smoking, they would have been forced to conclude that the observed potency difference was even greater than they believed; i.e., approximately 40 times.

On the basis of the findings referred to in this section, one can conclude only that cannabis appears to be more potent when smoked than when it is orally ingested. The magnitude of this potency difference remains undetermined. Therefore, direct quantitative comparisons between the results of studies using different routes of administration cannot be made with any degree of confidence.

(c) Subject's previous cannabis experience

It is commonly reported among people familiar with cannabis that the first time the drug is taken, the user is subjectively aware of few if any effects. Thereafter, if cannabis use continues, it is found that it takes less and less of the drug to produce a given level of intoxication. This lessening of the effective dose level has been referred to as "reverse tolerance" or "learning to get high"; the choice

of terms being, to some extent, a reflection of the researcher's theoretical bias. Mechoulam (1970) and Lemberger et al. (1970; 1971) have sought to explain this reported phenomenon in biochemical terms. They suggest that the substance responsible for the psychoactive properties of cannabis may actually be a metabolite of Δ^1THC (7-hydroxy-Δ^1THC) and not the Δ^1THC itself. This metabolite, which is produced by the liver, requires the presence of certain specific enzymes for its formation. It is theorized that the initial consumption of Δ^1THC acts as a trigger for the formation of these enzymes, which then become available to produce the active metabolite in greater quantities on subsequent administrations of the drug. In direct contrast to this theory, Jones (1971) believes that "learning to get high" is a primarily psychological phenomenon and, furthermore, when cannabis is used repeatedly, subjects develop a true tolerance and not a reverse tolerance to the drug. Smith and Mehl (1970) propose an even more complex explanation. On the basis of their clinical observations, they have concluded that:

> . . . the degree of marijuana tolerance is best described as a J-shaped function: that is, the novice has a moderate degree of tolerance; with increasing exposure to marijuana, tolerance appears to drop so that the occasional user has a low degree of tolerance; with increasingly heavier use, tolerance rises again so that a very heavy user has a high degree of tolerance. . . . It appears

> that the intial negative tolerance is a learned phenomenon as suggested by Becker (14), but that the later increased tolerance may be pharmacological in origin (p. 106).

Unfortunately, the behavioral and physiological findings which may be used in evaluating these theories are limited and often confusing. Nevertheless, since the extent of a subject's previous experience with cannabis may be a variable which could affect the outcome and interpretation of this and other studies, these findings must be considered. The writer is aware of four studies in which attempts were made, under controlled conditions, to compare the effects of cannabis on experienced and inexperienced (or naive) users of the drug. These studies, and some of their weaknesses, will be described separately after which their findings will be discussed together in relation to certain physiological and psychological measures common to all.

Of these four papers, the first to appear was the 1944 report of the New York City Mayor's Committee on Marihuana.[4] Orally ingested extracts and smoked marijuana were administered to 72 subjects, 24 of whom had not used the drug previously. Among the 48 users, reported frequencies of previous marijuana consumption ranged from five to six cigarettes per month, to as much as ten to fifteen per day.

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4 Hereafter this study will be referred to by its unofficial name, the LaGuardia Report.

All subjects were inmates of prisons in the New York area. During the experiment, subjective reports were obtained and extensive batteries of physiological, psychomotor and psychological tests were administered. (The results obtained from tests of intellectual functioning will be discussed in Chapter I, Section 6.) This report contains many serious weaknesses: double blind procedures and adequate control conditions were not employed, doses were often not standardized and dosage variations between subjects were not always taken into account, statistical procedures (if any) are not reported, and it is not always clear if the authors are discussing the effects of orally ingested or smoked marijuana or both. Because of these and other defects, the findings of this report should be regarded only as indications, to be confirmed by further research.

In 1968, Weil et al. (1968) studied the effects of smoked marijuana and placebo on nine marijuana-naive subjects and eight "heavy users" (4 to 7 times per week). The marijuana (estimated to contain 0.9% Δ^1THC) was administered in the form of hand-rolled cigarettes, which also contained unspecified amounts of mint leaves and tobacco used as filler material. The authors do not discuss the possible contaminating effects of these additional materials; in particular, one might question the effect of the tobacco on measures of pulse rate.

The placebo (also mixed with mint leaves) consisted of the chopped outer covering of the stalks of mature male plants, which were presumed to be devoid of THC. In addition to the placebo, two doses which the authors report as being 4.5 mg and 18 mg of THC, were administered in a double blind procedure to the naive subjects. The experienced subjects were given only the 18 mg dose. Since they were informed of its strength, their responses may have been influenced by expectation. Subjects were instructed to smoke the cigarettes down to a pre-marked ink line, leaving a butt of constant but unspecified length. The Δ^1THC trapped in the butt, and the estimated 50% lost in the smoke, could presumably have reduced the delivered doses to less than half the reported amounts. In commenting on this study by Weil et al., Hollister (1971b) expresses a similar doubt concerning the delivered dosages: "It seems possible, in retrospect, that the doses in this study were far less than assumed (p. 24)." The authors (Weil et al.) point out that their study was not specifically designed for the purposes of comparing users and non-users and that, therefore, the reported differences between these groups must be accepted with caution. This writer agrees.

Myer et al. (1971) compared the effects of smoking placebo, a fixed dose, and a self-selected dose of marijuana, on six heavy (once per day) and six casual (once per week)

users of the drug. The placebo consisted of natural marijuana with all cannabinols extracted. All materials were smoked in a pipe. The placebo and fixed doses were administered under double blind conditions. However, when the self-selected doses were given, the subjects were aware that they were smoking active marijuana. This is unfortunate, since the discussion section of the paper consists mainly of comparisons between the self-selected dose and placebo conditions, without considering the possible effects of the subjects' expectations. It is not known how much Δ^1THC is recovered from the smoke when marijuana is smoked in a pipe. However, if the 50% estimate is used, the delivered doses would have been 1.25 mg Δ^1THC for the fixed dose, and an average of slightly less than 2 mg Δ^1THC for the self-selected doses (heavy users: 1.7 mgs, and casual users: 1.9 mgs). This study is marred by a vague and incomplete presentation of results.

Drawing from a total group of 100 subjects, Jones (1971) compared the effects of placebo and smoked marijuana on the 25 most frequent users (seven or more cigarettes per week), and the 25 least frequent users (less than two cigarettes per month). An estimated delivered dose of 4.5 mg Δ^1THC was administered in hand-rolled cigarettes. The placebo consisted of marijuana from which all cannabinoids had been removed. These two treatment conditions were

administered in counterbalanced order, using double blind procedures. The writer can find no fault with the design of this study. In the same paper, Jones refers to another experiment in which he compared the effects of an orally ingested extract, smoked marijuana and placebo on eight frequent and eight infrequent users (rates of use are the same as above). The smoked dose is once again estimated as 4.5 mg Δ^1THC, delivered. However, the strength of the oral dose is uncertain. The author first reports that the oral extract contained 10 mg Δ^1THC and then, in a table on the same page, he gives the figure of 25 mg for the same extract (Jones, 1971, p. 365).

A number of inconsistencies and even outright contradictions exist among the findings of these four studies. The data on subjective reactions is particularly confusing. The LaGuardia Report (1944) found no difference between the two groups in terms of subjective response. Meyer et al. (1971) used two measures of subjective reaction: a five-point rating scale, and the Katz-Waskow Subjective Drug Effects Questionnaire. Results of the questionnaire indicated that, under the placebo condition, the casual users experienced more effects, while with active marijuana there was no difference between the two groups. However, on the five-point rating scale it was the heavy users who reported

greater feelings of intoxication after smoking active marijuana. Weil et al. (1968) found that after smoking active marijuana, heavy users became "high," according to their own reports and the reports of experimenters, while the naive subjects reported minimal effects. Jones (1971) had his subjects use a 0 - 100 rating scale to estimate their levels of intoxication, and obtained results which were in the opposite direction to those reported by Weil et al. The ambiguity of these findings may be due to a number of factors among which are the differences in the experimental procedures from one study to the next and/or the fact that subjective reactions to drugs are known to show great interindividual variability. It should also be noted that in the study by Weil et al. the responses of the heavy users could have been influenced by the fact that both the subjects and the experimenters were aware that active marijuana was being used. These possibilities will require further investigation. For the present, one can conclude only that it has not been established experimentally that heavy users of marijuana become subjectively "high" more readily than casual or naive users.

With regard to changes in pulse rate, Weil et al. (1968) found that, within the group of naive subjects, there were increases in pulse rate after smoking marijuana, but these increases were not dose dependent. It was also

found that after smoking the high dose the experienced users showed a significantly greater increase than the naive subjects. The findings are open to question: the sample size was small, double blind procedures were not used with the experienced subjects, and the marijuana was mixed with tobacco which is known to affect pulse rate. Furthermore, the statements by both the Weil group and the LaGuardia Report (1944) that pulse rate changes are not dose dependent have not been supported by later research (see Chapter 1, Section 5). On the other hand, the study by Jones (1971) has no such procedural defects and the findings on pulse rate change are in the same direction as the data from measures of salivary flow decrease and conjunctival injection, all of which show that casual users were more affected than heavy users. Jones' physiological results are also in accord with the data obtained from the psychometric measures used in the four studies.

Among all the results obtained from measures of psychomotor and psychological functioning used in these four studies, there were three cases in which no effects were observed in either group. All other results show that naive/casual users were more affected objectively by marijuana than heavy users.

Because of the defects present in these studies, and the ambiguity of the results, final conclusions cannot

be drawn. However, it can be said that the available evidence does not support a theory of "reverse tolerance." On the contrary, it appears that the objectively measured effects, and perhaps also the subjective effects, become less and not greater as the individual gains experience with the drug.

(d) Set, setting and personality

There is virtually complete agreement among cannabis researchers that set, setting, and personality structure are important factors in determining the subjective reactions of users to this drug. Mention of these variables is to be found most often in the literature on adverse psychological reactions to cannabis. The previously mentioned paper by Smith and Mehl (1970) gives an excellent overview of this topic. These authors state that:

> The effect marijuana has on an individual depends to a large extent on his personality structure, his expectations and attitude toward marijuana, and his mood at the time of use. The great variability of these factors makes the effects of marijuana rather unpredictable, . . . (p. 107).

They conclude that adverse reactions are most likely to occur in persons whose psychological adjustment was previously marginal. In better adjusted persons, uncertainty or false expectations (set) concerning the possible permanent nature of the drug's effects (e.g. "Marijuana will drive you

crazy.") may also cause severe anxiety. Similarly, unfamiliar or uncongenial surroundings and/or the presence of people perceived as being unfriendly or disapproving may produce feelings of anxiety and sometimes paranoid ideation.

These views are supported by the observations of Bialos (1970) who also agrees with Smith and Mehl concerning the need for a careful definition of the term "adverse reaction":

> Before the term is applied, the user's character structure, expectations of the experience, environmental factors present at the time of ingestion, and the amount ingested should be taken into account (p. 119).

An earlier paper by Becker (1967) also stresses the important role of expectation (set) in determining the type of experiences which may be induced by a number of drugs, including marijuana:

> So called "drug psychoses" can be interpreted as the reaction of a naive user occasioned by his fear that the temporary symptoms of drug use represent a permanent derangement of his mind. Participation in a drug-using subculture tends to minimize such occurrences, because other users present the person with alternative explanations of his experience that minimize its lasting effects (p. 163).

Most recently, the literature on adverse psychological reactions to cannabis has been extensively reviewed in the Le Dain Commission's (1972) report on cannabis. In their summary of this subject the authors point out that,

given the right setting and expectations concerning the possible effects of the drug, it would be possible to produce a "bad trip" in a significant proportion of marijuana users. However, they are also careful to add that the occurrence of cannabis related psychotic episodes requiring medical attention are statistically very rare, at least in North America. Concerning chronic psychopathology caused by cannabis, the report stresses that there is no clear evidence for the existence of such a condition, and goes on to add:

> If such chronic conditions exist, they are likely to be shaped as much by the prior personality of the individual as by the specific pharmacological effects of the drug (Le Dain Commission, 1972, p. 107).

This body of literature concerning the effects of set, setting and personality factors is based almost entirely on clinical observation and deals with the subjective reactions of users. Perhaps because these variables are difficult to isolate and quantify, almost nothing has been done to examine systematically the extent to which they may produce changes that can be measured. An exception to this statement is to be found in the work of Reese T. Jones (1971) referred to in the previous section. In order to test the effects of expectation (set), subjects were given both placebo and active marijuana cigarettes, and were asked to rate their degree of intoxication on an 0 - 100

rating scale, 30 minutes after smoking. The mean ratings, given by the group for marijuana and placebo on this scale, were 61 and 34, respectively. The author points out that, while this difference is significant, the variability within conditions was very great: placebo ratings ranged from 0 to 90, and marijuana ratings ranged from 0 to 95. Also, many subjects gave equal ratings to both conditions. This great variability in response was interpreted to mean that, in making their ratings, the subjects were being influenced by their expectations concerning the material being smoked. Furthermore, on the grounds that ". . . smoking a material that smells and tastes like marihuana may serve as a signal that produces an internal state that is interpreted by the subject as being high (Jones, 1971, p. 363)," it was hypothesized that the heavier users who had more experience with the smell and taste of marijuana would be less able to distinguish the placebo from the active material. In order to test this hypothesis, the ratings of the 25 heaviest users (more than 7 cigarettes per week) were compared with those of the 25 least experienced subjects (less than 2 cigarettes per week). Mean scores for the two groups showed that the less experienced subjects were able to make a clear distinction between the two types of material (marijuana: 67 ± 23, placebo: 22 ± 18), while the heavier users gave nearly identical ratings for both marijuana (52 ± 26) and

placebo (48 ± 21). An observation made by the same author in his previous study on alcohol and marijuana provides an interesting confirmation of these results:

> We've also observed that subjects with impaired taste and smell, because of a cold or an occluded nose can more readily distinguish placebo and active material (Jones & Stone, 1970, p. 115).

In contrast, when frequent and infrequent users were given orally administered extracts of marijuana, it was found that "without the familiar smell and taste cues both groups responded similarly to a placebo (Jones, 1971, p. 365)."

In the same paper Jones also describes an experiment in which he investigated the influence of setting on the behavior and subjective reactions of marijuana smokers. Sixteen subjects smoked marijuana on two occasions; once alone and once in the company of three other subjects who were also "smoking up." On both occasions their behavior was observed and, following each session, they were required to fill out the Subjective Drug Effects Questionnaire (SDEQ). Behavioral observations showed that:

> Subjects tested individually demonstrated the relaxed, slightly drowsy, undramatic state usually seen in our lab. In the group situation there was a consistent and impressive difference in behavior with elation, euphoria, uncontrolled laughter, and a marked lack of sedation (Jones, 1971, p. 367).

Results of the SDEQ agreed with these observations in showing a greater number of reported symptoms under the group condition, on all scales of the test, with the exception of the Dysphoria Scale. On this scale, which includes items such as "head feeling heavier," "sleepier," the subjects reported a greater number of symptoms under the individual condition. In contrast, and of particular interest for the purposes of this study, is the finding that on the Thinking Scale of the SDEQ, which includes items such as "easier to concentrate," "thinking clearer," "imagination more lively," "feel less like paying close attention to something," the subjects reported twice as many symptoms under the group condition as they did under the individual condition. In the conclusion of his paper, Jones states:

> In summary, these data suggest that marihuana when smoked at what was, for our subject population, a socially relevant dose, a level of intoxication is produced that allows the attitude of the subject, his set and expectations, the setting and his past experience to interact in a complex way to determine how the subjective state will be labeled and reported (p. 368).

The references cited in this section indicate that set, setting and personality factors are in fact important determiners of the subjective experiences of cannabis users. It would seem reasonable to infer that these variables might also influence the performance of cannabis users on a variety of objectively measured tasks, including those of the type

to be investigated in this study. Unfortunately, there appears to be no hard evidence which can be quoted in support of this inference. Nevertheless, the existence of this possibility is sufficient to indicate that investigations into the behavioral effects of cannabis should be designed in such a way that the effects of these variables are controlled, or at least carefully accounted for.

5. The Use of Heart-Pulse Rate Changes as a Bio-assay Technique

It is apparent from even the most cursory survey of the literature that in the past much of the cannabis research on humans has been done without adequate attention being given to the many sources of variance discussed in the preceding sections. As a consequence, the results obtained from different studies have been often ambiguous and at times directly contradictory. There is, however, one dependent variable which has been repeatedly investigated and for which relatively consistent results have been obtained from a number of experiments. "The Cannabis Report" states:

> Perhaps the most commonly reported physiological response to cannabis is a dose-related increase in heart pulse rate. In Commission experiments, a dose producing effects generally within the range of the subjects' past experience reliably increased pulse rate by more than one-third (Le Dain Commission, 1972, p. 111).

For the purposes of this study it was considered that it would be useful if heart-pulse rate changes could be used as an additional (bio-assay) technique for evaluating the strength of the dosage actually delivered to the subject. In addition, it is hoped that changes in the mean pulse rate of subjects, after smoking marijuana, may be used as a base line against which changes in other drug-dependent variables may be compared. From among the many papers reviewed, only four were found which met the criteria necessary for comparison with the present study: (a) marijuana was consumed by smoking, (b) doses were clearly specified, (c) pulse rates were measured within 20 minutes after the completion of smoking, (d) pulse rate changes were clearly specified, (e) there were no serious faults in the experimental design. In three of these four papers a relationship was looked for and found between the size of the dose and the magnitude of the pulse change. One study examined changes in pulse rate in relation to the interaction between dosage, and the time after smoking at which pulse recordings were taken. This dose-time interaction will not be discussed here since, in the present study, pulse recordings will be taken only once after smoking. The four studies considered are briefly described below and their results are presented in Table 1 and Figure 1. In all cases, the dosages shown are estimated

delivered doses, calculated on the assumption that approximately 50% of the THC contained in the marijuana is actually delivered in the smoke to the subject.

Manno et al. (1971) tested 12 subjects, four of whom ". . . reported prior experience with marihuana but only one of the four had used it more than twice (p. 203)." Marijuana and placebo in the form of cigarettes were administered under double blind conditions using ordinary smoking methods. Estimated delivered doses of 2.5 mg and 5.0 mg of Δ^1THC were given to all subjects. Pulse rates were measured before and 20 minutes after smoking.

Kiplinger et al. (1971) tested 15 subjects, eight of whom reported some (unspecified) experience with marijuana. Marijuana and placebo were in cigarette form and were smoked using ordinary smoking techniques. Dosages were calculated individually on a microgram per kilogram basis. The doses listed for this study in Table 1 are those which would have been received by an "average" man weighing 70 kg. Pulse rates were measured under no-drug conditions and 20 minutes after smoking.

Jones (1971) tested 100 subjects, whose previous marijuana experience ranged from less than two cigarettes per month to more than seven per week. Marijuana and placebo were administered in cigarette form and subjects were instructed to hold the butt with forceps so as to

ensure that the entire cigarette was consumed. The single dose used was estimated to be 4.5 mg of THC delivered. Pulse rates were measured before and shortly after smoking; the precise time after smoking is not specified.

Renault et al. (1971) tested ten subjects, four of whom claimed to be experienced marijuana users; i.e. they were currently using marijuana at least once per week. For smoking purposes marijuana was burned in a closed crucible, and all the smoke given off was collected in a spirometer where it was mixed with an equal amount of pure air. After combustion was completed, the subject drew the smoke from the spirometer in five-second inhalations, and held it in his lungs for 15 seconds. The doses listed for this study, in Table 1, were calculated on the assumption that 50% of the THC, originally present in the marijuana, is delivered in the smoke from the spirometer. In fact, it is not certain that this smoking method delivers the same percentage of THC as the more conventional "joint." Pulse rate measures were taken between ten and 20 minutes after smoking.

It should be noted that the four studies considered above are by no means identical in design, particularly with regard to smoking techniques and the previous marijuana experience of the subjects. Despite these differences, the results show a remarkably consistent relationship between dosage and pulse rate increase. In Figure 1 percentage pulse rate increases have been plotted against dosage.

Table 1

Heart-Pulse Rate Changes in Relation to Varying Doses of Smoked Marijuana

Study	N	Est. Δ^1THC Dose (del. in the smoke)	Heart-Pulse Rate Increase beats/min	Heart-Pulse Rate Increase % of no-drug pulse
Manno et al. (1971)	12	2.50 mg	16	22
		5.00 "	25	33
Kiplinger et al. (1971)	15	0.44 mg	4	6
		0.88 "	7	10
		1.75 "	11	15
		3.50 "	23	32
Jones (1971)	100	4.50 mg	24	32
Renault et al. (1971)	10	0.45 mg		5
		0.90 "		9
		1.90 "		16
		3.80 "		30

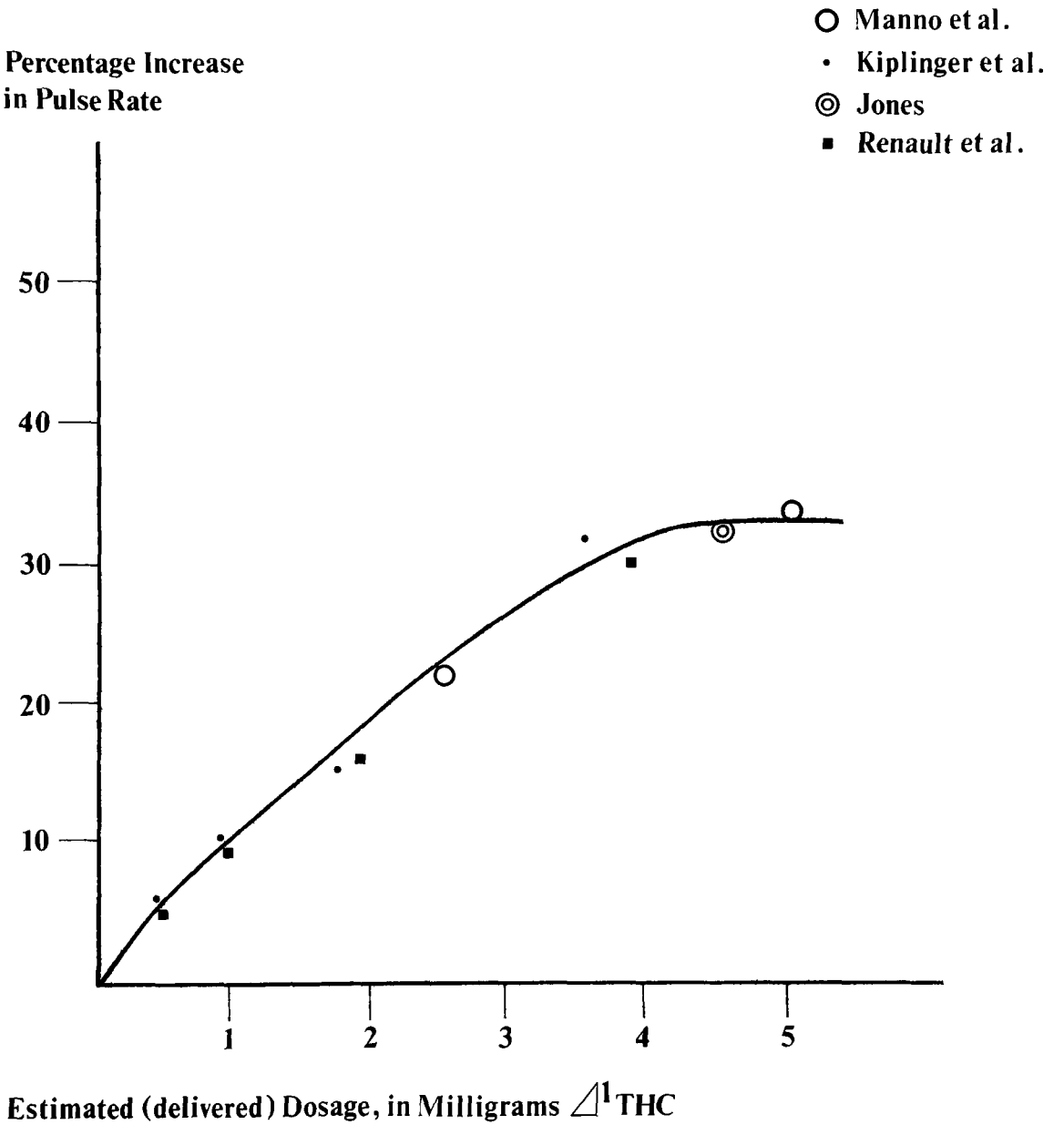

Figure 1.- Heart-Pulse Rate Changes in Relation to Varying Doses of Smoked Marijuana.

6. Effects of Cannabis on Intellectual Functioning

(a) Discussion of individual studies

The descriptive literature on the effects of cannabis dates back to pre-christian times and includes a number of articles and reports of superior quality (Le Dain Commission, 1970; Kalant, 1968). However, the LaGuardia Report of 1944 contains what may be described as the first attempt to examine the effects of cannabis on intellectual functioning, under controlled laboratory conditions. Unfortunately, as mentioned above (see p. 26), the sections of this report which are directly relevant to the present study are marred by serious weaknesses in experimental design and procedure. Nevertheless, by virtue of its great size and scope, it remains a major landmark in the history of cannabis research and, as such, it cannot be ignored. In the interests of brevity, experimental procedures and results will be described in outline only. Experiments using smoked marijuana are not discussed at all because there was no control of dosage whatever--subjects smoked as much as they wished, and in some cases were given additional "joints" during the actual testing session (LaGuardia Report, 1944, pp. 101-02). Two cc and 5 cc doses of marijuana extract were administered orally to between 20 and 28 subjects--the number varying from test to test. The

tests used were: (1) The Army Alpha, a group test of intelligence composed of eight subtests; (2) Pyle's Digit Symbol, a test of simple perceptual-motor functioning; (3) Geometric Cancellation Test which measures the individual's capacity to carry out a simple repetitive task; (4) seven different Form Board Tests; (5) Kohs Block Design, a test of spatial organization and perceptual motor functioning, used in the Wechsler tests of intelligence; (6) three different Memory Tests which measured, respectively, rote memory (Digit Span), memory for objects, and visual memory. All tests were administered repeatedly over a period of seven hours, following ingestion of the drug, with the result that, as the day wore on, most scores showed a marked increase due to practice effect. In many cases, when the author reports a decrement in performance, he is in fact reporting a decrease in this practice effect rather than an actual drop in test scores. No statistical treatment of the data is reported.

The overall scores for the Army Alpha test were only slightly affected by the 5 cc dose--a 3% drop at one hour post-drug and lasting till 4-1/2 hours. However, when the subtests were analyzed separately it was found that tests involving number concepts showed impairment within an hour after ingestion of both the 2 cc and 5 cc doses, while the scores on tests of verbal reasoning improved in relation to

no-drug scores. Kalant (1968), in her analysis of the LaGuardia Report, points out that "this apparent improvement was of roughly comparable magnitude to the impairment produced by 5 cc on the arithmetic sub-tests (p. 22)." On both the Pyle's Digit Symbol and Geometric Cancellation tests there was an increase in efficiency following the 2 cc dose, and a slight decrease following the 5 cc dose. From among the Form Board tests, only the Seguin Form Board, which is primarily a measure of complex reaction time, showed impairment amounting to 9% following the administration of both doses. Other Form Board test scores showed a slight improvement. On the Kohs Block Design test, the 5 cc dose produced a 16% drop in performance. On the Digit Span test the Digits Forward section was unaffected by either dose, while the repetition of digits in reverse order showed a slight dose-related impairment. Results of the Object Memory test are difficult to interpret, but it appears that both doses produced only a very slight impairment in functioning. On the Visual Memory test, which the author considers to be a more complex task than the other two memory tests, the 2 cc dose produced a 6% drop in scores, and the 5 cc dose produced a drop of 24%. The overall conclusions of the author may be summarized as follows: (1) "Marihuana taken either in pill or in cigarette form has a transitory adverse effect on mental functioning (LaGuardia Report,

1944, p. 106)"; (2) the extent and time course of this impairment are dose related; (3) complex intellectual functions are more adversely affected than simple ones; (4) non-users experience greater impairment than do regular users; (5) both speed and accuracy of intellectual functioning are adversely affected; (6) the use of marijuana does not cause permanent mental deterioration.

Kalant (1968), however, believes that these conclusions reflect a definite bias in the author's thinking, and she points out that

> . . . the main conclusion drawn, that marihuana generally impairs mental functioning, is not consistent with some of the results presented nor with Halpern's own discussion of these in the body of the paper (p. 22).

She then proceeds to offer her own alternative conclusion:

> In summary the results seem to bear out the conclusion that big enough doses of marihuana impair a variety of mental functions, while small doses may improve some of them. These conclusions, however, are only tentative because the author presents no statistical treatment of the data (p. 22).

Taken as a whole, the conclusions of the LaGuardia Report suggested that marijuana is a relatively innocuous drug which produces few if any long term adverse effects in those who use it. Despite this quite positive view, public opinion in North America remained strongly opposed to the use of this drug in any way. As a result, a period of nearly 25 years elapsed during which very little research

was carried out on the behavioral effects of cannabis in humans. The revival of experimentation concerned with its effects on perceptual, motor, and intellectual functioning in humans began in 1968.

In that year, Weil et al. (1968) conducted a study in which an attempt was made to pay much greater attention to the problems of experimental design and statistical treatment. An outline of this study and some of its weaknesses have already been presented above (see pp. 26-27). To recapitulate briefly, marijuana in cigarette form was administered to nine cannabis-naive volunteers and eight regular users. Three tests of attention and/or psychomotor functioning were used: (1) the Continuous Performance Test, intended to measure the subjects' capacity for sustained attention; (2) the Digit Symbol Substitution Test, described by the authors as a simple test of cognitive function; (3) the Pursuit Rotor, which is described as a measure of muscular coordination and attention. Results showed that scores on the Continuous Performance Test, which was given with and without distraction by a strobe light, were unaffected in either group. On both the Digit Symbol Substitution and the Pursuit Rotor tasks the performance of marijuana-naive subjects was significantly impaired after both high and low doses, while the performance of the regular users showed a slight improvement. The greater impairment, seen in the

scores of non-users, agrees with the conclusions of the LaGuardia Report (see above, p. 47). For seven of the naive subjects a five-minute time interval seemed to pass more slowly when they were under the influence of marijuana.

In 1969 Weil and Zinberg (1969) reported on the second half of the same experiment which is concerned with the effects of marijuana on speech. Immediately before, and 50 minutes after smoking, each subject was left alone for five minutes in a room with a tape recorder, and instructed to describe an interesting or dramatic experience in his life. In this way, verbal samples were collected from each of the naive subjects before and after smoking the placebo and both doses of active material, and from each regular user before and after administration of the high dose. Samples were analyzed by: (1) the Cloze method, which provides a measure of the understandability of verbal material; (2) a seven-point bipolar scale, on which the judges were asked to rate the samples with reference to nine categories (e.g. Coherence, Unity, Awareness of a Listener, etc.). The mood of each subject was evaluated by means of: (1) the Gottschalk-Gleser content analysis scales, which were used to analyze the verbal samples for levels of anxiety, hostility, etc.; (2) a self-rating bipolar scale on which the subjects rated themselves. No consistent changes in mood were detected by these latter

two scales in either of the subject groups. No change in the understandability of the samples was revealed by the Cloze method of analysis. Using the seven-point bipolar scale,

> . . . judges were able to guess correctly most of the time which were the before and which the after samples of users and for naives on high dose. . . . The trouble is that although the total score correlated well, no one category changed consistently for all subjects (Weil & Zinberg, 1969, p. 435).

Despite these largely negative findings, it is reported that both subjects and judges agreed, on the basis of their own observations, that when an individual is "high" on marijuana he experiences greater difficulty in maintaining a consistent flow of speech. The authors describe the two principal manifestations of this phenomenon as ". . . simple forgetting of what one is going to say next and a strong tendency to go off on irrelevant tangents because the line of thought is lost (p. 436)." In an attempt to explain this behavior, they theorize that it may be

> . . . a manifestation of a more general acute effect of marihuana on a specific mental function; namely, an interference with ultra-short-term (or immediate) memory. By immediate memory we mean memory over the past few seconds. To be more precise, the interference seems to be with retrieval of information while it is in an immediate memory storage; once it passes into the next (recent-memory) storage, it again seems to be easily accessible to consciousness (p. 437).

It is unfortunate that the observations on which this theory is based were not supported by the objective measures

obtained from the experiment. Furthermore, while not denying the possible existence of such a speech difficulty,[5] it would seem to be both premature and overly simplistic to attempt an explanation solely in terms of "ultra-short-term memory." Speech is a highly complex process which involves a number of cognitive functions in addition to memory, any one or more of which might be impaired by cannabis.

The research team of Clark and Nakashima (1968) has proposed a somewhat more complex theory to explain the effects of cannabis on cognitive functioning. Their initial study on cannabis, published in 1968, appears to have been greatly influenced by the LaGuardia Report to which the authors make frequent reference. Unfortunately, they also perpetuated many of its weaknesses in both their experimental design and in their failure to report statistical procedures. An extract of natural marijuana was administered in capsule form to 12 cannabis-naive volunteers. Although they report no assay of this material for THC content, the authors claimed that their dosages

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5 This writer has made a number of similar (undocumented) observations while talking with persons under the influence of cannabis. In each case, however, the speech problem seemed much more severe to the drug user than it did to the observer. In two cases, users reported that they considered themselves to be nearly incoherent, and were amazed that their listener could detect little or no change in their speech.

". . . corresponded by calculation and dose effect with the lower '2-5cc' doses . . . (p. 136)" described in the LaGuardia Report. The tests used include measures of (1) simple and complex reaction time; (2) digit code memory; (3) depth perception; (4) visual flicker fusion; (5) auditory discrimination; (6) Archemedes spiral after-image; (7) mirror pattern tracing; (8) visual-motor coordination as measured by the pursuit rotor. It was found that cannabis produced an impairment of performance on tests of complex (choice) reaction time (also found in the LaGuardia Report), and digit-code memory, a task in which the subject is required to memorize a group of digits during 250 repeated trials. Other tasks were not consistently affected. The authors point out that, on all tasks including reaction time and digit-code memory, there was a very high degree of inter- and intra-individual variability. In view of this, together with the relatively small sample and the lack of statistical treatment, this study must be regarded, in the authors' own words, as only "a preliminary effort."

However, in 1970 the same group of investigators (Clark, Hughes & Nakashima) conducted a second experiment in which they attempted to confirm and extend their earlier findings. On this occasion, 18 non-users received orally administered extracts of natural marijuana which had been assayed by means of gas-liquid chromatography and found

to contain a THC concentration of 10 mg/cc. (The extract was given on the basis of 0.03 cc/lb of body weight which works out to a dose of 47 mg THC for an "average" 70 kg man.) Because the GLC method of analysis was used, this figure is probably an over-estimate of the true oral dose (see above, Section 2). Tests included: (1) reaction time measures, at four levels of complexity; (2) digit-code memory; (3) time estimation tasks in which the subjects were required to estimate the time taken to complete digit-symbol problems of different durations; (4) four subtests of the Iowa Silent Reading Test, used to measure recall and comprehension. Once again, performances on the digit-code memory and complex reaction time tasks were adversely affected. However, the authors note that the impairment of reaction time performance resulted from an increase in the variability of the subjects' responses from occasion to occasion, rather than a consistent increase in reaction time on all occasions. They interpret this phenomenon as a "sporadic impairment of vigilance." Time estimation was also affected adversely (real time seemed longer), with the error magnitude being significantly greater for the longer time intervals. Results for the six subjects who took the Iowa Silent Reading Test showed a significant impairment of recall and comprehension under the drug condition, with the magnitude of the impairment being proportional to the complexity of the task. In

interpreting their findings the authors state that:

> Experimental data as well as introspective reports suggest that the processes involved in selective perception (and, conversely, habituation to irrelevant stimuli), immediate recall of preceding thoughts in order to keep on track, and capacity for goal-directed systematic thinking are particularly sensitive to relatively low doses of marihuana (p. 198).

Without attempting to dispute the results obtained from the individual tests used in this experiment, this writer finds it difficult to follow the authors in making a logical connection between the results obtained and the generalization from these results which is quoted above. In particular, it is not clear which tests (or combination of tests) may be considered to be a valid measure of "goal-directed systematic thinking."

This idea, that cannabis adversely affects goal-directed thinking, has been further examined by a group of researchers headed by Frederick Melges and Jared Tinklenberg at the Stanford School of Medicine and the Veterans Administration Hospital in Palo Alto, California. This group performed a single experiment composed of several parts which were reported separately in four different papers published in 1970 and 1971 (Melges, Tinklenberg, Hollister & Gillespie, 1970a; Tinklenberg, Melges, Hollister & Gillespie, 1970; Melges, Tinklenberg, Hollister & Gillespie, 1970b; Melges, Tinklenberg, Hollister & Gillespie, 1971). The sample con-

sisted of eight young male graduate students, all of whom had used cannabis previously, but in no case at a frequency greater than once per month. The cannabis was administered orally and consisted of an extract of natural marijuana dissolved in a solution of 95% ethanol. The extract was assayed by means of both thin-layer and gas-liquid chromatography and found to contain 20 mg Δ^1THC per milliliter of ethanol. The placebo consisted of an extract of marijuana from which all cannabinoids had previously been removed. The placebo and three doses containing 20 mg, 40 mg, and 60 mg Δ^1THC were administered in random order to each subject on four different days, separated by at least one week. Testing was done at intervals of 1-1/2, 3-1/2 and 5-1/2 hours after ingestion of the drug. The main focus of the experimenters' interest was a phenomenon which they refer to as temporal disintegration.

> Temporal disintegration means that the individual has difficulty in retaining, coordinating and serially indexing those memories, perceptions, and expectations that are relevant to the goal he is pursuing (Melges et al., 1970a, p. 1118).

Temporal disintegration was measured by a task called the Goal Directed Serial Alternation (GDSA) in which the subject was given a starting number between 106 and 114 and instructed to alternately subtract 7 and add 1, 2, or 3 until he reached a specified goal between 46 and 54. The final score for the test gives equal weight to both speed and

accuracy. Two other tasks were also given to the whole group: the Serial Subtraction of Sevens and the Digit Span Test (repeating digits forward and backward). An additional task was given to a sub-group of three subjects, each of whom was required to arrange in serial rank order a list of random digits which was shorter by two numbers than his previously established forward memory span.

In their article of May 1970, the authors report that cannabis produced a significant drop in scores on the GDSA, and that this effect was dose related. In addition, the higher doses affected performance for longer periods of time. Performance on the Digit Span Test, considered to be a measure of short-term memory, was also significantly impaired by all doses, but the effects were not dose related. In contrast to these results, performance on the Serial Subtraction of Sevens was not affected by any of the doses. The authors describe this latter task as a measure of sustained attention and long-term memory. It is noteworthy that in analyzing the types of mistakes made on the GDSA, the authors found that there were relatively more errors in immediate memory operations such as loss of place, failure to alternate between addition and subtraction, and forgetting the goal number. Conversely, there were fewer errors in the actual adding and subtracting which are considered to be operations stored in long-term memory. In their paper of

June 1970, the authors report that the three subjects given the serial rank ordering task also showed a significant decrement in performance under the drug conditions. In their papers published in September 1970 and June 1971, they report a correlation between these changes in cognitive functioning and an increase in subjectively reported feelings of depersonalization, confusion of past, present, and future, and greater concentration on the immediate present. (Weil and Zinberg (1969) also noted a tendency, which was not statistically significant, for time orientation to be shifted from the past or future to the present.) In evaluating the results of their cognitive tests, the authors emphasize that, although there was a drop in the scores of the Digit Span Test which measures simple rote memory, this decrement was not dose related and was much less severe than the impairment of serial immediate memory which is evident in the type and magnitude of the errors made on the GDSA. They consider serial immediate memory to be a more dynamic process which involves the subject in keeping track of recent stimuli at the same time that he is manipulating them. They go on to theorize that:

> This temporal incoordination of recent memories with intentions may account, in part, for the disorganization of speech patterns that occurs under marihuana intoxication (Melges et al., 1970a, p. 1120).

Such a theory would seem to be more nearly consistent with the findings presented thus far.

However, in December 1972, the same group of researchers (Tinklenberg, Kopell, Melges & Hollister) conducted a second experiment in which they compared the effects of an orally administered extract of marijuana, alcohol, and placebo on the test performance of 15 experienced (frequency not more than twice per week) subjects. The median marijuana dose of 26 mg Δ^1THC was slightly more than the low dose (20 mg) used in their previous study. In this experiment, testing consisted of: (1) time production of 30, 60, and 120 second intervals (by counting silently to himself the subject attempted to estimate when he thought each of the specified time intervals had elapsed); (2) the Goal-Directed Serial Alternation Test (GDSA); (3) the Running Memory Span Test (RMS) which measures immediate memory by requiring the subject to write, in correct sequential order, as many digits as he can remember from lists of numbers which are randomly varied in length. Results showed that, relative to the placebo and alcohol conditions, the time productions of the subjects were significantly shorter under the marijuana condition. That is, their "internal clocks" used in making time judgments were speeded up, with the result that objectively measured time seemed to pass more slowly. In contrast to their previously reported results, the authors found that

in this experiment marijuana did not significantly affect the scores of either the GDSA or the RMS test of immediate memory. (Under the marijuana condition, all subjects showed the conjunctival injection and increased heart rate characteristic of this drug. Also, nearly all subjects rated their degree of intoxication between 60 and 90 on a 0 - 100 scale.) As a possible explanation of the discrepancy between these results and those from the previous study, the authors point out that their initial group of eight subjects showed considerably higher base-line (no-drug) scores on the GDSA than did the second group, and that they might therefore be expected to be ". . . more prone to show impairments in cognitive operations during marihuana intoxication (p. 814)." They also suggest that the inconclusive results obtained with the RMS test may be due simply to the fact that ". . . this measure does not sensitively reflect the subtle cognitive effects of moderate doses of marihuana or alcohol (p. 814)." The logic of these explanations is not entirely clear. Certainly, until further direct evidence is available, they can be regarded only as interesting speculations.

Memory functions were also examined by Waskow et al. (1970). The subjects were 32 paid volunteers, all of whom were inmates at a treatment center for emotionally unstable criminal offenders. Only seven had some (unspecified) previous experience with marijuana. Subjects were randomly

assigned to one of four testing conditions: THC with music, THC with no music, placebo with music, and placebo without music. The drug consisted of an oral administration of 20 mg Δ^1THC, dissolved in 95% ethanol and diluted with cherry syrup. The placebo contained an equal amount of ethanol and cherry syrup, but no Δ^1THC. Tests were administered 1-1/2 and 3-1/2 hours post-drug. The cognitive tests used were the Memory Control Section of the Wechsler Memory Scale which consists of three parts: (1) counting backwards; (2) saying the alphabet; (3) serial addition, and the Memory Span Section of the same scale which involves the repetition of digits forward and backward. It is reported that the subjects' scores on counting backwards, saying the alphabet, and repeating digits forward and backward, were not significantly affected by the drug. Under the music condition, a significant difference was found between the mean scores of the THC and placebo groups on the serial addition task. However, when music was not present, there was little difference between the groups. Furthermore, the authors add that ". . . the difference between music groups was due more to the superior performance of the placebo-music subjects than to the impairment of the THC-music subjects (p. 104)."

As part of an investigation concerned mainly with the neurological effects of cannabis, Rodin et al. (1970) gave the Serial Subtraction of Sevens Test to ten experienced subjects, following the administration of smoked

marijuana. Since the subjects were allowed to smoke as many cigarettes as they wished, the dosage cannot be determined exactly. A rough estimate of the average dose would be between 5 mg and 6 mg Δ^1THC, delivered in the smoke. There appears to have been no statistical treatment of the data, but it is reported that the serial seven subtractions were carried out more slowly and there was a tendency toward more errors. Because of the absence of any controls, little confidence can be placed in this report.

Dornbush et al. (1971) tested ten medical students, all of whom had had some (unspecified) previous experience with marijuana. The marijuana which, according to the assay done by the National Institute of Mental Health, contained 1.5% Δ^1THC was administered in the form of cigarettes containing a mixture of marijuana and oregano. Placebo cigarettes contained plain oregano. The two doses given were reported to contain 7.5 mg and 22.5 mg Δ^1THC. Assuming 50% THC loss in the smoke, this would mean delivered doses of 3.25 mg and 11.25 mg. If accurate, the high dose of 11.25 mg, delivered in the smoke, would have been approximately three times as great as the estimated delivered dose of 1 to 4 mgs Δ^1THC needed to produce a typical "social high" (see above, Section 4(a)). However, it should be noted that the authors apparently did not re-assay their marijuana, but accepted the NIMH estimate without question. Secondly, the reported

heart-pulse rate increase for the 3.25 mg dose of between three and five beats per minute is very close to the increases seen in other studies after smoking a delivered dose of only about 0.5 mg Δ^1THC (see above, Section 5). The tests used in this experiment were: (1) recall of three-letter trigrams, either immediately or after short intervals of up to 18 seconds; (2) simple auditory and visual reaction time tests; (3) time production tasks in which the subject was required to reproduce a prior visual or auditory stimulus. Results showed some interference with short-term memory, as measured by the trigram recall test, with greater interference being seen after the longer delay times. It is not clear if these differences were statistically significant. Simple reaction time, in both modalities, was significantly longer after administration of the high dose. Time production tasks were unaffected by either dose.

Casswell and Marks (1973a) conducted an experiment in which they administered three of the same tests which were used in the study done by Melges et al. (1970a). (Apparently Casswell and Marks were not aware of the 1972 study by these authors since they make no reference to it.) Marijuana, the THC content of which had been assayed by means of gas-liquid chromatography was administered in cigarette form to nine naive and nine experienced volunteers (median frequency was once per week, over three years). The Δ^1THC content of the

high and low dose cigarettes was estimated to be 6.6 mg and 3.3 mg, respectively (assuming 50% THC loss in the smoke, the delivered doses would have been 3.3 mg and 1.7 mg). The placebo consisted of natural marijuana from which all cannabinoids had been extracted. The GDSA, the Digit Span Test, and the Serial Subtraction of Sevens were administered under double blind conditions to all subjects at all three dose levels. Significant dose-related increases in heart-pulse rate were noted after smoking the active material, but there was no difference in the mean pulse rates of the two groups of subjects. Similarly, there were no significant differences between the scores of the users and non-users on the three cognitive tests. For the total sample of 18, there was a significant dose-related impairment of performance on the GDSA during marijuana intoxication; a finding which agrees with the results reported in 1970 by Melges et al. However, in contrast to these earlier findings, there was also a dose-related decrement in the scores of the Serial Subtraction of Sevens, a fact which Casswell and Marks (1973a) consider to be indicative of ". . . impairment either in the long-term memory operations involved in the task, or in the subjects' ability to maintain sustained attention (p. 804)." Also, in contrast to the findings of Melges et al. the authors report no significant differences in the scores of the

Digit Span Test under the three conditions. (So far as this writer is aware, Melges et al. are the only researchers to have reported a significant impairment of Digit Span performance in connection with cannabis intoxication.) Marks and Casswell (1973[a]) conclude that:

> The results obtained support conclusions previously drawn (4, 8, 11, 15) that doses of cannabis up to 10 mg smoked and 20 mg ingested do not significantly impair simple tasks of short duration such as the DS, whereas more complex tasks involving both short-term memory and serial manipulation of information are impaired (p. 805).

Abel (1970) investigated the effects of smoked marijuana on memory, using a verbal task rather than the numerical tasks commonly employed by other researchers. Eight young college students, all of whom had some (unspecified) previous experience with marijuana, were tested individually on two occasions, once in a no-drug condition and once after smoking two cigarettes, the THC content of which was not known. Five minutes after smoking, all subjects were asked if they felt "high," and all answered in the affirmative. At each of the two testing sessions (separated by at least one month), the subject read through a copy of Bartlett's War of the Ghosts. Fifteen minutes after reading, he was instructed to write down as much of the story as he could remember, using the same words and phrases whenever possible. A standardized method of analysis (the King method) was applied to each protocol by three

judges whose ratings were averaged to provide a single score for each subject. It was found that, under the marijuana condition, there was a significant decrease in the subjects' ability to recall identical content words, two-word sequences, and idea units. It was also noted that seven of the eight subjects wrote less under the marijuana condition, but this difference was not statistically significant. The author concludes by saying that ". . . although individuals did do worse under marijuana, they were still able to read, remember and write when they needed to (p. 1151)."

In the following year Abel (1971a) reported on a second experiment in which 13 experienced subjects participated, seven of whom were required to smoke marijuana cigarettes of undetermined THC content, while the remaining six served as a no-drug control group. Cognitive testing consisted of: (1) an anagrams task in which the subject is first required to unscramble combinations of five letters so as to form a recognizable word and, secondly, after solving the anagrams, to write down as many of the unscrambled words as he can remember; (2) recall of a verbally presented "newspaper report" which was in fact a copy of the Babcock Memory Test. The two groups were pretested under no-drug conditions and no significant differences were found in either the times taken to solve the lists of

anagrams, or in the number of words correctly recalled. During the actual experiment, subjects were first asked to listen to the verbally presented "newspaper report." Following this, experimental subjects were given two marijuana cigarettes to smoke, and control subjects were allowed to sit quietly for an equivalent period of time. Ten minutes after the end of the smoking period, all subjects were given the Taylor Manifest Anxiety Scale, after which they were required to write out as much of the "newspaper report" as they could remember and, finally, the anagram task was administered. MAS results were not reported. Analysis of the cognitive test scores showed that, under the experimental conditions, the two groups did not differ in the times taken to solve the anagrams. However, when called upon to recall both the visually presented anagram words and the verbally presented "newspaper" story, the performance of the marijuana subjects was significantly poorer than that of the controls. These results are consistent with the impairment of memory for verbal material seen in Abel's (1970) previous experiment. However, they do not provide any clear answer to the question of whether it is the input or retrieval functions of memory which are adversely affected.

In September 1971, the same author addressed himself to this question directly in a paper entitled Marihuana and Memory: Acquisition or Retrieval (1971b). This paper

describes two experiments, each of which deals with one half of the problem. The first experiment is concerned with the retrieval of information from long-term memory. Prior to smoking, the subjects were presented with 18 lists containing ten words each. Each subject was then required to smoke one cigarette containing an undetermined amount of marijuana or, in the case of the placebo subjects, plain tobacco. Members of the control group were allowed to rest during this period. After smoking, 25 minutes elapsed during which subjects were kept occupied with cognitive tasks. Following this interval, they were first required to write out as many words as they could remember from the previously presented total of 180 words. Then, from a list of 300 words, 150 of which were contained in the previously presented lists, they were required to discriminate between those words which they had seen previously and those which were new. Space limitations do not permit a more detailed description of the procedures used in this complex experiment. However, there are some aspects of the experimental design which must be mentioned because they limit the degree of confidence that can be placed in the results. (1) The 49 subjects were divided into three groups of marijuana, placebo and control subjects. However, the groups were not matched for previous cannabis experience, or for other physical or psychological variables which might have

affected their reaction to the drug. (2) The "placebo" consisted of ordinary tobacco cigarettes. The subjects were told that these had been dipped in THC and would therefore have the same effects as ordinary marijuana. It is difficult to believe that an experienced user could be easily convinced by such a story. (3) The marijuana was not assayed for THC content, so no estimate of the dosage is possible. (4) Subjects were asked to rate their level of intoxication on a 1 - 10 rating scale, and only the scores of those marijuana subjects who rated themselves at five or more on this scale were included in the statistical analysis of the data. The great variability of subjective reactions to cannabis, discussed in Section 4(d) of this chapter, makes such a rating scale a very doubtful basis for subject selection. (5) The marijuana subjects so selected were matched with equal numbers of placebo and no-drug subjects on the basis of their pretest scores on the task involving the immediate recall of verbally presented word lists. There is no evidence to indicate that this criterion would guarantee group equivalence with respect to other variables which might influence a subject's reaction to the drug. These reservations should be kept in mind when considering the results which showed that (1) on the free recall test there was no difference between the groups in terms of the number of words remembered; (2) on the recognition test the groups

also did not differ with respect to the number of previously presented words which were correctly identified. However, the marijuana subjects did accept a significantly greater number of incorrect (not previously presented) words. The author concludes that, while the retrieval process itself was unaffected, subjects under the influence of marijuana tended to be less cautious in discriminating between previously learned and new material.

In the second experiment, designed to measure memory input, Abel tested ten experienced subjects who acted as their own controls. During the marijuana session they were allowed to smoke as much as they wished, after which they were asked to rate their level of intoxication on a 1 - 10 scale. All subjects gave a rating of seven or more. Beginning five minutes after smoking, subjects were verbally presented with ten 12-word lists, each of which they were required to repeat immediately after presentation. After the last list had been tested, they were allowed five minutes in which to write down as many of the previously presented 120 words as they could remember. On the immediate recall task, subjects were able to repeat significantly fewer words while under the influence of marijuana. In the delayed recall task, eight out of ten subjects wrote fewer words under the marijuana condition, but it is not entirely clear from Abel's (1971b) report if this latter difference was

statistically significant. Finally, the data were analyzed to show the number of words correctly recalled from each serial position in the 12-word lists. It was found that items in serial positions 10 through 12 were recalled equally well under both conditions. Abel considers that items from these positions are held in what he calls the "sensory register component of memory (p. 1039)." Because no differences were found in this type of memory, the author concludes that information is being received equally well under both experimental conditions. Items in serial positions 6 to 9 and 1 to 5 are considered to represent respectively information contained in the short-term and long-term memory stores. According to Abel, information is transferred from the sensory store to the short-term store, where it must be rehearsed if it is to be retained long enough to permit transfer to the long-term store where it is held permanently. It was found that more words in serial positions 1 to 5 and 6 to 9 were recalled under the control condition than under the marijuana condition. From this observation, plus the finding that on the delayed recall test more words were also remembered during the control condition, Abel concludes that while under the influence of marijuana subjects cannot concentrate long enough to be able to rehearse information held in short-term memory, to an extent sufficient to permit its transfer to the long-term memory store. The

overall conclusions drawn by Abel may be summarized briefly by saying that marijuana does not affect retrieval from the long-term memory store, but it does adversely affect the process of putting information into that store and, finally, that this impairment of input is due to a disruption of the individual's ability to concentrate.

The three studies carried out by Kiplinger, Manno and their associates at the Indiana University Medical Center are remarkable for the excellence of their experimental procedures, particularly in regard to problems related to the quantification of dosages. In the first of these studies, published in 1970 (Manno et al.), the sample consisted of eight male volunteers, all of whom had previously smoked either marijuana or tobacco. All subjects were tested on two occasions, on one of which they received a placebo cigarette composed of marijuana with all the cannabinoids removed and, on the other, they smoked active material which provided a delivered dose of 5 mg Δ^1THC. Testing involved motor performance as measured by four pursuit meter tasks and a series of cognitive tasks in which the subjects were required to give verbal responses while listening to their own voices under a condition of delayed auditory feedback. The cognitive tasks consisted of nine tests, each lasting two minutes: (1) Verbal Output, in which the subject read a passage from Aristotle's Selections; (2) Reverse Reading

of a similar passage; (3) Reverse Counting; (4) Progressive Count, in which the subject adds a given number repeatedly to the previous total; (5) Addition; (6) Subtraction; (7) Addition plus 7; (8) Subtraction plus 7; (9) Color Differentiation. On the pursuit meter tasks subjects made significantly more errors under the marijuana condition than they did under the control condition. Marijuana also produced a significant drop in the scores of five of the nine cognitive tasks: Verbal Output, Reverse Reading, Progressive Count, Addition plus 7, and Subtraction. In their conclusions the authors report simply that marijuana produces decrements in human motor and mental performance. They offer no rationale for conducting the cognitive tasks under delayed auditory feedback conditions, nor do they attempt to explain why some of these tasks were affected and not others.

In 1971, researchers from the same laboratory used the same tests in an experiment designed to compare the effects of marijuana and alcohol combined, with the effects of marijuana taken by itself (Manno et al.). The marijuana cigarettes were calibrated to deliver doses of 0 mg, 2.5 mg, and 5 mg Δ^1THC. These were smoked either alone, or in combination with a plain fruit-flavored drink, or in combination with the same drink containing 15 ml of alcohol per 50 lbs of body weight. Twelve subjects with limited marijuana experience were tested in a randomized block design,

such that each subject received all six drug conditions. As in the previous experiment, marijuana impaired performance on all four of the pursuit meter tasks. However, the impairment was not dose related. The effect of alcohol was additive, but only for the first pursuit meter pattern was the impairment, produced by the combination of drugs, significantly greater than the effect of marijuana alone. On the DAF tasks, marijuana produced a significant decrement in scores on seven of the nine tests, Subtraction plus 7 and Color Discrimination being the exceptions. Only the Reverse Reading test showed a significantly greater degree of impairment under the combined alcohol marijuana conditions, as compared to the effect of marijuana alone. Once again, the possible theoretical significance of the results from the cognitive (DAF) tests is not discussed. However, it was suggested that the failure to demonstrate dose response relationships may have been due to the fact that the calibration of dosages, without regard to body weight, may be too imprecise a method to permit such relationships to emerge.

A third experiment was therefore conducted in which marijuana cigarettes were calibrated on an individual basis to deliver doses of 0, 6.25, 12.50, 25, and 50 μgms per kilogram of Δ^1THC per kilogram of body weight (Kiplinger et al., 1971). (For an "average" 70 kg man, the doses would have been 0.44, 0.88, 1.75, and 3.50 mg Δ^1THC.) Fifteen subjects

were tested, eight of whom had some previous experience with marijuana. Tests were the same as those used in the previous two experiments, with the addition of a measure of stability of stance. The authors report that marijuana produced a dose-dependent decrement in performance in all four pursuit meter tasks and in the scores from the stability of stance measure. It is also claimed that linear dose-dependent decrements in performance were found in four of the nine DAF tests: Verbal Output, Reverse Count, Progressive Count, and Color Discrimination. It must be noted, however, that on the Reverse Count and Color Discrimination tests, performance after the 25 μgm dose was superior to that following the 12.5 μgm dose, and that on the Progressive Count test performance improved after the 12.5 μmg dose as compared to the 6.25 μgm dose. The authors offer no explanation of why the Subtraction plus 7 test should be the only one to remain unimpaired by marijuana in all three experiments. Nor do they explain the fact that scores from the Color Discrimination test showed a significant decrement after smoking the smallest dose of marijuana, when in previous experiments a significant decrease was not found after smoking much larger doses. Finally, generalization from these cognitive test results is limited by the fact that they were carried out under conditions of delayed auditory feedback.

Hollister and Gillespie (1970) compared the effects of marijuana, ethanol and dextroamphetamine on mood and mental functioning in 12 healthy subjects. All had used alcohol previously and most had some limited experience with marijuana and dextroamphetamine. All drugs were administered orally in a flavored beverage and doses were calculated on the basis of body weight. The median doses for the sample were: marijuana 32 mg Δ^1THC, dextroamphetamine 15 mg, and ethanol 57 gms. The placebo, which was also mixed with the same beverage, consisted of a marijuana extract from which all the cannabinoids had been removed. The cognitive tests, which were administered during periods beginning 1 hour and 3-1/2 hours post-drug, included: (1) the Rod and Frame Test; (2) the Digit Symbol Substitution Test; (3) simple reaction time; (4) the Number Facility Test, composed of simple arithmetic problems; (5) the Flexibility of Closure Test which requires the subject to trace in a field of dots a figure drawn in a similar field; (6) a time production task in which the subject is required to listen to a tone and then, by depressing a key, to attempt to produce a tone which is half the duration of the original tone; tone intervals were 1, 3.5, and 6 seconds. Only the results of the marijuana condition will be reported here. Scores on the Rod and Frame Test, the Digit Symbol Substitution Test, and the Flexibility of Closure Test were not significantly affected

by marijuana. A significant decrement in reaction time performance was found during the second testing period (four hours post-drug). Although the subjects tended to produce shorter tone blasts for all the time intervals, the difference was significant only for the 3.5 second interval. (Under-production of time intervals was even greater under the other two drug conditions.) Marijuana produced a significant drop in the scores of the Number Facility Test during both test periods. In their conclusions the authors state that dextroamphetamine tended to improve performance on psychometric tests, while alcohol and marijuana tended to impair it.

The work of Jones and Stone (1970) and Jones (1971) has been discussed in previous sections of this chapter. To recapitualte very briefly, in the first of these studies it was found that subjects over-estimated the duration of a 15-second interval to a significant degree, but no changes in performance were observed on a time-production task. Scores on the Rod and Frame Test and the Digit Symbol Substitution Test were also unaffected by smoked cannabis. In the second experiment it was observed that on the Digit Symbol Substitution Test and a measure of reaction time, there was a significant drop in the performance of infrequent users, while the scores of experienced marijuana smokers were not significantly affected.

The Cannabis Report presents preliminary results from four experiments carried out under the direct supervision of the Le Dain Commission (1972). The results of experiment number two which is concerned with automobile driving are not directly relevant to this discussion. In the first experiment, designed primarily to compare the effects of natural marijuana and synthetic THC, a number of cognitive tasks were used, including: (1) a time production task which required the subjects to specify 15-second time intervals while carrying out a distracting task; (2) a time-estimation task in which the subjects were required to guess the duration of other tasks used during the experiment; (3) Short Term Serial Position Memory which requires subjects to identify the position at which a given digit appeared in a previously presented nine-digit series; (4) the Digit Symbol Substitution Test. Fourteen male volunteers were each tested under a no-drug condition, and on seven other occasions during which they smoked either an alfalfa placebo, or natural marijuana, or alfalfa with synthetic Δ^1THC added. It was estimated that 53% of the Δ^1THC, contained in the natural marijuana cigarettes, was delivered in the smoke to the subjects, which would mean that for this sample the average delivered doses were 0.37 mg, 0.80 mg and 3.30 mg Δ^1THC. No significant differences were found between the effects of natural marijuana and

synthetic Δ^1THC. Under the effects of cannabis time estimates were longer and this effect was dose dependent. However, the time production task was not affected. The Digit Symbol Substitution Test was also unaffected at any dose level. Serial Position Memory was impaired by the highest dose of cannabis.

In experiment number three, concerned with the effects of marijuana and alcohol on psychomotor tracking performance, 22 subjects were tested using a placebo composed of extracted marijuana, and with active material at doses of 0.8 mg and 3.4 mg Δ^1THC delivered in the smoke. Tests consisted of (1) a simple tracking task in which the subjects were required to keep a moving circle centered on a target line; (2) complex tracking which involved the same task complicated by sudden reversals of the polarity of the control mechanism or the periodic addition of a complex (choice) reaction time task. Marijuana produced a dose related impairment in both simple and complex tracking performance, but it is not clear if this difference was statistically significant. Tracking, or pursuit meter, performance has been interpreted as a measure of attention as well as motor functioning (Weil, et al., 1968).

In experiment number four, the effects of marijuana on vigilance and attention was measured by means of a visual signal detection task. Five subjects were tested four times

each, twice with a placebo (extracted marijuana), and twice under a single dose of active material estimated at 2.35 mg Δ^1THC delivered in the smoke. Subjects were required to detect the presence of very short intervals when a continuously burning light was turned off, and to indicate their degree of confidence in their decisions. Five 100-trial sets of these signals were administered in a 40-minute period. Marijuana produced a consistent decrement in performance on this task, as well as lessening the subjects' confidence in their decisions. The authors interpret these results as ". . . strong evidence for a marijuana-related decrease in directed attention when a boring and tedious task is involved (Le Dain Commission, 1972, p. 144)."

Casswell and Marks (1973b) examined the effects of cannabis on divided attention, using a task similar to the one described above. In this experiment the apparatus consisted of ten lights on a 150° perimeter, and a central light which flashed at the rate of once per second. The subject was required to press a key whenever there was a break in the sequence of center light flashes and to depress a second key whenever one of the peripheral lights flashed. Using double blind procedures, ten experienced and ten naive subjects were tested after smoking a placebo (extracted marijuana), and two doses of active material estimated at 1.65 mg and 3.3 mg Δ^1THC, delivered in the smoke. It was

found that, after smoking both doses of marijuana, the subjects missed significantly more of both the central and peripheral light flashes. These effects were dose related. It is noteworthy that the degree of impairment did not differ between experienced and naive subjects. The authors suggest that the effects of boredom, induced by the nature of the task, may have obscured differences between the two groups.

Galanter et al. (1973) compared the effects of natural marijuana and synthetic Δ^1THC on a variety of variables, including: (1) EEG, alpha power; (2) pulse rate change; (3) digit recall of six sets of nine digits each, repeated either immediately (forwards and backwards) or after a four-second delay during which the subject recited letters of the alphabet; (4) complex (choice) reaction time; (5) production and recall, after 20 minutes of free associations to common words. Natural marijuana was administered in the form of cigarettes containing 10 mg Δ^1THC. Ten mg of synthetic Δ^1THC was injected into the center of placebo cigarettes composed of extracted marijuana. According to the findings of Fehr and Kallant (1972), the THC losses from natural marijuana and synthetic Δ^1THC, administered in this way are approximately 50% and 70%, respectively. Thus, although the Δ^1THC content was equal in both types of cigarettes, the delivered doses of Δ^1THC would have been approximately 5 mg for the natural marijuana and 3 mg for

the synthetic material. The effects of the two types of material were significantly different on only the pulse and EEG measures, and the authors suggest that these differences were probably the result of inequalities in the delivered doses. Complex reaction time scores were unaffected by either substance. Also, under both drug conditions, subjects did not produce more uncommon or idiosyncratic responses to the free association task, nor was there any difference in the number of these words recalled after a 20-minute interval. This latter finding provides additional evidence which indicates that cannabis does not affect long-term memory. The subjects' scores in repeating digits forwards, backwards and after a four-second delay all showed a significant decrease after smoking cannabis. The authors also analyzed frequencies of recall in relation to the serial positions in the nine-digit sequence. They found that the entire frequency curve, obtained in this way, was depressed by cannabis but was not altered in shape, from which they conclude that:

> This indicates that there was no significant difference between recall for digits whatever their place in the sequence of presentation and is indicative of an attentional defect rather than its passage into memory stores (Galanter et al., 1973).

Rafaelsen et al. (1973), in a single experiment, compared the effects of alcohol and orally administered cannabis on car driving, and a variety of mood scales,

personality and cognitive tests. In this paper they report the results from the cognitive measures which included: (1) Digit Span Test; (2) addition; (3) serial subtraction of sevens; (4) Bourdon's Cancellation Test, a measure of sustained attention; (5) finger labyrinth tasks, with subjects blindfolded, at four levels of complexity. Cannabis, in the form of cakes of natural resin, was administered at three dose levels estimated at 8 mg, 12 mg, and 16 mg Δ^1THC. The placebo consisted of the same material with all THC extracted. (These doses are unusually small in comparison with the oral doses used in other studies mentioned in this review.) The alcohol dose was reported to be 70 gms, administered in fruit juice. The alcohol appears to have had no significant effect on any of the variables. The Digit Span and Cancellation tests were not significantly affected by any of the three cannabis doses. On the addition test and the serial subtraction of sevens, the 12 mg and 16 mg Δ^1THC doses increased the working times of the subjects, but did not significantly affect their error scores. These effects were dose related. The two higher doses of cannabis also significantly lengthened working time on the three most difficult finger labyrinth tasks, and caused some increase in error scores. The authors consider the differential effect of cannabis on time and error scores to be important and conclude by stating: "This may be related to the loss of

items from short term memory, while long term memory is relatively unaffected." It might have been said that short-term memory and attention, as measured respectively by the Digit Span and Cancellation tests, were not impaired, while numerical reasoning, as measured by the addition and subtraction tests, was slowed down but not otherwise affected. It is also possible to speculate that the absence of significant differences may have been due to the relatively small amounts of cannabis employed.

Klonoff et al. (1973) used a battery of 13 tests to study the effects of two doses of smoked marijuana and placebo on motor and cognitive functioning and learning. The cognitive tests included: (1) Halstead Category which measures concept formation by requiring subjects to name the similarities and differences by which stimuli might be classified; (2) Trail Making which requires subjects to recognize the symbolic significance of numbers and letters and to be able to identify the sequence in which they appear; (3) Halstead Tactual Performance, a form board test (blindfolded) requiring tactile discrimination and memory for spatial relationships; (4) Seashore Tonal Memory which measures attention and immediate memory for tonal sequences; (5) Benton Sentence Repetition which measures immediate memory for semantically meaningful material; (6) Picture Recognition, an immediate memory test which requires the

subject to identify 16 pictures which appear more than once in a series of 76; (7) Peterson Visual Memory which measures retention and recall of verbal trigrams, following a brief interval of counting. Subjects were 81 experienced volunteers of both sexes who were first divided into two groups, one of which received the low dose of 2.4 mg Δ^1THC reinforced by 1.2 mg one hour later, while the other group received the high dose of approximately 4.5 mg Δ^1THC reinforced by 2.25 mg one hour later. (These doses are estimates based on the assumption of 50% THC loss in the smoke.) In an attempt to study the effects of marijuana on learning, all subjects were tested twice with the same battery, using four different sequences of drug conditions. The two original groups (high and low dose) were therefore subdivided into four groups each corresponding to the four experimental sequences: marijuana/marijuana, marijuana/placebo, placebo/marijuana, placebo/placebo. On each testing occasion the effects of the drug were assessed by comparing the scores of subjects who received active marijuana with those who were given a placebo.

Analysis of the tables of results, presented in the body of the paper, reveals that on both testing occasions the scores of both the high dose and low dose groups were significantly lower than those of the placebo groups on the Trail Making Test, the Halstead Tactual Performance Test and the Peterson Visual Memory Test. The Seashore Tonal

Memory Test was unaffected by either dose on either occasion. Picture Recognition was impaired by the high dose on both occasions, but not by the low dose. The Halstead Category Test was impaired by the high dose on both occasions, and by the low dose on the first occasion only. Sentence Repetition was impaired by the first high dose and by both low doses, but the second high dose produced no significant effect. Memory for tactually presented spatial relationships (Test No. 3) was significantly affected only by the first high dose. Improvements were noted in the scores on a number of tests from the first to the second session, but these changes were independent of whether the subjects had received marijuana or placebo in the first session.

This study was weakened (as was Abel's (1971b)) by comparing the scores of apparently unmatched groups of subjects instead of using each individual as his own control. Also, it is felt that in their discussion the authors tend to gloss over the inconsistencies and poor reliability of the results presented in the body of the paper. They conclude that marijuana produces an impairment in all mental processes; i.e., concept formation, memory, tactile form discrimination, and motor functioning, and they suggest that these effects are specifically related to an impairment in the output (recall) aspect of memory, ". . . due to interference with central integrative processes (Klonoff et al., 1973, p. 156)." It is noteworthy that this conclusion is in direct contrast to the position taken by Abel (1971b) who concluded that it is the inpute phase of memory which is adversely affected.

In Section 6(a) studies concerned with the effects of cannabis on intellectual functioning have been examined in some detail. In Section 6(b) an attempt will be made to summarize the more important findings of these many and varied experiments.

(b) Summary of findings

The first four sections of this chapter were devoted to a discussion of the more important variables which can influence the outcome of experiments involving the use of cannabis. It may now be apparent that, among the experiments reviewed in this section, there has been little uniformity in the procedures used to control or account for these variables. As a result, it is often impossible to make meaningful comparisons between studies. Also, there has been very little method evident in the choice of the tests used, and no attempt has been made to interpret the results from these diverse instruments within the framework of a comprehensive theory. Finally, the conclusions which may be drawn from a number of these studies have been severely limited by weaknesses in their experimental designs. As a consequence of these many problems, there remains very little which can be asserted with real confidence concerning the effects of cannabis on intellectual functioning. In fact, with regard to the more complex intellectual tasks, the evidence is so limited that it is impossible to say with certainty if cannabis has any effect whatever. Nevertheless, in the remainder of this section an attempt will be made to discover

general trends in the available evidence which may be used as a basis for the formulation of new hypotheses.

Of such trends, the one most consistently reported is the impairment of the ability to estimate the duration of externally presented stimuli. In all cases, objectively measured time seemed to pass more slowly, indicating a speeding up of the subject's "internal clock." On time production tasks, in which subjects are required to indicate time intervals without immediate reference to outside stimuli, results are less clear cut but in the same direction. Unfortunately, no attempts have been made to relate this phenomenon of subjective time alteration to other aspects of mental functioning.

Attention was measured by Casswell and Marks (see above, p. 79) and the researchers of the Le Dain Commission (see above, p. 80) using two similar signal detection tasks. In both studies there was a significant drop in the scores of subjects after smoking marijuana. In contrast, the performance of both experienced and naive subjects on the CPI, a signal detection task used by Weil et al. (see above, p. 49) was not affected by marijuana. In a number of studies, cannabis impaired performance on complex reaction time and pursuit rotor tasks, both of which involve an attention factor as well as speed of response. Of particular interest is the observation by Clark and Nakashima (see above, p. 53)

that the drop in reaction time scores, seen in their study, was due to a greater degree of variability in the subjects' responses rather than an overall increase in reaction times. They attribute this change to a "sporadic impairment of vigilance."

The aspect of intellectual functioning most frequently investigated by cannabis researchers has been memory. A wide variety of verbal and numerical tests has been used to measure recall, both immediately after stimulus presentation and following delays varying from a few seconds up to 25 minutes. In the great majority of studies, cannabis ingestion has been followed by a significant drop in the scores from these tests. A notable exception has been the Digit Span Test (repeating digits forward and backward), the results of which have been unaffected by cannabis at any dose level in four out of five studies. Abel (see above, pp. 70-71) has theorized that the drop in memory test scores which he observed is due to a disruption of the acquisition or input processes of memory. Specifically, it is theorized that cannabis-intoxicated subjects have greater difficulty in concentrating and therefore are unable to rehearse information held in the immediate memory store to an extent sufficient to permit its transfer to longer term memory. Abel's work is marred by a number of weaknesses in design (see above, pp. 67-68). Nevertheless, his theory does accord well with the previously

mentioned data concerning the effects of cannabis on attention. It may also explain why the Digit Span, a test of immediate memory, is unaffected by cannabis while other tests involving longer delays show impairment. Galanter et al. (see above, p. 81) go a step farther in suggesting that changes in memory test scores are due to the drug's impairment of attention alone, rather than the actual process of transferring information into memory stores. Klonoff et al. (see above, p. 84) have taken an opposite position and suggested that it is the recall or output processes of memory which are disrupted by cannabis, and that this disruption in turn leads to a general impairment of all intellectual functioning, including the more complex processes.

This study by Klonoff et al. contains a number of design weaknesses which limit the confidence which can be placed in its conclusions. Unfortunately, other studies concerned directly with the effects of cannabis on complex tasks have been few in number and their findings are frequently contradictory. The LaGuardia Report (see above, p. 47) has suggested that cannabis impairs complex intellectual functions, while leaving the simpler ones relatively unaffected. Kalant (see above, p. 47) has questioned this interpretation and suggests that while marijuana may impair performance on some tasks, notably those involving numerical reasoning, others which require verbal reasoning have shown improvement.

Other investigators of complex functions have used mainly numerical tasks, particularly tests of serial subtraction and addition. Taken as a group, the findings of these studies have been inconclusive. Nevertheless, on the basis of results from these tests, three separate groups of authors have all concluded that cannabis impairs the ability to keep track of recent stimuli while manipulating them in the process of multi-stage sequential reasoning (see above, pp. 54, 57, and 64).

The foregoing review raises a great number of questions which can only be answered by further research. Among these, there remains the basic question concerning whether or not cannabis does in fact impair performance on tests of complex intellectual functioning. The first task of the present study will be to seek a clear answer to this question. Assuming that it can be shown that cannabis does have an effect on tests of complex intellectual functioning, a second question then arises concerning which type (or types) of task will be most affected. The literature suggests three possible answers to this question which may be examined within the confines of a single study.

It has been suggested that cannabis disrupts the process of putting information into the permanent memory store, but does not affect either very short-term memory or the ability to recall information contained in the long-term

memory store. If this theory is correct, then cannabis should produce impairment in tests of intermediate memory; i.e., tests in which subjects are required to memorize new material and repeat it after a time lapse of one or more minutes. However, it should not affect a wide variety of tasks which require the subject to manipulate old information contained in the long-term memory store.

Klonoff et al. have taken the opposite position in suggesting that it is the process of recalling information from long-term memory that is impaired by cannabis. If this view is correct, then it might be expected that cannabis would impair performance on a wide variety of tasks involving complex problem solving, but would not affect tests of intermediate memory and tests of very short-term memory; i.e., tests which require immediate repetition of presented material. It might also be expected that cannabis would have little effect on tasks involving recognition, comparison, and judgment in relation to stimuli which are immediately present.

Finally, it may be theorized that it is not any form of intellectual functioning per se which is affected by cannabis, but rather the underlying ability to concentrate on the task in hand irrespective of what that task may be. If this view is correct, then it might be expected that cannabis would produce a fairly uniform impairment in performance on a wide variety of tasks, including tests

concerned with both the input and output aspects of memory.

It is felt that the contradictions inherent in these views have not been resolved to date because they have not been examined within the context of a single comprehensive theory of intellectual functioning. J. P. Guilford's Structure of Intellect theory[6] would appear to offer just the type of framework which is required for the task of comparing and interpreting the results of tests which measure a number of different types of intellectual functioning. Guilford's SI model also has a very great practical advantage. So far as this writer knows, it is the only comprehensive system in which the tests, used to measure different intellectual functions, are all sufficiently short that a number of them can be administered within the comparatively brief period of maximum intoxication (approximately one-half hour) produced by smoked marijuana. The next section of this chapter will be devoted to a description in outline of this theory. Thereafter an attempt will be made to use the language of Guilford's theory to formulate hypotheses which may be tested experimentally.

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6 Hereafter the Structure of Intellect theory will be referred to by the letters SI.

7. J. P. Guilford's Structure of Intellect Model

The most salient feature of Guilford's theory (Guilford, 1967; Guilford & Hoepfner, 1971) is his assertion that intelligence is a heterogeneous entity composed of a number of separate abilities. While a number of these abilities may be and usually are employed together in the process of problem solving, they are nevertheless relatively independent of each other in the population as a whole. Thus, an individual who does well on a test measuring one ability, may do poorly on a test of another ability. This view of intelligence is in direct contrast to the more traditional and holistic concept advanced by Charles Spearman in his two-factor theory of intelligence. Spearman proposed that there will be, necessarily, a high degree of correlation among all tests of intelligence, because there is a single underlying intellectual ability which is measured to a greater or lesser extent by all such tests and which is, therefore, responsible for the relationships between them. In addition, he suggested that each test measures a second factor or variable which is unique to that test and which does not contribute to its intercorrelation with other tests. This theory was not supported by the subsequent work of L. L. Thurstone. In a series of factor analytic studies, Thurstone and his associates succeeded in isolating a number

of separate intellectual factors, six of which were considered to be sufficiently distinct to merit inclusion in Thurstone's test of primary mental abilities. Guilford's theory owes much to this earlier work of Thurstone. However, the actual data on which it is based were derived from two groups of factor analytic studies: the Aviation Psychology Program of the U.S. Army Air Forces during World War II and the Aptitudes Research Project which began in 1949 at the University of Southern California.

In order to provide a logical system for organizing and understanding these independent abilities, Guilford proposed a morphological model of intelligence which he named the Structure of Intellect (SI model). In proposing this model Guilford not only rejected Spearman's g factor theory of intelligence, he also rejected the hierarchical classification proposed by Burt, Vernon and others, on the grounds that the abilities isolated by factor analysis were all of approximately equal generality (i.e., an approximately equal number and variety of tests could be found to represent each ability). Guilford adopted a cross classification system which takes into account the fact that, even though intellectual abilities may be independent of each other, they can still be grouped according to certain properties which they have in common. The precise meaning of this apparently contradictory statement can be best illustrated by describing the model itself.

The SI model classifies all the intellectual abilities in terms of three main dimensions called Operations, Contents, and Products. If the organism may be regarded as a processor of information, analogous to an electronic computer, then the dimension of Operations may be thought of as encompassing all those intellectual activities or ways of functioning in which the organism may engage while processing information. More will be said about this dimension in the following pages. For the moment it is sufficient to note that the term Operations connotes an essentially dynamic concept. In contrast, the dimensions of Content and Products are essentially static and both may be regarded as ways of classifying the information which is processed by the organism. (Information is defined broadly by Guilford (1967) as "that which an organism discriminates (p. 221).")

The four categories of Content pertain to the substantive aspects of information; i.e., <u>what</u> is processed. The first of these is the Figural category which refers to the concrete aspects of information as it is perceived, or as it is recalled in the form of images. The term Figural always implies some degree of figure-ground differentiation and may involve any of the sense modalities. Thus, figural information might include such properties as dimension, texture, color, tone, etc. The term Symbolic refers to information contained in denotative signs which have no

significance in themselves, such as letters, numbers, musical notations, codes, etc. The Semantic category includes information in the form of concepts, mental constructs and meanings to which words are frequently (but not always) attached. Thus, it is most evident in verbal communication. The commonly made distinction between "concrete" and "abstract" thinking may be thought of, in terms of the SI model, as a distinction between abilities which belong in the Figural category and those which may be included in either the Symbolic or Semantic category.

When constructing his model, Guilford also added, on the basis of speculation only, a fourth content category which he called Behavioral. This category pertains to information about human interactions, attitudes, needs, intentions, etc. Thus, it may be thought of as referring to what has been termed "social intelligence" as distinct from concrete or abstract intelligence. Since 1949 a number of behavioral abilities predicted by the model have been demonstrated in factor analytic studies.

The six categories of the Product dimension are concerned with the <u>form</u> which information takes when it is processed by the organism. Information may be in Units which are relatively circumscribed "chunks" of information having thing-like properties. It may also be in the form of Classes of things which can be grouped by reason of their

common properties. The third category, called Relations, involves information about connections between things or ideas. Examples of Relations are found in such terms as "bigger than," "son of," etc. A number of standardized IQ tests include items which require the subject to discern relations between pairs or sequences of numbers or words; e.g., A is to B as C is to what? The category of Systems refers to information in the form of complexes or organizations of many parts and may include patterns of different types of relations. The fifth category, called Transformations, refers to changes, modifications or revisions in information. Guilford points out that this category has some of the dynamic qualities of a process usually ascribed to the Operations categories. Nevertheless, Transformations may still be the objects of Cognition or other operations of intellectual functioning. Examples of Transformations are found in such words as reddening, growing, hardening, etc. Finally, the category of Implications involves information which is suggested or implied by other information. As such it involves foresight or prediction and is exemplified by phrases of the "if-then" type. Chess is a game which is based almost entirely on the ability to be aware of implications.

As mentioned above, the five categories of the Operations dimension describe the ways in which the organism

functions when it is processing information. The first, Cognition, involves discovery, rediscovery or recognition of information in any of its various forms. It is the process by which the organism becomes aware of information in the present which may then be further processed through the mechanisms of the other operations. Memory, the second category, refers to the process of storing and retaining information. As such it must be clearly distinguished from the memory store itself. The memory store is the repository of all previous learning and depends not only upon the ability to store and retain information, but also upon the extent and variety of the information to which the individual has been exposed in the past. The memory store underlies all forms of intellectual activity and may be considered as a necessary, though not sufficient, condition for all the functions included in the Operations dimension. Concerning the process of Memory, Guilford discusses but does not finally make a clear distinction between the terms "short," "medium," and "long-term" memory. For the most part, tests used in the SI studies measure memory over a period of two minutes or less.

In the SI model there are two operations, Convergent Production and Divergent Production, which involve the generation of new information from given information. The given information may come from a stimulus input, or from

the memory store or, more commonly, from a combination of both. In practice, in tests of Divergent Production, each item serves as a stimulus or cue to which the subject responds by producing a number of diverse responses; e.g., name as many items as you can which are both hard and black. The stimulus item provides the broad limits which define the type of response required. The subject is then obliged to recall from his memory store as many items as possible which satisfy the limits set by the stimulus. In the case of the foregoing example (Divergent Production of Semantic Units-DMU) the process involves mainly the simple retrieval of stored information. Divergent Production of Systems is a more complex process in that the subject is required, not only to recall items from the memory store, but also to arrange them into a system or construct which may be entirely new. For example, the subject is required to write as many four-word sentences as possible, using words which begin with designated letters: W_____ C_____ E_____ N_____. Possible responses might be: "We can earn nothing" or "William can enunciate nonsense." This operation has been commonly associated with such qualities as mental flexibility, fluency, imagination, originality, and is considered to be an important component of that loosely defined concept called creativity.

In the case of tests of Convergent Production, the limits of the response are much more closely defined and the

subject is required to find a particular or unique solution which satisfies the requirements of the stimulus. An example of the Convergent Production of Semantic Relations (NMR) is the Part-Whole Relations test which requires the subject to name the smallest possible whole of which a given thing is a part. Guilford (1967) makes a clear distinction between Divergent Production and Convergent Production as follows:

> We might say that in divergent production we are generating the logical possibilities from given information, whereas in convergent production we are generating logical necessities (p. 215).

The fifth operation, Evaluation, involves the assessment of information either cognized or produced, and the making of judgments concerning its goodness or appropriateness with respect to predetermined criteria. In practice the process frequently involves comparison and choice, as in a test of Evaluation of Figural Units (EFU) in which the subject is asked to choose one of four figures which is most like the test figure.

The foregoing presentation has given a brief outline of the three dimensions and fifteen categories of the SI model. According to Guilford (1968), each intellectual ability is made up of ". . . a unique conjunction of one kind of operation, one kind of content and one kind of product (p. 620)." In the illustration on p. 101 each of these

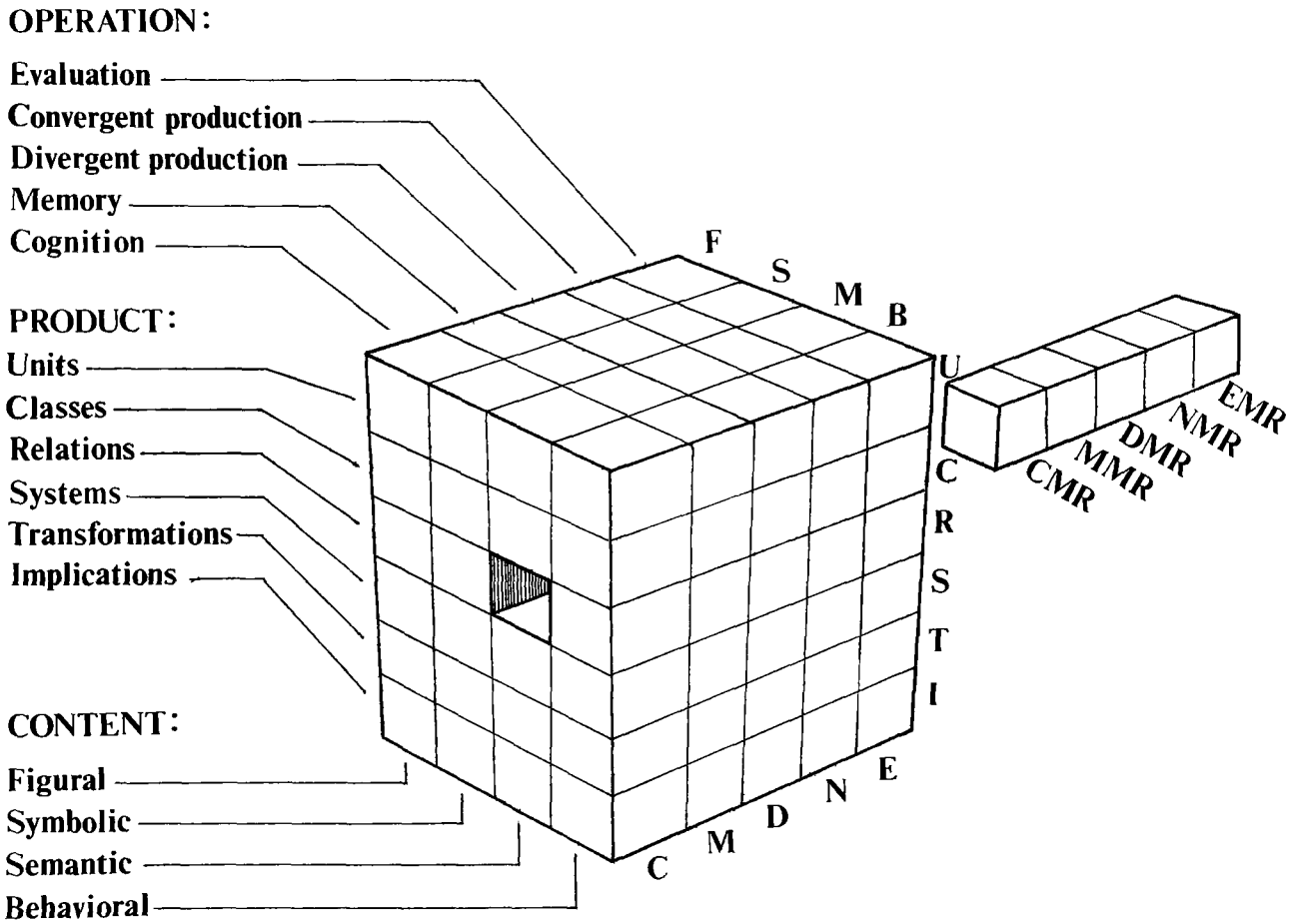

Figure 2.- Illustration of the Structure of Intellect Model.

abilities is represented by a cell in the SI cube. Each of these abilities/cells is a psychological construct derived from a mathematical factor which has been demonstrated in one or a number of factor analytic studies. Operationally, each ability is defined in terms of scores on those tests which have been shown to load significantly on one mathematical factor, and on no other factors in the SI model. Thus, theoretically at least, tests which are used to represent the different abilities of the model should show very low intercorrelations.

However, it must be stressed that, while each of the abilities is statistically distinct from every other in the population as a whole, in the intellectual functioning of the individual they work together in a dynamic unit which makes possible the solving of complex problems. It is only by the careful construction of special tests and the application of the methods of factor analysis that it is possible to isolate these abilities which are the individual building blocks of the total structure of intellect. The whole process of problem solving has been described, using SI terminology, as follows:

> Becoming aware that a problem exists is a matter of cognition, often emphasizing the product of implication. Before progress can be made toward a solution, the problem must be understood; it must be structured, which usually means cognition of a system. Having structured the problem, the individual generates alternative solutions, which

> is divergent production. All the way along the problem-solving event there is evaluation, in the form of accepting or rejecting cognitions of the problem and the generated solutions. At any step whatever happens may become fixated and retained for possible later use, so that memory is involved. When evaluation leads to rejections, there may be new starts with revised cognitions and productions (Guilford & Hoepfner, 1971, p. 31).

It is apparent that if any step in this train of events is disrupted, then the whole complex process of problem solving may break down. Research to date gives some reason to believe that cannabis does interfere with complex problem-solving activity. However, the point (or points) in the reasoning process at which this interference occurs remains uncertain. It is hoped that a systematic investigation based upon the Structure of Intellect model may lead to a removal of this uncertainty.

8. Derivation of Hypotheses

Ideally, such an investigation would simultaneously examine the effects of cannabis on the scores of tests representing all the SI abilities. For a variety of reasons, foremost among which is the comparatively short intoxication period produced by smoked marijuana, a project of such magnitude is not practical within the confines of a single study. Also, it is doubtful if such an extensive test battery would be necessary. Intuitively, it seems unlikely

that any drug would be so selective that only one ability would be affected to the exclusion of all others. It would seem more probable that an entire group of abilities would be influenced. The most obvious basis for grouping abilities is in terms of the three main dimensions of the SI model. It is possible to provide a rationale for using any one of these dimensions as a starting point. The final decision, therefore, concerning what abilities should be investigated first must be largely arbitrary.

For the purposes of this study it was decided to investigate the effects of smoked marijuana on the five categories of the dimension of Operations. This decision was made for two reasons. First, the Operations dimension describes the dynamic activities in which the organism engages during the process of problem solving. Intuitively it seems most likely that a drug would affect one or another of these activities, rather than a product or content common to all of them. Secondly, it was considered that the Operations dimension would provide the most suitable basis from which to approach the general hypotheses formulated on pages 90 to 92.

In order to investigate the effects of cannabis on the five Operations categories, it was necessary to select particular cells of the SI model which had been equated in terms of Content and Product. The decision to choose

the Semantic category from the Content dimension was made on a purely arbitrary basis. The writer is employed in the field of education in which the Semantic category is obviously of central importance.

The six Product categories may be thought of as a hierarchy in terms of complexity, extending from simple Units to more complex Implications. This study is concerned with complex intellectual functioning, as opposed to those types of mental activities involved in the performance of simple rote tasks. At the same time it was feared that if tasks were made too complex, their very complexity might mask possible differences in the effects of the drug on the individual Operations. It might be hypothesized (following conclusions in the LaGuardia Report) that if any intellectual task is sufficiently complex, it will be impaired by cannabis irrespective of which Operation it involves. It was hoped to avoid such a possibility by selecting a Product category from the middle range of complexity. On the basis of inspection it was considered that the category of Relations would best serve the purpose.

In this way it was decided to investigate the effects of cannabis on:

1. Cognition of Semantic Relations (CMR)
2. Memory for Semantic Relations (MMR)
3. Divergent Production of Semantic Relations (DMR)
4. Convergent Production of Semantic Relations (NMR)
5. Evaluation of Semantic Relations (EMR)

The selection of the tests to be used to represent these abilities was made on practical grounds. Each test had to be sufficiently short so that the entire battery could be administered within the 30-minute period of maximum intoxication produced by smoked marijuana. From among the available SI tests which were sufficiently short, tests were selected which had (1) the maximum reliability coefficients and (2) the maximum loading for the particular factor being investigated. (For details of SI tests and test selection, see Chapter II, Section 5.)

It was decided to use smoked marijuana in this study because it was considered that this mode of administration permits more accurate quantification of (delivered) doses than does the oral route. (See Chapter I, Sections 2 and 4(b).)

Since it has been reported that the effects of cannabis on intellectual functioning may be dose related (see above, Sections 3 and 6), it was decided to use two dosage levels in this study. The low dose was intended to be within the range of what has been estimated to be the

amount commonly consumed in a social context (see above, Section 4(a). The high dose was intended to be double the amount of the lower dose. Since it has been reported that the effects of cannabis are influenced by the expectations of subjects (see above, Section 4(d), it was decided to include a placebo condition and to conduct the study under double blind conditions. For purposes of comparison, a control (no-drug) condition was also added.

It has been reported that there is a difference between the reactions of experienced and drug-naive subjects to cannabis (see above, Section 4(c)). It was also feared that drug-naive subjects would be more likely to be distracted from the tests by anxiety and/or the novelty of the drug experience. It was decided, therefore, to use only experienced subjects. Differences in the reactions of males and females to cannabis have not been demonstrated. Nevertheless, in order to avoid any chance that scores might be influenced by this variable, it was decided to use an all-male sample.

It has been reported that there is a high degree of intersubject variability in response to cannabis (see Chapter I, Section 3). In view of this fact,it was decided that the chance of finding significant differences would be greatly increased by the use of a repeated measures design,in which the same subjects would be tested under

all conditions. Details of the alternate forms of each test and the various experimental procedures required by this design are presented in Chapter II, Sections 5 and 6.

In addition to the SI test battery, it was decided that the Otis Self-Administering Test of Mental Ability Higher Examination, Forms A & B would be administered separately to all subjects under no-drug and high dose conditions. This decision was made because it is recognized that the SI tests are experimental instruments and therefore they may not have the same face validity as a standardized and widely used test such as the Otis SA. It was hoped that if drug effects could also be demonstrated with the Otis SA, these findings might lend support to results obtained from the SI tests. It was also hoped that results from the Otis SA might prove to be useful for purposes of comparison and interpretation.

Finally, it was decided to administer the Digit Span Test in conjunction with the SI battery. This was done in order to provide a very short-term memory test which could be used for purposes of comparison with the more complex intermediate term memory test included in the SI battery.

Having established the general framework of the study it is now possible to reformulate the general hypotheses stated on pages 90 and 92 in such a way that they can be tested experimentally. The first hypothesis concerns the

basic question: Does cannabis impair performance on tests which measure complex intellectual functioning of any kind? A significant difference obtained on the Otis SA, or any one of the SI tests mentioned in this section, would provide a clear answer to this question. The first hypothesis may therefore be stated in two parts as follows:

H_1 (a) On at least one SI test there will be a significant difference between the mean score obtained under the control (no-drug) condition and the mean score obtained under the high dose condition.

(b) There will be a significant difference between the mean IQ score on the Otis SA, Form A, obtained under the control (no-drug) condition and the mean IQ score on the Otis SA, Form B, obtained under the high dose condition.

Assuming that cannabis does have some effect on complex intellectual functioning, there are three possible explanations which have been offered concerning the nature of this effect. The first suggests that cannabis disrupts the process of putting information into the long-term memory store, and furthermore that cannabis does not disrupt either very short-term memory or the ability to recall information which is already stored in long-term memory. This theory leads to the formulation of the second hypothesis:

H_2 Of all the measures used in this study, only the test of Memory for Semantic Relations will show a significant difference between the mean score obtained under the control (no-drug) condition and the mean scores obtained under the high dose, or both the low and high dose conditions.

The second explanation presents the opposite view that cannabis impairs the ability to recall old information from the long-term memory store and, therefore, affects any task which is mainly dependent on the manipulation of such information. This theory may be expressed in the terms of the present study as follows:

H_3 On tests of Divergent Production of Semantic Relations and Convergent Production of Semantic Relations there will be a significant difference between the mean scores obtained under the control (no-drug) condition, and the mean scores obtained under either the high dose, or both the low and high dose, conditions. At the same time on the Digit Span Test and the Test of Memory for Semantic Relations, there will be no significant differences among the mean scores obtained under any of the treatment conditions.

Finally, it has been suggested that cannabis does not affect complex intellectual functioning directly, but rather the underlying ability to concentrate on the task in hand, whatever that task may be. This suggestion leads to the following hypothesis:

H_4 There will be a significant difference between the mean IQ score on the Otis SA, Form A, obtained under the control (no-drug) condition and the mean score on the Otis SA, Form B, obtained under either the high dose or both the high and low dose conditions, and on all the SI tests there will be significant differences between the mean scores obtained under the control (no-drug) condition and the mean scores obtained under either the high dose or both the high and low dose conditions, and all of these differences will be of roughly comparable magnitude.

9. Statement of the Null Hypotheses.

The foregoing hypotheses may be combined and examined within a single experiment, which is designed to test the following null hypotheses:

1. When comparisons are made between the SI model test scores of 40 experienced male marijuana users, tested under conditions of control (no-drug), placebo, low dosage, and high dosage of smoked marijuana, there are no significant differences among the four means obtained for each of the six tests.

2. When comparisons are made between the Digit Span Test scores of 40 experienced male marijuana users, tested under conditions of control (no-drug), placebo, low dosage, and high dosage of smoked marijuana, there are no significant differences among the four means.

3. There is no significant difference between the mean IQ score of 40 experienced male marijuana users, tested with the Otis SA Test of Mental Ability Higher Examination, Form A, under the control (no-drug) condition, and the mean IQ score of the same group tested with the Otis, Form B, under the high dosage of smoked marijuana.

The following chapter describes the experimental procedures used to test these null hypotheses.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter presents the experimental design and statistical procedures used to test the hypotheses of this study. In fact, two independent studies are described: (1) the main drug study which was used to test directly the hypotheses stated in Chapter I; and (2) a no-drug experiment which was used to determine the reliability of the SI model tests selected for use in the main drug study. Section 1 describes the sample of 40 subjects used in the main drug study. A description is also given of a subgroup of ten subjects (drawn from the group of 40) who were retested a year after completion of the main experiment. Section 2 describes the physical setting in which the drug study was carried out. Section 3 describes the two smoking devices used in the drug study, and section 4 outlines the methods employed to quantify doses of Δ^1THC delivered in the smoke by these devices. In section 5 a description is given of all tests and other measures used in the experiment. Section 6 presents the counterbalancing systems used to determine the sequence of treatment conditions for each subject, and the order in which tests and test forms were administered under each condition. Section 7 describes in detail the day-to-day procedures used in carrying out the

experiment. In section 8, the complete no-drug reliability study is presented, including descriptions of the sample (N=132), tests, counterbalancing, and experimental procedures. Section 9 describes the statistical procedures used to analyse the data.

1. Sample

The recruitment of subjects for the main experiment was done by word-of-mouth. Potential subjects were told only that they would be given an opportunity to participate in a study concerned with the effects of marijuana on intellectual functioning. As an inducement to participate (in addition to the privilege of smoking "government grass") they were promised a complete explanation of the experiment and a full disclosure of their test results, after all aspects of the study had been completed. Free transportation by taxi to and from the testing site was provided. No financial rewards were offered.

Of approximately 60 subjects who expressed initial interest, a total of 40 finally agreed to participate. All were males ranging in age from 21 to 36 years, with a mean of 24.8 and a standard deviation of 3.8. Subjects ranged in weight from 130 lbs to 210 lbs, with a mean of 162.65 lbs and a standard deviation of 19.9. Each participant was required to fill out a brief medical questionnaire, and

all reported themselves to be in good health. With regard to education levels, the sample was divided as follows: 12 were full-time university students (10 undergraduates and 2 at the graduate level). Of the remaining 28, 3 had completed high school, 9 had dropped out of university before graduating, 11 had BA or BSc degrees, and 5 held post-graduate degrees. In order to be eligible for participation, it was required that all subjects have used cannabis on at least three previous occasions. Reported frequency of use prior to the experiment ranged from less than once per seek to more than seven, with a mean of 2.21 and a standard deviation of 1.63. All subjects were asked, "When (approximately) did you first use cannabis?" The reported period of use prior to the experiment ranged from 9 to 87 months with a mean of 35.18 and a standard deviation of 18.87.

One year after completion of the main experiment, ten subjects from among the original 40 were retested under a "very high" dose condition. These were subjects numbered 4, 5, 6, 7, 17, 22, 25, 30, 35, and 36. They ranged in age from 22 to 36, with a mean age of 27.20 and a standard deviation of 4.40. Their weights ranged from 135 lbs to 180 lbs, with a mean of 161.78 lbs and a standard deviation of 13.36. Reported frequency of cannabis use prior to the experiment ranged from less than once per week to

twice per week, with a mean of 1.05 and a standard deviation of 0.65. Reported period of use prior to the experiment ranged from 9 months to 87 months, with a mean of 32.40 and a standard deviation of 22.96. Subjects were selected for this subgroup on a basis of chance only: they were the first ten subjects who were at home when the writer called, and were also willing to be retested.

2. Setting

The experiment was carried out in a suite of three rooms (referred to as the Intake Room, the Testing Room, and the Recovery Room), located in a quiet area on the top floor of the faculty of psychology building at the University of Ottawa. The Intake Room, where the marijuana was smoked, was furnished as a comfortable living room containing wall-to-wall carpeting, a sofa, easy chairs, coffee and end tables, table lamps, and paintings on the walls. A refrigerator containing soft drinks and cold water for the use of subjects was located in one corner behind a screen. Windows were covered with venetian blinds and drapes, and soft electric lighting was maintained at a constant level throughout the experiment. Continuous music, at a constant low volume, was provided by a four-track stereo tape loop, with speakers located on the floor at either end of the sofa. The same piece of music, "Days of Future Past"

by the Moody Blues With the London Festival Orchestra, was played during all sessions. This tape lasts for just under half an hour, so that it was heard in its entirety by each subject on each occasion. Magazines were provided, but were seldom used. The same experimenter (a registered nurse, dressed in casual clothing) was present in the room throughout every session.[1]

The Testing Room was plainly furnished so as to provide minimal distraction to the subjects while doing the tests. It contained a filing cabinet, two chairs, a table at which the subject worked and, at right angles to it, a desk for the experimenter. The window was covered by venetian blinds and drapes, and lighting was provided by a single fluorescent light fixture in the ceiling. The same experimenter (a graduate student in psychology) administered the tests to all subjects on all occasions.

The Recovery Room was lighted and furnished in a manner similar to the Intake Room, with the addition of a desk at which subjects worked when doing the Draw-A-Person Test. Continuous music, at a constant low volume, was provided. In this room the selection played was "Memphis Underground" by Herbie Mann. The same experimenter (a

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1 Arrangements were made for a medical doctor to be on call at all times during the experiment. His services were not required at any time.

graduate student in psychology) was present to interview subjects during every session. Cheese and crackers and chocolate cookies were provided in the Recovery Room and subjects were invited to eat as much as they wished.

All three rooms were kept at a constant temperature of 72°F by thermostatically controlled air conditioners. With the air conditioners on and no music playing, the background noise level in the three rooms was 50, 58, and 48 decibels, respectively.[2] When the connecting doors were closed, this background noise was sufficient to mask all other sounds coming from adjacent rooms.

3. Smoking Apparatus

Two methods of smoking marijuana were used in this experiment. The first, illustrated in Figure 3, was used by all 40 subjects during administration of the complete SI test series and the Otis, Form B. The second apparatus, illustrated in Figure 4, was used only by the subgroup of ten subjects who were retested with the SI battery one year after completion of the main experiment.

When the first apparatus was used, loose marijuana (or placebo) was placed in a corked, round-bottom flask into which air was admitted through a one-way valve. Heat

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2 As measured by a Bruel and Kjoer type 2204 Impulse Precision Sound Level Meter.

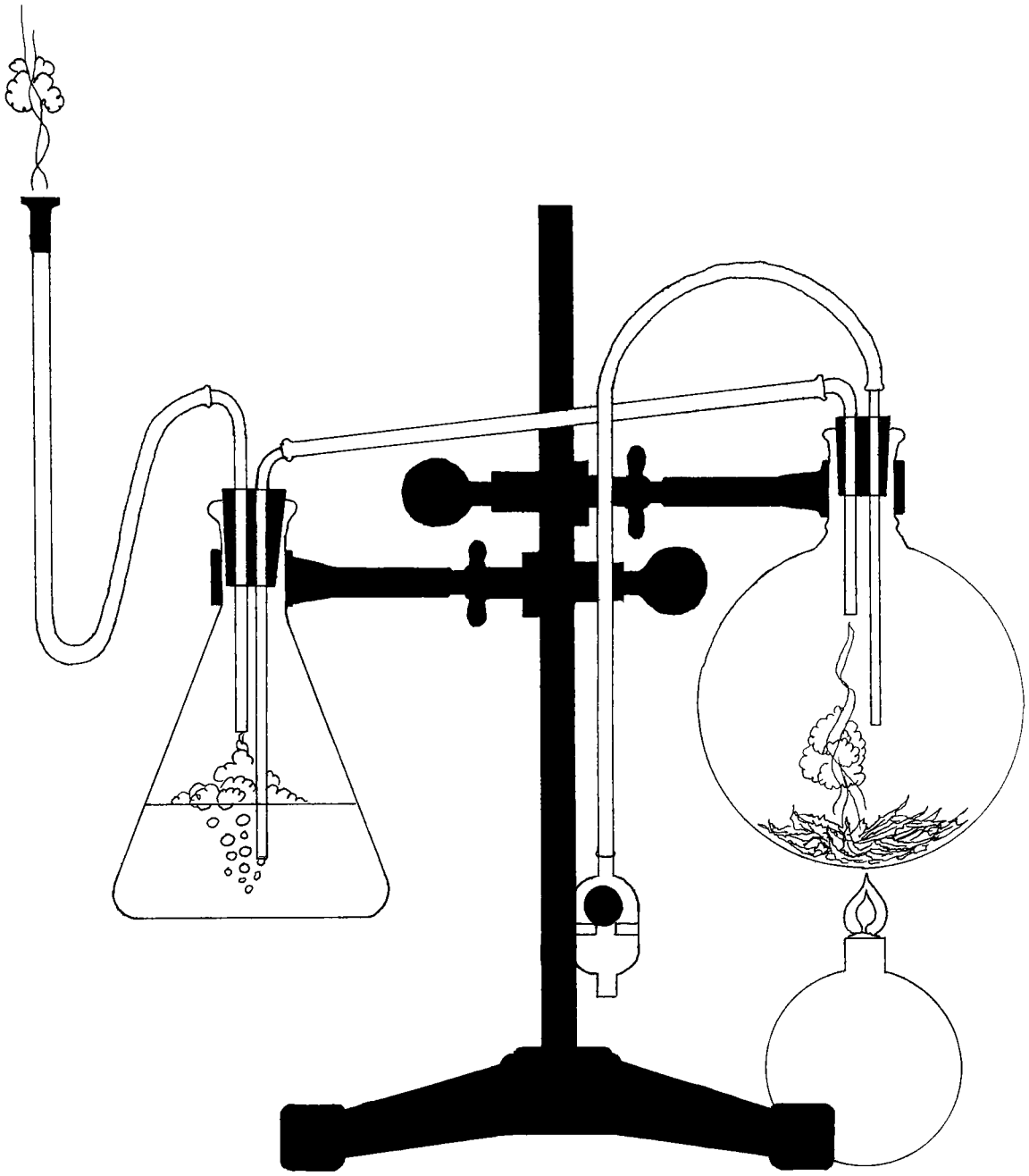

Figure 3.- First Smoking Apparatus.

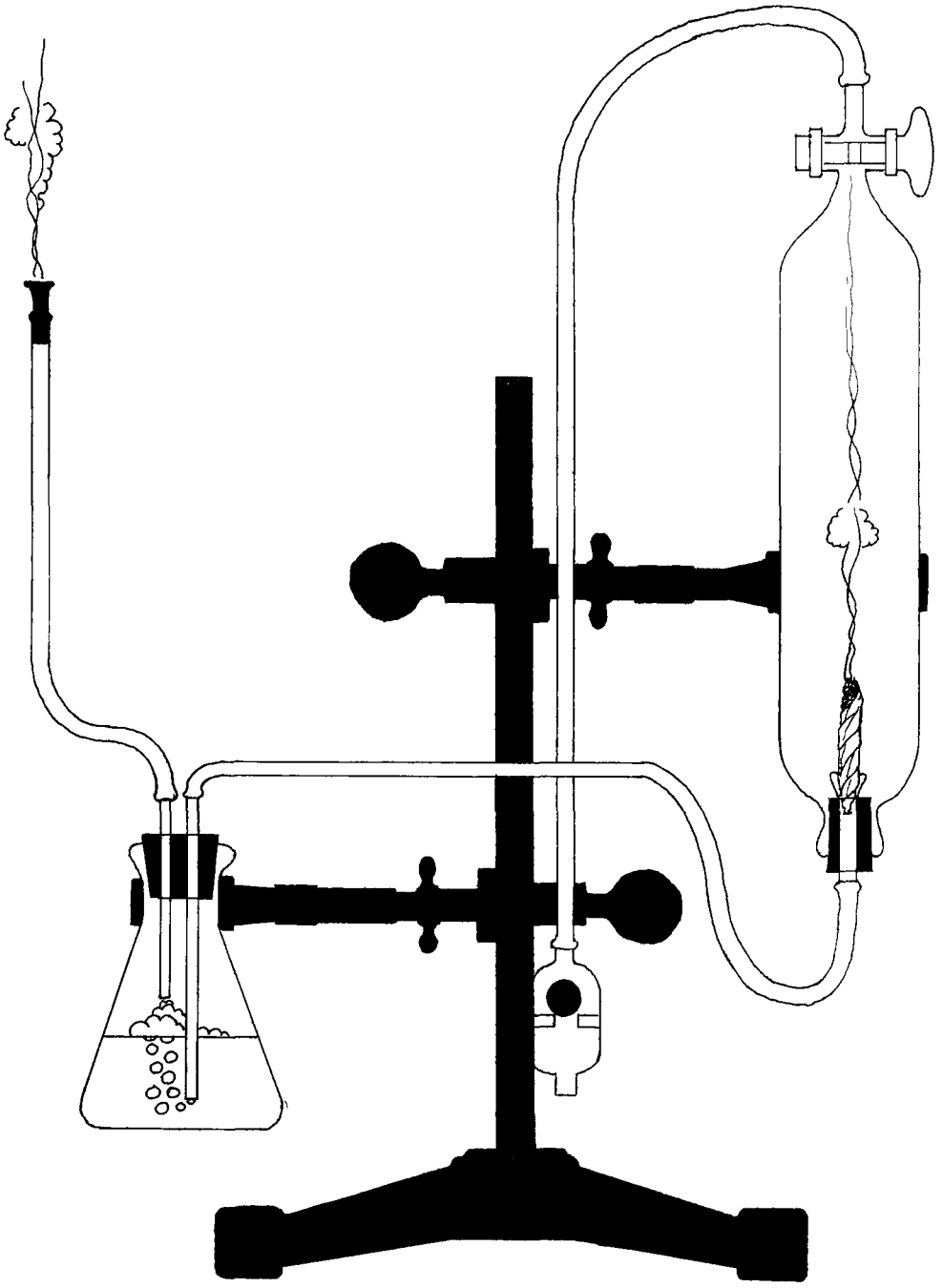

Figure 4.- Second Smoking Apparatus.

from a spirit lamp placed under the flask caused the marijuana to ignite and give off smoke. A short length of tube connected the round-bottom flask to a water-filled Erlenmeyer flask which in turn was joined to a plastic mouthpiece by three feet of flexible rubber tubing. When the subject inhaled, smoke was drawn out of the round-bottom flask and cooled by bubbling through the water in the Erlenmeyer flask. The one-way valve prevented smoke from escaping into the atmosphere. When the subject was not inhaling, he placed his thumb over the end of the mouthpiece so as to trap the smoke. Simultaneously, the spirit lamp was removed from beneath the round-bottom flask in order to retard combustion.

It was hoped that, by thus preventing smoke loss, the percentage of Δ^1THC delivered to the subject would be greater than that which could be obtained from a conventional "joint." In fact the opposite proved to be true (see Chapter II, Section 4) and the delivered doses of Δ^1THC, while still adequate for the purposes of this experiment, turned out to be considerably less than originally expected. It was therefore decided to retest a group of ten subjects using the second type of smoking device which had been shown to deliver a higher percentage of Δ^1THC (see p. 124).

In this second apparatus the water-filled Erlenmeyer flask and the rubber smoking tube were used as before. However, the round-bottom flask of the first apparatus

was replaced by the body of a separating funnel which contained a "cigarette holder" into which was inserted a hand-rolled marijuana cigarette. The "cigarette holder" was made by heating and flaring the end of the glass tube which passed through the cork which was used to seal the bottom of the separating funnel body. When the subject was ready to begin smoking, the cork was removed, the marijuana cigarette was inserted into the holder and lighted, and the cork was quickly pushed back into place. A one-way valve, attached to a short length of tubing at the top of the separating funnel body, allowed air to enter and prevented smoke from escaping. Once the cigarette had been lighted, the subject followed the same smoking procedure used with the first apparatus. Smoking continued until the cigarette was entirely consumed.

4. Quantification of Doses

Cannabis plant material, which had been grown in Mississippi, was made available for use in this study by the office of the Minister of National Health and Welfare in Ottawa. The active marijuana was assayed by the Department of National Health and Welfare and was reported to contain 1.5% Δ^1THC. Shortly before the experiment was begun, it was re-assayed, by means of gas-liquid chromatography, at the Department of Pharmacology, Faculty of

Medicine, University of Ottawa, and the estimate of 1.5% Δ^1THC was confirmed. The placebo consisted of cannabis (taken from the same batch) from which all cannabinoids had been chemically extracted. This placebo material was also assayed twice by means of gas-liquid chromatography and no Δ^1THC was detected. As a further check, the writer and two laboratory assistants at the Department of Pharmacology each smoked 1000 milligrams of the placebo material. No feelings of intoxication were reported. In terms of physical appearance, the placebo and active marijuana were indistinguishable.

All seeds and twigs had been removed prior to delivery. In order to assure uniform burning, all cannabis material was ground twice with mortar and pestle and sifted through a standard number 10 sieve. Any residue which remained in the sieve was discarded.

It has been estimated that doses in the range from 1 mg to 4 mg Δ^1THC delivered in the smoke will produce effects similar to those commonly experienced by marijuana users in a social situation (see Chapter I, Section 4(a)). In this study it was originally planned to administer to each subject a placebo, a low dose corresponding roughly to a "social" dose, and a high dose which would be significantly greater than a "social" dose. In accordance with this plan, three dose levels were prepared, each of which consisted

of 800 mg of cannabis material. The placebo consisted of 800 mg of extracted cannabis material and contained no Δ^1THC. The low dose consisted of 400 mg of extracted (placebo) material and 400 mg of active marijuana which contained 6 mg Δ^1THC, and was expected to yield a dose of approximately 3 mg Δ^1THC delivered in the smoke. The high dose consisted of 800 mg of active marijuana which contained 12 mg of Δ^1THC and was expected to yield a dose of approximately 6 mg Δ^1THC delivered in the smoke.

Prior to the start of the actual experiment, four experienced volunteers smoked the high dose, using the first smoking device. Three reported that they were "very stoned," and the fourth became ill before he had completed smoking. Unfortunately, precise measurements of the doses delivered by this device were not made until all experimental sessions had been completed. At that time, 800 milligrams of cannabis material were loaded into the smoking device which was connected to a vacuum pump. The vacuum pump was repeatedly turned on for six seconds and off for 20 seconds, and the spirit lamp was moved periodically from beneath the flask in an attempt to duplicate as nearly as possible the <u>in vivo</u> smoking process. Combustion was continued until only a white ash remained in the flask. The smoke was passed through two hexane traps which extracted all cannabinoids. Completeness of absorption was checked by

passing the smoke through a third trap. Tars which accumulated in the glass pipettes in the traps were dissolved in alcohol and added to the hexane, which was then evaported with argon. The residue was redissolved in GLC grade hexane and injected into a Hewlett Packard 402 High Efficiency Gas-Liquid Chromatograph. Material from the third trap was assayed first and no Δ^1THC was detected, indicating complete absorption in the first two traps. When material from these two traps was assayed, the following results were obtained: placebo dose = 0 mg Δ^1THC, low dose = 1.08 mg Δ^1THC, high dose = 2.16 mg Δ^1THC. These figures indicate that the first smoking device was delivering in the smoke only 18% of the Δ^1THC available in the marijuana.

One year later, when it was decided to retest ten subjects, the marijuana was re-assayed and found to contain 1.4% Δ^1THC. Eight hundred milligrams of this active marijuana was "smoked" using the second smoking device (see Figure 4) connected to a vacuum pump and cannabinoids were extracted from the smoke by the method just described. On this occasion the dose delivered in the smoke was 5.4 mg Δ^1THC, or 48% of the Δ^1THC available in the marijuana.

All measures described in this section were repeated on at least two occasions and no significant differences

were found in any of the results. Table 2 summarizes the actual delivered doses used in this experiment.

5. Tests

Psychometric measures. The five Operations categories of the Structure of Intellect model were measured by means of six tests, selected from those used by J. P. Guilford and his associates in their factor analytic studies. The final choice of tests was made on the basis of two criteria: (1) each test had to be short enough so that the whole battery could be administered in less than half an hour (the period of maximum intoxication following the smoking of marijuana); and (2) tests were chosen which had maximum reliability coefficients and maximum factor loadings for the ability being investigated. Table 3 lists the six tests used and the SI abilities they represent and shows the reliability coefficient, the factor loading, and the administration time for each. This information was obtained from a list of all available SI tests provided by Sheridan Psychological Services Inc.

The design of this study requires that all subjects be tested with the above-named SI tests on four separate occasions, under differing dosage conditions. Ideally, such a procedure would call for the use of four parallel forms of each test. Unfortunately, such parallel forms did

Table 2

Estimated Doses of Δ^1THC Used in this Study

Dose	Smoking device	Cannabis weight & type	Δ^1THC content	Delivered Doses in mgs Δ^1THC	Delivered Doses as % of content
Placebo	First	800 mg placebo	0 mg	0	-
Low	First	400 mg placebo 400 mg active marijuana	6 mg	1.08	18
High	First	800 mg active marijuana	12 mg	2.16	18
Very high	Second	800 mg active marijuana	11.2 mg	5.40	48

Table 3

Structure of Intellect Tests Used in this Study

	SI ability code	No. of items per test form	Factor loading (r_{ft})	Reliability (r_{tt})	Administration time (for each form)
Word Linkage	CMR	15	.48	.74	4 min.
Remembered Relations	MMR	20	.51	.63	4.5 min.
Associational Fluency	DMR	2	.58	.70	2 min.
Part-Whole Relations	NMR	10	.52	-	1 min.
Associations III(DMR=.40)	"	15	.52	.73	6 "
Verbal Analogies III	EMR	10	.60	.60	3 min.

not exist for any of the chosen tests. However each test as originally constructed was composed of two separately timed parts of equal length. In a private communication of December 3, 1970, Guilford suggested that these two parts ". . . could be used as alternate forms." (See Appendix 2.) In order that this could be done, minor alterations were required in the instruction page of each test; e.g., for Word Linkage the original instructions read, "This test has two pages with 15 items on each page. You will have four minutes to work on each page." This was changed to read, "This test has 15 items. You will have four minutes in which to work." Following these alterations, it was then possible to use the same instruction page with both halves of each test. (See Appendix 3.) The third and fourth "forms" of each test, required by the experimental design, were obtained by the simple expedient of repeating each of the two test parts referred to above.

One test was used for each Operations category, with the exception of Convergent Production of Semantic Relations (NMR) which was represented by two tests, Part-Whole Relations and Associations III. The only two tests for NMR listed in the Sheridan catalogue, Associations III and Associations IV, were not considered to be entirely

satisfactory because both showed a secondary factor loading for the ability Divergent Productions of Semantic Relations (DMR) (Sheridan Psychological Services). In a private communication, dated April 2, 1971, Guilford suggested that this problem might be overcome by using the test Part-Whole Relations which he had recently revised. (See Appendix 2.) Unfortunately, no reliability data were available for this revised test. It was therefore decided that it would be more prudent to continue to use the test Associations III, with Part-Whole Relations added as a possible source of supportive evidence.

All SI tests were scored in accordance with scoring keys provided by Sheridan Psychological Services. It should be noted that none of these tests has been standardized on a large population. Thus, their usefulness is confined mainly to experimental studies similar to the present one.

In addition to the SI tests, intellectual functioning was also measured by means of the Otis SA Test of Mental Ability, Higher Examination, Forms A and B. The Otis, Form A was administered to all 40 subjects, under no-drug conditions, during their initial screening interview. Approximately six weeks later, following completion of all SI testing, Form B was individual administered to 31 subjects under the "high dose" condition. Both forms were given with a 20-minute time limit, using standard instructions.

Immediate memory was measured by means of the Digit Span subtest taken from the Wechsler Adult Intelligence Scale. Administration was done according to the standard instructions given in the WAIS manual. The Digit Span was given as part of the battery of SI tests.

Personality tests. All 40 subjects were given the Minnesota Multiphasic Personality Inventory, under no-drug conditions, during their initial screening session. For the purposes of this study, data from the MMPI (together with information from individual interviews) were used only as a basis for screening out subjects who might be showing signs of severe psychological disturbance. (Only one out of 60 applicants was judged to be unacceptable for this reason.)

Following each administration of the SI test battery, all subjects proceeded to the Recovery Room where they were asked to do a Chromatic Draw-A-Person Test. The subject was given a set of seven colored pencils and instructed to "draw a complete person, using as many colors as you wish." In this way four drawings were collected from each subject; one for each dosage condition. These drawings were not used as part of this study. Data from the MMPI and the DAP will be presented and discussed in a subsequent paper.

Rating scale. Shortly after entering the Recovery Room all subjects were asked to rate their level of intoxication on a 0 - 100 scale, where zero was defined as "the

worst (weakest) grass I have ever had," and 100 was defined as "the best (strongest) grass I have ever had."

Subjective descriptions and spontaneous verbalizations. In the Recovery Room subjects were asked also to give a verbal description of their reactions to the drug. The experimenter was instructed not to ask questions that were clearly leading in their wording. Apart from this restriction, he was given freedom to elicit responses in any way which seemed appropriate. Commonly used questions included, "How do you feel?" "How was the grass this time?" In the Intake and Testing Rooms no explicit questions concerning subjective reactions were asked, but experimenters were instructed to record any spontaneous remarks made by the subjects. These qualitative reports (see Appendix 5) provide a rough basis for validating the quantitative measures obtained from the rating scale.

6. Counterbalancing Systems

It was planned to test each subject under four dosage conditions, high, low, placebo, and control (no drug), using the entire SI battery on each occasion. Two forms of each test were available and these were both repeated, thus providing a complete set of tests for each condition. It took seven working days to test all 40 subjects once each, at the rate of six per day for six days and four on the

seventh day. Testing was carried out six days per week. Thus the four testing sessions for each subject were separated by eight-day intervals. In order to minimize the influence of possible practice and fatigue effects and individual subject variables, it was decided to counterbalance (a) the order in which dosage conditions were administered, (b) the sequence in which the tests were given on any one occasion, (c) the sequence of test forms used for each test from occasion to occasion, and (d) the times of day at which subjects were tested. The precise sequence of conditions, tests, forms, times, and dates of testing were thus worked out for each subject number in advance of the experiment. Numbers were assigned to subjects during their initial interview on a first-come-first-served basis, so that each subject received a complete appointment schedule before any testing began.

Counterbalancing was begun by writing each of the 24 possible combinations of high, low, placebo, and control on individual pieces of paper and placing them in a container. The five SI Operations categories were designated A to E[6] and the 120 possible combinations of these five letters were also written on individual pieces of paper which were placed

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6 For purposes of counterbalancing the two tests used to measure Convergent Production of Semantic Relations (NMR) were considered as one test.

in a separate container. For each subject number, one piece of paper was drawn from the first container to give the order of conditions, and four pieces of paper were drawn sequentially from the second container to give the order of tests for each of the four conditions. This procedure was followed until the containers had been emptied. All papers were then replaced in the containers and drawing was continued until condition and test sequences had been established for each subject.

Once the test sequences had been established, counterbalancing of test forms was begun starting with the first sequence for subject number one. This was done by using Form 1 of the first test in the sequence, Form 2 of the second test, Form 1 of the third and so on. Thus, the sequence of tests and forms for subject number one on day one became $D_1E_2A_1B_2C_1$. On day two, the form used for each test was the alternate of the form used for that test on day one. Thus, the sequence of tests and forms for subject number one on day two was $B_1A_2C_2E_1D_2$. The test forms used on days three and four were a repeat of those used on days one and two, respectively. This procedure used for counterbalancing test forms was the same for all subjects except for one detail: for all odd numbered subjects, the sequence of forms on their first testing day was 1, 2, 1, 2, 1, while for all even numbered subjects the sequence of forms on their first testing day was 2, 1, 2, 1, 2.

Since subjects were tested in groups of six per day, it was possible to vary the times at which they were tested by varying the order in which they were tested on each of their four SI testing days. Table 4 shows the testing order and times for subjects 1 to 6 on each of the four SI testing days. The same system was used for all other groups of subjects tested during one day.

The two tests for NMR, Associations III and Part-Whole Relations, were always presented together, with their order of presentation being alternated from one subject to the next. Similarly, the Digit Span Test was always paired with the SI memory test, Remembered Relations, and their order of presentation was likewise alternated from subject to subject.

Once all of the above counterbalancing procedures had been completed, it was possible to draw up a complete testing schedule which showed for each testing day (a) the subjects to be tested, (b) their testing times, (c) the dosages they were to receive, and (d) the sequence of presentation for the SI tests, and the forms of these tests to be used for each subject. (This Daily Testing Schedule is shown in Appendix 4.)

When ten subjects were retested one year later, under the "very high" dose condition (second smoking device), the test forms and sequences of administration used for each subject were the same as those which had been administered to them previously under the no-drug (control) condition.

Having described the counterbalancing system used in this study, the author feels constrained to point out that this system, and the repeated-measures design with which it is associated, represent a degree of compromise. The repeated-measures design was selected because it was felt that this procedure would be most effective in minimizing unwanted variance resulting from the large interindividual differences which have been shown to occur in response to this drug. At the same time it is recognized that this design is subject to contamination by variance resulting from practice effects, treatment order effects, and the possible divergence of the test forms from the criteria of strict parallelism. It is assumed that the counterbalancing system described above is adequate to remove most of the variance resulting from these variables. However, in order to be certain of removing all such variance it would be necessary to adopt a more complete counterbalancing system in which subjects were tested with all possible combinations of all tests, test forms and treatment orders (an undertaking which would require a sample of astronomical size). Alternately, an attempt might have been made to use a different design, such as a Graeco-Latin Square, in which the effects of practice might be more completely controlled. The first alternative was rejected on the grounds of practicality. The second was rejected because (a) such a design is considered to be less effective in controlling for interindividual differences and (b) because one of the assumptions of this design, i.e., zero

Table 4

Testing Times for Subjects Nos. 1 to 6 on Each of Four Testing Days

Times	Testing Days			
	1	2	3	4
9:00 am	1	6	4	5
10:00 am	2	5	1	3
11:00 am	3	4	2	6
1:00 pm	4	3	5	1
2:00 pm	5	2	6	4
3:00 pm	6	1	3	2

interactions among variables, would be difficult or impossible to meet. In finally deciding on a repeated measures design, the author concedes that the lack of a total counterbalancing may result in an increase in error variance which could serve to obscure possible treatment effects.

7. Testing Procedures (Drug Study).

All 40 subjects were tested on six occasions during July and August. Ten subjects were retested on a seventh occasion (using the second smoking device) approximately one year later.

Introductory session. The initial session for all subjects began with a brief introductory statement in which they were informed that they would be given a series of paper-and-pencil tests during five experimental sessions spread over a period of approximately six weeks. They were told that on four of those five occasions they would be required to smoke marijuana which would be varied in strength from occasion to occasion. No mention was made of a placebo. Information was also given concerning the duration of each session, and the procedures to be followed in each of the three experimental rooms. Subjects were told that they would be given no further information about the purposes or design of the experiment until all testing had been completed. Complete confidentiality was promised with regard to the names of the subjects participating and the results of their tests.

Following this introduction, all subjects were required to fill out and sign the following documents: (1) a legal consent form; (2) a brief medical questionnaire; (3) a personal information sheet containing questions about age, education, occupation, etc.

The Otis Self Administering Test of Mental Ability, Higher Examination, Form A was then administered, using a 20-minute time limit and standard instructions. After the Otis, the Minnesota Multiphasic Personality Inventory, 1967 edition, was administered using standard instructions.

After completing the MMPI, each subject was interviewed individually by the writer. At this time each subject was assigned a number and given an appointment slip which specified the date and time for each of his subsequent appointments. All subjects were requested to refrain from the use of cannabis and other drugs for the duration of the experiment.

SI testing. All testing was carried out under double blind conditions. The writer was aware of all details of the design and the doses to be given. However, neither the registered nurse who administered the drug, the two test administrators, nor the subjects themselves had any information concerning the magnitude or sequence of doses. Each morning the nurse-experimenter in the Intake Room was given a list of the numbers and first names of the six subjects to be tested

that day. Opposite each name was written either "Drug" or "No Drug." A small plastic container, holding 800 mg of cannabis material and identified by number only, was provided for each "drug" subject. It was impossible to tell by observation whether any given container held a high, low, or placebo dose.

After entering the Intake Room each subject was allowed to relax for approximately five minutes during which time he was engaged in casual conversation. After five minutes, his pulse was measured manually at the wrist and recorded. The cannabis dose, identified by the subject's number, was then placed in the smoking device, and the spirit lamp was lighted and placed under the flask. The subject was instructed to sit in a comfortable position on the sofa, holding the smoking tube in his hand with his thumb over the mouthpiece. As soon as the flask began to fill with smoke, he was instructed to inhale slowly through the mouthpiece and to hold the smoke in his lungs for as long as possible. At intervals during the smoking period the experimenter moved the spirit lamp away from the bottom of the flask so as to prevent overheating. If the subject wished to rest, the flame was removed entirely so that combustion ceased until he was ready to begin smoking again. Smoking was continued until all cannabis material had been reduced to a fine white ash. Average smoking time was

between 15 and 20 minutes. Five minutes after the completion of smoking the subject's pulse was again measured and recorded. Thirty minutes after entering the Intake Room he moved to the Testing Room. During this time the experimenter recorded any spontaneous remarks made by the subject concerning the cannabis and his reactions to it.

On those occasions when no drug was being administered, the subject was required to remain in the Intake Room for 30 minutes, during which time he could read, relax or talk as he wished. The nurse-experimenter also remained in the room throughout this period. The subject's pulse was measured and recorded five minutes and 25 minutes after he entered the room.

Each morning the experimenter in the Testing Room was given a list of the numbers and first names of the six subjects to be tested that day. Opposite each number were written the SI test forms to be given to that subject and the sequence in which they were to be administered. No information was given concerning whether or not a subject would receive marijuana that day. Experimenter and subject sat opposite each other at a table. The subject was given a copy of the first test in the sequence and asked to read the instructions to himself. He was asked if he had any questions (very few subjects did), after which he was told to begin. This procedure was followed with all tests in

the sequence, with the exception of Digit Span, the instructions for which were read aloud by the experimenter. The experimenter was instructed to be polite, but to avoid conversation with the subject as much as possible. He was also required to record any spontaneous remarks made by the subject about the cannabis and his reactions to it. Total time to administer all tests was approximately 30 minutes, after which the subject moved to the Recovery Room.

Each morning the experimenter in the Recovery Room was given a list which contained only the numbers and first names of the six subjects being tested that day. Shortly after entering the Recovery Room each subject was asked to rate his level of intoxication on the scale of 0 - 100. He was explicitly asked to describe his reactions to the cannabis (if any) which he had been given that day. Following these questions, he was asked to do a Chromatic Draw-A-Person Test. After completing the DAP the subject was permitted to remain in the room and relax for as long as one hour if he wished. When he was ready to leave, the experimenter, who had been in the room at all times, telephoned for a taxi to take him home.

The foregoing procedures were followed during all 160 sessions in which the SI test battery was administered. When the Otis, Form B was administered (after all SI

testing had been completed), procedures were basically the same with the following exceptions: (1) the remarks of subjects concerning their reactions to the drug were not recorded; (2) in the Recovery Room the Rating Scale and the Chromatic DAP were not given; (3) in the Testing Room the instructions for the Otis, Form B were read aloud by the experimenter in accordance with the standard directions given in the Otis manual.

One year later ten subjects were retested with the SI battery. Each subject smoked two 400 mg cigarettes of active marijuana, using the second smoking device. In the Testing Room the SI test forms and sequence of administration for each subject were the same as those which he had been given during his "No Drug" testing session a year before. In the Recovery Room subjects were not required to do the Chromatic DAP. In all other respects procedures were the same as those used during the earlier SI testing sessions.

8. Evaluation of SI Model Tests (No-Drug Study)

In order to assess the reliability of the two forms of each of the SI model tests to be used in this study, it was decided to administer these instruments to a separate, and larger, group of subjects under no-drug conditions. The sample consisted of 132 first- and second-year

undergraduates from the nursing, physical education, and general arts programs at the University of Ottawa and Carleton University. One hundred were females and 32 were males. They ranged in age from 17 to 48, with a mean age of 21.44, and a standard deviation of 1.29. As an inducement to participate they were promised a complete explanation, during class time, of the purposes and design of this study. All subjects were volunteers. No financial rewards were offered.

The total sample was divided by classes into three groups of 32, 39, and 61 students each. The tests were administered to all members of each group at the same time during regular class hours. At the beginning of each testing session every subject was given a file which contained all six SI tests, arranged in predetermined order, and numbered from 1 to 6. Prior to the administration of each test, subjects were instructed to remove it from the folder and to write on it their name and the date. Instructions for the test were then read aloud by the examiner. Subjects were permitted to ask questions in order to clarify points in the instructions. (There were few questions.) After completion, each test was returned to the bottom of the pile in the folder. At the end of each testing session subjects were asked not to compare answers, nor to discuss the tests among themselves.

Because a group testing procedure was used, it was only possible to partially counterbalance the sequence in which the SI tests and their two forms were administered. This partial counterbalancing system is presented in Table 5.

Following completion of the four SI testing sessions, all subjects were given the Otis Self-Administering Test of Mental Ability, Higher Examination, Form A. Administration of the Otis, Form A was also done in groups, using standard instructions.

9. Analysis of Data

All statistical calculations were done on the IBM-360 computer at the University of Ottawa, using programs written in APL language. The computer programs referred to below are contained in the APL library at the University of Ottawa Faculty of Education.

The reliability study of SI model tests (described in the previous section) was carried out in order to assess the stability of the individual forms of these instruments over time. Test-retest coefficients of reliability were computed for each form of each test using the Pearson product-moment coefficient of correlation (program name: COR). As a check on the reliability figures supplied by Sheridan Psychological Services (see Table 3, p. 127),

Table 5

Partial Counterbalancing System for the Evaluation (No-Drug) Study of Structure of Intellect Tests

Test session	Test and Form Sequences		
	Group 1 (N=32)	Group 2 (N=39)	Group 3 (N=61)
1	$A_1\ B_1\ C_1\ D_1\ E_1$	$E_1\ D_1\ C_1\ B_1\ A_1$	$C_2\ E_2\ B_2\ D_2\ A_2$
2	$A_2\ B_2\ C_2\ D_2\ E_2$	$E_2\ D_2\ C_2\ B_2\ A_2$	$C_1\ E_1\ B_1\ D_1\ A_1$
3	$A_{1R}B_{1R}C_{1R}D_{1R}E_{1R}$	$E_{1R}D_{1R}C_{1R}B_{1R}A_{1R}$	$C_{2R}E_{2R}B_{2R}D_{2R}A_{2R}$
4	$A_{2R}B_{2R}C_{2R}D_{2R}E_{2R}$	$E_{2R}D_{2R}C_{2R}B_{2R}A_{2R}$	$C_{1R}E_{1R}B_{1R}D_{1R}A_{1R}$

test-retest reliability coefficients were also computed for each complete SI test, i.e., Form 1 + Form 2 against Form 1_R + Form 2_R.

In the main experiment, the same 40 subjects were tested repeatedly under control (no-drug), placebo, low dose, and high dose conditions, using a test battery which consisted of six SI model tests and the Digit Span Test. The sequence of conditions, the order of tests under each condition, and the order of SI test forms across conditions were fully counterbalanced (see Chapter II, Section 6). It was assumed that these counterbalancing procedures would be adequate to cancel out any sources of variance arising from possible differences among the test forms and their repetitions. For each SI test a one factor analysis of variance for repeated measures (program name: RMAOV-1) was used to test for differences among the means of the four treatment conditions. The significance level for the F ratio was set at $p \leq .05$. The .05 level was chosen in preference to the .01 level because it was felt that, in this study as in other drug studies, it would be preferable to increase the chance of a Type I error rather than decrease it and thereby run the risk of missing a drug effect which might have serious consequences for the user. In the event that the F ratio proved to be significant, it was planned to use the Tukey test (program name: CONTUK) as a post hoc procedure to

locate differences between all possible pairs of means. The probability level for the Tukey test was also set at $p \leq .05$.

Analysis of the Digit Span Test scores was complicated by the fact that, due to an error in the instructions to the test administrator, this instrument was not used during the first five days of testing. As a result, the number of Digit Span scores obtained under each condition was different (Control N=31, Placebo N=34, Low Dose N=32, High Dose N=33). Furthermore, because of the counterbalancing procedures, the test was missed by different subjects under each condition. Because all subjects had taken the Digit Span under at least three of the four conditions, it was still necessary to use an analysis of variance for repeated measures to test for differences among the means. Since this method requires an equal number of cases in each cell, it was decided to equalize the Ns by using the mean of each condition as an estimate for each of the missing scores within that condition. This procedure may be defended on the grounds that in each of the conditions the dispersion of obtained scores is very small (see Appendix 7) and therefore the mean may be considered as a reasonable estimate of any single score within the distribution. Following the analysis of variance ($p \leq .05$), it was planned to use the Tukey test as a post hoc procedure, if needed.

Thirty-one subjects of the experimental group were given the Otis, Form A under the no-drug condition, and Form B of the same test under the High Dose condition. Scores for (1) the number of questions attempted (in 20 minutes), (2) the number of questions answered correctly, and (3) the IQ, were obtained for each subject on both occasions. A *t* test for the difference between the means of correlated samples (program name: TCOR) was used to test for differences in the means of each of these three parameters. The significance level for the *t* tests was set at $p \leq .05$.

Heart-pulse rates were recorded for all subjects before and after smoking each of the high, low, and placebo doses. Change scores were computed for all subjects under all three conditions. A one-factor analysis of variance for repeated measures ($p \leq .05$) was used to test for significant differences among the mean change scores of the three conditions. It was planned to use the Tukey test as a *post hoc* procedure, if needed. Because of a confusion in the instructions to the experimenter, heart-pulse rates were recorded before and after a 20-minute period of relaxation for only 31 subjects under the control condition. The mean and standard deviation for this group were computed, but because of the requirement of equal numbers of subjects in each cell, these scores could not be used in the analysis of variance.

After smoking each of the high, low, and placebo doses, all subjects were required to rate their level of intoxication on a scale of 0 - 100. A one factor analysis of variance for repeated measures ($p \leq .05$) was used to test for differences among the mean ratings of the three conditions.

Ten members of the original experimental group of 40 subjects were retested with the SI and Digit Span Test battery,after smoking a marijuana dose which was more than twice the strength of the previously used high dose. For purposes of analysis, these ten subjects were treated as a separate group and their test results were analyzed using the same statistical procedures described above. The only difference being that, for this subgroup, there were five treatment conditions instead of the original four.

This chapter has presented the procedures used to test the hypotheses stated in Chapter I. In Chapter III the findings of the study are presented and discussed.

CHAPTER III

PRESENTATION AND DISCUSSION OF RESULTS

Section 1 of this chapter presents findings on the reliability of the Structure of Intellect tests used in this study. Sections 2, 3, 4, and 5 present the results obtained from the various measures used in the main portion of the experiment. Section 6 contains results obtained from a subgroup of ten subjects who were retested with the SI and Digit Span Test battery under the Very High Dose condition. In Section 7 the findings of the study are discussed and suggestions for further research are offered. The final section contains a brief summary and statement of conclusions.

1. Reliability of SI Model Tests (No-Drug Study)

On the Otis SA Test of Mental Ability, Higher Examination, Form A, the 132 subjects in the SI reliability (no-drug) study obtained a mean IQ of 118.89 with a standard deviation of 8.11. On the Otis, Form A, under no-drug conditions, the 40 subjects in the main experimental group obtained a mean IQ of 124.28 with a standard deviation of 7.13. All subjects in the reliability group were university undergraduates. In the experimental group 21 were enrolled or had been enrolled in university and 16 held graduate or post-graduate degrees; the remaining three had completed

high school. The mean age of the reliability group was 21.44 years with a standard deviation of 1.29. The mean age of the experimental group was 24.8 years with a standard deviation of 3.8. The reliability group consisted of 100 females and 32 males. The experimental group was all males.

Thus, in terms of age, education level, and level of achievement on a standardized measure of complex intellectual functioning, the two groups were similar. The difference in sex is not considered to be a relevant variable affecting performance on the SI tests used in this study. Guilford has listed the SI tests in which sex-related differences in scores have been consistently reported (Guilford, 1967, p. 404). None of the tests used in this study is included in the list. In discussing sex differences in relation to SI abilities in general, Guilford has concluded that: "Differences are very small in the great majority of instances (p. 411)." No attempt was made to deliberately equate the two groups in terms of all subject variables. However, on the basis of the foregoing comparisons, it would seem reasonable to assume that findings obtained in the reliability study may be generalized to the main experimental group (Guilford, 1967, p. 38).

The test-retest reliability coefficients ($r_{1,1R}$ and $r_{2,2R}$) obtained for each form of each SI model test are presented in Table 6. Also shown are the test-retest

Table 6

Test-Retest Reliability Coefficients for Structure of Intellect Test Forms, and Total Tests

	CMR	MMR	DMR	NMR		EMR
	Word Linkage	Remembered Relations	Assoc. Fluency I	Part-Whole Relations	Associations III	Verbal Anals. III
$r_{\text{Form 1,Form 1R}}$	.52	.52	.53	.57	.73	.62
$r_{\text{Form 2,Form 2R}}$	.69	.60	.56	.65	.78	.65
r_{tt}	.76	.69	.67	.71	.84	.69
$r_{tt(\text{Sheridan})}$[a]	.74	.63	.70	-	.73	.60

[a]Reliability coefficients quoted in Sheridan Psychological Services catalogue.

reliability coefficients obtained for each of the complete SI tests (Form 1 + Form 2). It can be seen from the table that the reliability coefficients obtained in this study for each of the complete SI tests closely approximate the reliability coefficients obtained from previous factor analytic studies.

Test-retest coefficients obtained for the individual forms are lower than those obtained for the (longer) complete tests. It is recognized that some of the lower coefficients might be considered insufficient for purposes of diagnosis or prediction with individual subjects. However, Guilford (1954) has pointed out that for research purposes reliabilities of .50 may be considered acceptable (p. 388). This study is concerned, not with individual scores, but only with differences among group means which are much less susceptible to the effects of error variance. It is considered, therefore, that the obtained reliability coefficients indicate that the functions being measured by these SI test forms are sufficiently stable across time (two weeks) to permit their use in a repeated measures design, in which effects of the independent variable are measured in terms of changes in group means. This assumption is strengthened when, as in this study, the orders of presentation of tests and test forms to each subject are fully counterbalanced across treatment conditions.

2. Subjects' Self-Ratings of Levels of Intoxication

All subjects were required to rate their level of intoxication, on a 0 - 100 scale, approximately 35 minutes after smoking each of the marijuana and placebo doses. The mean ratings for each treatment (see Table 7) were: Placebo = 31.15, Low Dose = 52.18, High Dose = 63.15. A one-factor analysis of variance for repeated measures was used to test for differences among the means. The obtained F ratio ($F = 26.6747$) was significant at $p \leq .001$. The Tukey test was applied as a post hoc procedure and significant differences ($p \leq .05$) were found between all pairs of means.

It is noted that the range of individual ratings for each dose level covered almost the entire scale. Also, there were some subjects who rated their level of intoxication after smoking the placeo as being higher than their level of intoxication under either the low or high dose conditions. These observations agree with the findings of Jones (see Chapter I, pp. 36-37) and are interpreted to mean that, in making their ratings, subjects were being influenced by their expectations concerning the material they were smoking.

Despite this variability in the ratings, the group as a whole was able to distinguish between the three dosage levels which they were given. The obtained ratings are

Table 7

Subjects' Self-Ratings of Their Levels of Intoxication, Using a 0 - 100 Rating Scale[a]

Condition	Delivered dose in mg Δ^1THC	Subjects' Ratings		
		Mean rating	Standard deviation	Range
High	2.16	63.15	20.62	0-98
Low	1.08	52.18	22.18	5-90
Placebo	0	31.15	25.81	0-90
$\underline{F}$[b]		26.6747		

[a]where 0 = worst (weakest) grass I ever had
100 = best (strongest) grass I ever had

[b] $.95F_{1,(n-1)} = 4.08$
$.95F_{k-1,(k-1)(n-1)} = 3.13$

interpreted to mean that, on the average, subjects considered their levels of intoxication after smoking the low and high doses to be at least equal to the levels of intoxication which they commonly experienced in other (social) settings.

In Appendix 5 are listed the numerical ratings, together with the verbal comments of the individual subjects concerning each of the treatment conditions. The verbal comments lend support to the foregoing interpretation of the rating scale results. It may be seen that after smoking both doses of active marijuana, the majority of subjects reported themselves as being "high," "stoned," or "ripped." Furthermore, these sensations were reported to be similar to those which they commonly experienced in a social setting.

3. Effects of Smoked Marijuana on Heart-Pulse Rate

Heart-pulse rate measurements were made on all subjects before and after smoking each of the marijuana and placebo doses (see Appendix 6). Due to a misunderstanding, the experimenter in the Intake Room made heart-pulse rate measurements on only 31 subjects during the control condition. The means of these measurements, together with the mean change scores for each condition, are presented in Table 8. A one-factor analysis of variance for

Table 8

Mean Heart-Pulse Rates, Before and After Smoking Marijuana

Condition	Delivered dose in mg Δ^1THC	Mean Heart-Pulse Rates		Change	
		before	after	Beats/min	%
High	2.16	82.13 σ13.63	99.90 σ17.00	17.77 σ12.47	21.64
Low	1.08	85.23 σ14.92	96.90 σ17.38	11.67 σ11.17	13.69
Placebo	0	82.15 σ11.51	83.45 σ10.65	1.50 σ8.62	1.58
Control[a]	-	79.40 σ12.92	78.28 σ9.03	-1.12 σ10.14	-1.41
F[b]				23.1278	

[a] Control n = 29

[b] $95F_{1,(n-1)} = 4.08$
$95F_{k-1,(k-1)(n-1)} = 3.13$

repeated measures was used to test for significant differences among the mean change scores of the high, low, and placebo conditions. The obtained $\underline{F}$ ratio ($\underline{F} = 23.1278$) was significant at $p \leq .001$. The Tukey test was used as a post hoc procedure and significant differences ($p \leq .05$) were found between all pairs of means.

These results are in agreement with the finding consistently reported in the literature that there is a dose-related increase in heart-pulse rate associated with the smoking of marijuana. In Figure 5, the percentage increases in heart-pulse rate are plotted together with the percentage increases obtained in four other studies, under similar experimental conditions (see Chapter I, Section 5). It can be seen that the ratios of percentage pulse-rate increase to dosage, obtained in this study, are very close to the values which might be expected from the findings of the previous studies. These figures are interpreted as further confirmation that the Δ^1THC doses of 1.08 mgs and 2.16 mgs, estimated by means of gas-liquid chromatography (see Chapter II, Section 4), were actually delivered in the smoke to the subjects in this study.

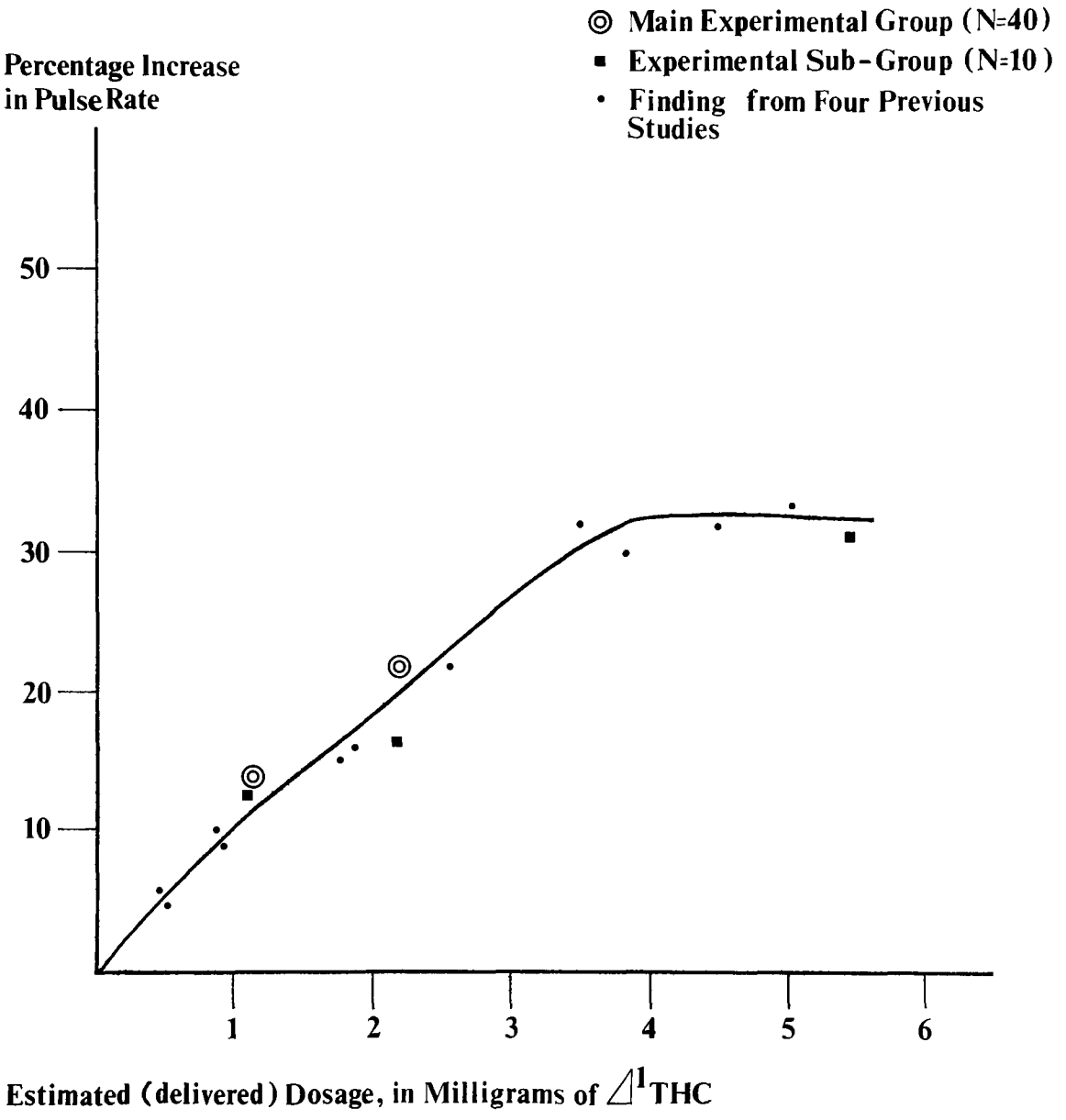

Figure 5.- Heart-Pulse Rate Changes in Relation to the Doses of Smoked Marijuana Used in This Study.

4. Mean Scores on Structure of Intellect Model Tests and Digit Span

Forms 1 and 2 and Forms 1_R and 2_R of each SI model test were administered in counterbalanced order to all subjects under high, low, placebo, and control (no drug) conditions (see Appendix 7). The mean scores for each test under each condition are presented in Table 9. A one factor analysis of variance for repeated measures was used to test for significant differences among the four means obtained for each test. The F ratios obtained for each test are presented at the bottom of Table 9. None of the obtained F ratios was significant at $p \leq .05$, therefore, the first null hypothesis stated in Chapter I cannot be rejected.

For purposes of analysis, the Forward and Reverse portions of the Digit Span Test were treated separately (see Appendix 7). A one factor analysis of variance for repeated measures was used to test for significant differences among the four means obtained for each portion (see, also, Chapter II, p. 146). The F ratios obtained for each portion of the test are presented at the bottom of Table 9. Neither of these F ratios was significant at $p \leq .05$, therefore the second null hypothesis stated in Chapter I cannot be rejected.

It may be noted that out of the five studies reviewed in Chapter I in which the Digit Span was used, only

Table 9

Mean Scores on Structure of Intellect Tests and Digit Span Test

Condition	CMR	MMR	DMR	NMR		EMR	Digit Span	
				P-W Rels	Assoc III		Forward	Reverse
High	13.60 σ1.44	8.71 σ4.08	7.93 σ2.55	4.93 σ2.39	9.68 σ2.62	7.03 σ1.44	7.52 σ1.37	5.94 σ1.45
Low	13.33 σ1.25	9.97 σ4.45	8.65 σ2.68	5.35 σ2.07	9.10 σ3.26	7.63 σ1.20	7.41 σ1.16	6.19 σ1.28
Placebo	13.70 σ1.14	10.10 σ4.03	8.33 σ2.16	5.55 σ2.18	9.45 σ2.60	7.68 σ1.37	7.62 σ1.46	6.15 σ1.48
Control	13.62 σ1.09	9.82 σ4.07	8.23 σ1.93	5.50 σ2.43	8.98 σ3.02	7.68 σ1.35	7.65 σ1.25	6.16 σ1.39
Maximum possible score	15	20		10	15	10	9	8
F[a]	1.0853	1.9391	0.9372	0.6969	1.1755	2.2780	0.6825	0.5480

[a] $_{95}F_{1,(n-1)} = 4.08$
$_{95}F_{k-1,(k-1)(n-1)} = 2.68$

(Melges et al., 1970a) reported significant differences in the scores of this test.

5. Mean Scores on the Otis SA, Test of Mental Ability

Scores were obtained from 31 subjects on the Otis SA, Test of Mental Ability, administered under both the Control condition (Form A) and the High Dose condition (Form B) (see Appendix 8). Time between test administrations was approximately seven weeks. Table 10 shows the mean number of questions attempted, the mean number of questions correct, and the mean IQ obtained under each of the two conditions. t tests for the difference between the means of correlated samples were used to test for significant differences between the means of each parameter. The obtained t values for each of the three pairs of means are shown at the bottom of Table 10. None of these t values was significant at $p \leq .05$. Therefore, the third null hypothesis stated in Chapter I cannot be rejected.

6. Experimental Sub-Group (N=10): Results of Retesting under Very High Dose Conditions

The two doses of Δ^1THC used in the main portion of this study were comparable in magnitude to doses given by other researchers in studies where smoked marijuana was used (see Chapter I, Sections 5 and 6). They also fell within

Table 10

Mean Scores on Otis SA Test of Mental Ability, Higher Examination, Forms A and B, Obtained under Control and High Dose Conditions[a]

Condition	Delivered dose in mg Δ^1THC	Otis Form	Number attempted	Number correct	IQ
Control	-	A	61.00 σ 9.68	56.29 σ 9.73	124.19 σ 7.25
High	2.16	B	61.68 σ 9.46	53.55 σ 8.85	122.48 σ 8.59
t[b]			.5584	1.8335	1.3469

[a] n = 31

[b] $_{95}t_{n-1} = 2.042$

what has been estimated to be the range of doses commonly consumed by marijuana smokers in a social context (see Chapter I, Section 4(a)). Nevertheless, it was recognized that, because no statistically significant results were obtained on the tests used in this study, it might be charged that the marijuana doses employed were simply not large enough to have any effect on complex intellectual tasks. It was therefore decided to retest ten subjects from the original sample, using a Δ^1THC dose (5.4 mgs) which was more than double the previous high dose.

As on previous testing occasions, all subjects were required to rate their level of intoxication, on the 0 - 100 scale, after smoking the Very High dose. For these ten subjects the mean ratings for each treatment were: Placebo = 26.00, Low Dose = 51.50, High Dose = 61.50, Very High Dose = 72.50 (see Table 11). A one-factor analysis of variance for repeated measures was used to test for differences among the means. The obtained F ration ($F = 9.2280$) was significant at $p \leq .05$. The Tukey test was used as a post hoc procedure. Significant differences ($p \leq .05$) were found between the mean placebo rating and the mean ratings for each of the three active drug conditions. No significant differences were found among the mean ratings for the three active drug conditions.

Table 11

Experimental Subgroup (N=10): Subjects' Self-Ratings of Their Levels of Intoxication, Using a 0 - 100 Rating Scale[a]

Condition	Delivered dose in mg Δ^1THC	Subjects' Ratings		
		Mean	Range	SD
Very High	5.40	72.50	60-90	12.50
High	2.16	61.50	0-90	26.93
Low	1.08	51.50	35-80	16.13
Placebo	0	26.00	0-70	25.38
F[b]		9.2280		

[a] where 0 = worst (weakest) grass I ever had
100 = best (strongest) grass I ever had

[b] $_{95}F_{1,n-1} = 5.12$
$_{95}F_{k-1,(k-1)(n-1)} = 2.63$

In evaluating these results, it may be noted that the Placebo, Low Dose, and High Dose ratings of the ten subjects correspond closely to the ratings given by the total group for these conditions. The subgroup may therefore be considered to be a representative sample, in terms of self-ratings. The mean rating of 72.5 given for the Very High dose is not statistically different from the mean rating for the High Dose. Nevertheless, it may be interpreted as an indication that these ten subjects considered their level of intoxication, after smoking the Very High dose, to be greater than that which they commonly experienced in a social context. The verbal comments made by these subjects (see Appendix 5) support this interpretation of the numerical rating. Eight out of ten subjects reported their level of intoxication after smoking the Very High dose as being either "more than a social stone" or "more than last time."

Table 12 shows the mean heart-pulse rates of these ten subjects before and after smoking the Very High dose, together with the mean change scores for each of these conditions (see also Appendix 6). A one factor analysis of variance for repeated measures was used to test for significant differences among the mean change scores. The obtained $\underline{F}$ ratio ($\underline{F} = 9.5633$) was significant at $p \leq .05$. The Tukey test was used as a post hoc procedure. Significant differences ($p \leq .05$) were found between the mean change

Table 12

Experimental Subgroup (N=10): Mean Heart-Pulse Rates before and after Smoking Marijuana

Condition	Del. dose in mg Δ^1THC	Mean Heart-Pulse Rates before	Mean Heart-Pulse Rates after	Mean Change beats/min	Mean Change %
Very High	5.40	84.80 σ13.60	110.80 σ18.25	+26.00 σ18.95	+30.66
High	2.16	85.60 σ10.46	90.60 σ13.08	+14.00 σ 9.34	+16.35
Low	1.08	83.90 σ12.27	94.20 σ15.76	+10.30 σ 6.87	+12.28
Placebo	0	83.60 σ10.80	83.80 σ10.49	+0.20 σ5.86	+0.24
Control[a]		81.43 σ13.21	77.14 σ 9.96	-4.29 σ 5.28	-5.27
$\underline{F}$[b]				9.5633	

[a] Control

[b] $_{95}F_{1,n-1} = 5.12$
$_{95}F_{k-1,(k-1)(n-1)} = 2.63$

score for the placebo and the mean change scores for both the High and Very High doses and between the mean change scores for the Low and Very High doses. Although all differences between means were not statistically significant, the trend of these figures does lend further support to the earlier conclusion that there is a dose-related increase in heart rate associated with the smoking of cannabis. It may be seen from Figure 5 that the ratio of percentage pulse rate increase to dosage, obtained for the Very High dose, corresponds to the value which might be expected from the findings of previous studies.

Under the Very High dose condition, each of the ten subjects in the subgroup was given the same sequence of tests and test forms which he received one year earlier under the Control condition (see Appendix 7 and Appendix 9). The mean scores of the group for each SI test under each condition are presented in Table 13. A one factor analysis of variance for repeated measures was used to test for significant differences among the five means obtained for each test. The $\underline{F}$ ratios obtained for each test are presented at the bottom of Table 13. None of these $\underline{F}$ ratios was significant at $p \leq .05$. Therefore, the null hypothesis of no significant difference between the means cannot be rejected.

Table 13

Experimental Subgroup (N=10): Mean Scores on Structure of Intellect Tests and Digit Span Test

Condition	CMR	MMR	DMR	NMR		EMR	Digit Span	
				P-W Rels	Assoc III		Forward	Reverse
Very High	13.80 σ0.87	9.14 σ5.30	9.40 σ3.29	6.10 σ2.43	9.50 σ3.43	7.10 σ1.76	7.60 σ1.36	5.50 σ1.50
High	13.20 σ1.60	8.43 σ5.58	7.50 σ2.16	5.90 σ2.84	10.20 σ3.16	6.60 σ1.50	7.10 σ1.29	5.90 σ1.66
Low	13.50 σ0.92	11.37 σ5.74	9.80 σ2.36	4.70 σ2.19	10.10 σ3.33	8.10 σ1.30	7.25 σ1.30	6.75 σ0.66
Placebo	13.70 σ0.90	9.67 σ3.89	8.00 σ1.90	6.40 σ2.73	9.40 σ2.65	8.30 σ1.35	7.59 σ1.32	6.50 σ1.66
Control	13.40 σ0.80	10.70 σ4.99	8.30 σ1.68	6.40 σ2.11	9.10 σ2.21	7.30 σ1.35	7.43 σ1.63	5.70 σ1.67
Maximum possible score	15	20	∞	10	15	10	9	8
F[a]	.6389	1.5971	2.1716	.9933	.3705	2.4716	.5570	7.4478

[a] $_{95}F_{1,(n-1)} = 5.12$
$_{95}F_{k-1,(k-1)(n-1)} = 2.63$

Similarly, for the Digit Span Test, both Forward and Reversed, no significant differences were found between the mean scores obtained under the five conditions.

Thus it may be said that the Very High dose had no greater demonstratable effect on the measures of intellectual functioning used in this study than did any of the other doses.

7. Discussion of Results and Suggestions for Further Research

The marijuana used in this experiment was repeatedly assayed by means of gas-liquid chromatography, and it was demonstrated that the Δ^1THC content was 1.5%. It was determined that the two quantities of active marijuana used in the main portion of the experiment yielded doses of 1.08 mgs and 2.11 mgs Δ^1THC delivered in the smoke to the subjects. These amounts are comparable to the doses used in other cannabis studies (see Chapter I, Section 6). It has also been reported by other researchers that doses of approximately the magnitude used in this study produce feelings of intoxication similar to those experienced by marijuana smokers in a social context.

When administered to subjects in this experiment, these amounts of Δ^1THC (1.08 mgs and 2.16 mgs) produced dose-related increases in heart-pulse rate which corresponded

closely to the increases reported by other researchers who used similar amounts. These heart-pulse rate increases were interpreted as additional evidence that subjects actually received in the smoke the amounts of Δ^1THC estimated by means of the "smoking machine" and the gas-liquid chromatograph.

Further evidence that subjects in this experiment were affected by the marijuana which they smoked is provided by their verbal comments and the results of the 0 - 100 rating scale. By means of these instruments, the majority of subjects reported, after smoking the two doses of active marijuana, that (1) they felt "high" or "stoned" and (2) that their levels of intoxication were at least equal to the feelings produced by the drug in a social context.

On the basis of the foregoing evidence, there can be little doubt that subjects in this experiment actually received and were affected by socially relevant doses of Δ^1THC. Despite this fact, no significant differences were found in the mean scores of any of the tests used to measure complex intellectual functions.

In order to forestall a posible charge that the doses administered were simply too small to affect these functions, it was decided to retest ten subjects after they had received an amount of Δ^1THC (5.40 mgs) which was more than double the previously administered High dose. Once again

no significant differences were found in the mean scores of tests measuring a variety of complex intellectual functions. In short, it has not been possible to demonstrate that cannabis has any effect on complex intellectual functioning.

In order to provide a final answer to the question of how big a dosage might be needed to affect the scores of tests used in this study, it would be necessary to extend the experiment so that subjects were tested under a series of doses containing increasingly massive amounts of Δ^1THC. It might be interesting to learn from such a study if there is an amount of Δ^1THC which would impair performance on these tests without also causing the subjects to become ill or otherwise generally incapacitated. It should be noted that, while such a study might be of academic interest, it would have little relevance outside the laboratory because it would involve the use of doses well in excess of those commonly consumed in a social context. However, a study of this kind could provide valuable information concerning heart-pulse rate increases in relation to larger (delivered) doses of Δ^1THC. The available evidence (see Figure 5) suggests that the curve of dose-related increases levels off at about four milligrams, so that doses in excess of this amount have no additional effect on heart-pulse rate. Confirmation of this observation would be of value in establishing the limits within which heart-pulse rate

increases may be used as a means of estimating delivered doses of Δ^1THC.

In seeking explanations for the failure to find significant differences among the mean scores of SI tests, under the five treatment conditions, it is also possible to speculate that marijuana does not, in fact, have any effect upon the particular abilities chosen for examination in this study. Support for this inference might be obtained by conducting additional studies in which the same experimental design and the same dosage levels were used to examine the effects of smoked marijuana on other abilities in the SI model. Of the many possible groups of abilities which might prove to be fruitful areas for investigation there is one group that would seem to be an obvious choice. In the LaGuardia study it was reported that, on the Army Alpha Test, the scores of subtests involving number concepts showed impairment after ingestion of both the 2 cc and 5 cc doses (see Chapter I, p. 45). Hollister and Gillespie reported that an orally administered marijuana extract containing 32 mg Δ^1THC produced a significant drop in scores on the Number Facility Test composed of simple arithmetic problems (see Chapter I, p. 75). The Goal Directed Serial Alternation (GDSA) and the Serial Subtraction of Sevens were administered to subjects in two studies in which oral doses of marijuana extract were used (see Chapter I, pp. 55-56). Casswell and

Marks used the same tests in conjunction with smoked marijuana (see Chapter I, pp. 63-64). These tests require subjects to carry out numerical operations of subtraction and addition in sequence. Conflicting results were obtained. Scores on the GDSA showed impairment in Casswell and Marks' study and in the first study by Melges et al., but not in the second study by these authors. Casswell and Marks reported a drop in scores of the Serial Subtraction of Sevens after smoking marijuana, while Melges et al. found no change in the results from this test. Despite these somewhat contradictory findings, there appears to be sufficient evidence to warrant the hypothesis that cannabis has an adverse effect on one or more of the abilities involved in the performance of mathematical tasks.

It should be noted that Guilford and Hoepfner have demonstrated that tests of simple mathematical operations, which traditionally have been regarded as measures of a single number factor, are in fact more complex factorially. In a factor-analytic study designed to determine the validity of SI model tests as predictors of success in general mathematics, Guilford and Hoepfner reported that "in the order of contribution, the variance of the general-mathematics score can be accounted for by factors representing DSR, MSI, EMR, NSI, CMU, CMR, and CSR . . . (p. 299)." In another validity study concerned with higher mathematics

(mainly calculus), the same authors concluded that ". . . among the SI abilities that are assets in achievement in higher mathematics are CFS, CFT, DFT, and either EMI or EMR, or both (p. 291)." The exact factorial composition of the numerical tests reportedly affected by marijuana is uncertain. However, it would seem reasonable to suppose that, if marijuana does in fact impair performance on mathematical tests, this effect would also show up on tests measuring one or more of the SI abilities listed above.[1] It is suggested that a study be carried out in which subjects are tested twice under each treatment condition. On one occasion under each condition the tests used in this study could be repeated, and on the other occasion under each condition tests could be used which measure abilities related to mathematics. It might be hypothesized that the SI tests used in this study would once again show no drug-related effects, while tests measuring abilities for mathematics would show impairment.

Experiments, such as the one just described, are essential for a thorough investigation of the possible effects of cannabis on the individual abilities of the SI model. However, in suggesting such research it must also

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1 Tests measuring CMR and EMR were used in the present study.

be said that there is a real possibility that cannabis will not affect the scores of any test measuring a single SI ability. As mentioned in Chapter I (see p. 86), the writer is unaware of any well designed study in which it has been shown conclusively that cannabis impairs complex intellectual functioning per se. In this study no change was found in the scores of tests representing five SI abilities. Also in this study marijuana produced no significant changes in either the number of questions attempted, the number of answers correct, or the IQ scores obtained on the Otis SA, Test of Mental Ability. Since the Otis SA is a multi-factor test (which includes a number of mathematical items), it might be assumed that if marijuana affected any of its component factors, this effect would show up in the overall score.

A theoretical explanation for this general lack of positive results may be found in the conclusions of Casswell and Marks (see Chapter I, p. 64). These authors have suggested that cannabis does not affect simple tasks of short duration, but it does impair more complex tasks which involve both short-term memory and the serial manipulation of information. Very similar theories have been advanced by Clark and Nakashima and by Melges et al. (see Chapter I, pp. 54 and 57). As an extension of these theories, it may be hypothesized that cannabis will not impair performance

on any test of any intellectual ability when that test is composed of items which are clearly circumscribed and of short duration (as are the items on the Otis SA and the SI tests used in this study). However, cannabis may impair performance on any test in which subjects are required to employ a number of intellectual abilities, simultaneously or sequentially, in the solution of multistage problems (as in the GDSA test). An analogy may be drawn between the abilities in the SI model and the many different, physical skills needed by a juggler in the performance of his art. It might be that cannabis would have no effect on any of these skills when they are tested one at a time. Nevertheless, the drug might still impair the juggler's overall ability to keep a number of objects in the air at the same time. In order to test this hypothesis, more carefully controlled experiments are needed in which subjects are required to solve multistage goal-oriented problems. Using the GDSA test as a model, it may be possible to design additional tests which have mainly figural, semantic, or behavioral content.

Finally, in conducting such research it will be necessary to determine the extent to which test scores might be indirectly influenced by the effects of cannabis upon attention. It has been widely reported in the literature that cannabis impairs the ability of subjects to pay adequate

attention to a variety of tasks, including signal detection, complex reaction time, and tests of memory. The validity of these reports is not disputed, but it should be noted that in experiments where attention has been studied directly, the tasks employed have invariably been routine and uninteresting. The writer suggests that when subjects are confronted with relatively interesting tasks, or when they are otherwise well motivated (as in the present study), it is possible for them to control and greatly reduce the adverse effects of cannabis on attention. It is expected that this would be particularly true in the case of tests having items of short duration. The authors of the Le Dain Commission's report (1972) on cannabis also have suggested that it may be possible for cannabis users to control their "high" at will (p. 49). In order to test this hypothesis it is suggested that from among the tests mentioned in Chapter I on which significant results have been obtained, a number be selected for administration, under control and high dose conditions, to subjects who have been promised payment for good performance. It is hypothesized that with subjects highly motivated in this way, the previously reported differences obtained between drug and no-drug conditions would largely disappear. However, it may also be hypothesized that even such highly motivated subjects would be unable to maintain their level of performance

on complex multistage tasks while under the influence of cannabis.

It is hoped that these interpretations and suggestions will direct other experimenters into areas of research which will improve understanding of the short-term effects of cannabis on intellectual functioning.

SUMMARY AND CONCLUSIONS

In the present study an attempt was made to examine systematically the short-term effects of smoked marijuana on intellectual functioning.

The first four sections of Chapter I contained a review of literature dealing with technical problems which directly affect the design, outcome, and interpretation of research into the behavioral effects of cannabis. These problems included methods of quantifying dosages, dose magnitudes, routes of administration, the previous cannabis experience of subjects, and the effects of set, setting, and personality. Section 5 contained a discussion of the uses of heart-pulse rate as a bio-assay technique.

Section six reviewed the literature concerned with the effects of cannabis on psychomotor and intellectual functioning. In reviewing this literature it became apparent that, in many of the studies, the variables discussed in sections one to four had not been adequately controlled or accounted for. These weaknesses, together with the absence of any unifying theory of intellectual functioning, made it difficult to draw meaningful comparisons between the results of the various studies.

Nevertheless, on the basis of the available evidence, it was possible to formulate three general questions which could be examined within the confines of a single study.

First, if cannabis does affect complex intellectual functioning (and this had not been clearly demonstrated), what particular functions are most affected? Secondly, and more specifically, does cannabis impair the input or the recall processes of memory? Finally, does cannabis affect any particular form of intellectual functioning per se, or does it impair the underlying ability to focus attention on the task in hand irrespective of the nature of that task? These questions were then re-examined within the framework of J. P. Guilford's Structure of Intellect theory and reformulated using the terminology of the SI model.

In an attempt to answer the questions raised in this way, three null hypotheses were tested experimentally using the Otis SA, Test of Mental Ability, the Digit Span Test, and six SI model tests administered to 40 subjects under five treatment conditions, employing double blind procedures, and a repeated measures design in which the order of SI tests, test forms, and treatment conditions were counterbalanced.

On the basis of physiological findings, subjects' verbal comments and their self ratings on a 0 - 100 scale, it was possible to demonstrate that the subjects actually ingested and were affected by socially relevant doses of Δ^1THC, and that the resultant feelings of intoxication

were at least equal to the drug effects which they commonly experienced in a social setting. Despite these demonstratable effects, no significant changes were found on any of the measures of intellectual functioning employed in the study. In order to check on the possibility that the absence of significant results was due to inadequate dosages, ten subjects were retested with the SI battery, after smoking a quantity of marijuana that yielded a dose of Δ^1THC which was more than double the amount delivered by the previous high dose. This increased dose, which was in excess of the amounts commonly consumed in a social setting, also produced no significant change in the scores of any of the tests of intellectual functioning.

In attempting to account for these results, it has been argued that marijuana does not, in fact, impair performance on any test of any type of intellectual functioning, provided that the test items are clearly circumscribed and of short duration. However, on the basis of other findings reported in the literature, it has been hypothesized that cannabis does impair the capacity of subjects to solve multistage goal-directed problems in which they are required to employ a number of intellectual abilities (including memory) in rapid sequence. It is also suggested that many of the significant findings reported in the cannabis literature are the result of the drug's effect on attention, rather

than its effect on a particular intellectual ability. It is further suggested that, if subjects are strongly motivated, they can control the effects of cannabis on attention to the point where they can function at no-drug levels of efficiency on most intellectual tasks. However, it is questionable if they can achieve a degree of control which would enable them to overcome cannabis-related impairment of performance on multistage, goal-directed tasks.

Further research will be needed in order to provide final answers to these questions.

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APPENDIX 1

EXPERIMENTAL GROUP: SUBJECT VARIABLES

APPENDIX 1

EXPERIMENTAL GROUP: SUBJECT VARIABLES

Subj.	Age (yrs)	Height (ins)	Weight (lbs)	Edu. level completed	Cannabis Exp. Prior to Study period of use	Cannabis Exp. Prior to Study freq. per week[a]
1	21	72	173	Arts I	17	1
2	22	73	190	Eng II	18	3
3	22	66	140	Arts III	54	4
4	31	70	160	LLB	9	0.5
5	22	69	135	Arts II	44	2
6	24	71	165	BA + I	18	2
7	26	69	160	BA	35	0.5
8	23	69	135	Arts I	66	1
9	23	70	155	High School	48	8
10	24	71	130	Arts II	48	5
11	33	66	140	LLB	30	3
12	22	70	145	High School	60	4
13	23			Arts II		
14	21	74	165	Arts I	47	5
15	24	66	130	Arts I	45	2
16	22	75	150	BSc	19	2
17	28	70	170	BA	48	1
18	25	72	210	BEd	18	0.5
19	22	74	185	Arts III	30	4
20	21	71	165	Sci III	32	0.5
21	29	67	130	BA	36	2
22	29	70	145	Arts I	42	0.5
23	23	69	163	BA	22	3
24	24	70	150	BA	60	4
25	36	70	180	BSc	87	0.5
26	28	74	180	BCom	43	1
27	27	70	200	Arts II	72	2
28	24	70	190	Engr III	36	3

[a]For statistical purposes all subjects who reported a frequency of use of less than once per week were arbitrarily recorded as 0.5 (once in two weeks). Subsequent questioning showed this to be a reasonable approximation.

Subj.	Age (yrs)	Height (ins)	Weight (lbs)	Edu. level completed	Cannabis Exp. Prior to Study period of use	freq. per week
29	23	73	171	Arts III	14	2
30	22			Arts III	15	2
31	34			LLB	18	0.5
32	21	70	155	BA	36	3
33	24	67	165	Arts II	18	3
34	22	73	145	High School	12	0.5
35	31	68	175	MA + I	12	1
36	23	67	166	Arts II	14	0.5
37	22	72	185	BA	53	3
38	22	75	170	Engr II	36	2
39	24	72	165	BA	48	3
40	25	69	180	MEd	12	0.5
M	24.80	70.38	162.65		35.18	2.21
σ	3.80	2.45	19.90			

APPENDIX 2

CORRESPONDENCE FROM J. P. GUILFORD

J. P. GUILFORD
POST OFFICE BOX 1288
BEVERLY HILLS, CALIFORNIA 90213

December 3, 1970

Dr. H. P. Edwards
The Faculty of Psychology
University of Ottawa
1245 Kilborn Avenue
Ottawa 8, Canada

Dear Dr. Edwards:

Your letter of November 12 to Dr. Hoepfner was forwarded from USC to him at UCLA and he has referred it to me. It was received by me only today. The Aptitudes Research Project had ended its activities last year.

In order to make Project tests available to others for research purposes, we placed them in the hands of Sheridan Psychological Services. Some have been published and are sold in quantities, but most of them are available only in single copies, with permission for investigators to reproduce them.

I think you are wise to sample systematically from the SI model in your experimental use of tests. I could ask the publisher to send you the tests you have listed, but you would need to order directly, and you should consider some new information first. The enclosed list of tests for factors incorporates the most pertinent, accumulated information regarding tests that can be recommended. You will note that some of the tests you mentioned are not listed, for the reason that they were derived from other sources (e.g. Thurstone) and could not be protected by copyright or distributed without special permission. I have penned in a new test for NMR(Part-Whole Relations), which came to light more recently.

Most of the tests have two separately timed parts, which could be used as alternate forms. I should not recommend breaking them down further to obtain more forms. You might attempt to produce new parallel forms by writing new items.

Just in case you should decide to use a published test, the enclosed catalog will inform you of prices. Single copies of published tests are not sold; only review copies, which are informplete.

Enclosed are forms for ordering unpublished tests.

Sincerely,

J P Guilford

J. P. Guilford

Enc: Test list
Catalog (Sent separately)
Request forms

J. P. GUILFORD
POST OFFICE BOX 1288
BEVERLY HILLS, CALIFORNIA 90213

April 2, 1971

Dr. Henry P. Edwards
The Faculty of Psychology
University of Ottawa
1245 Kilborn Avenue
Ottawa 8, Canada

Dear Dr. Edwards:

In view of your interest in using our test PART-WHOLE RELATIONS as a measure of NMR, I have revised it, and I hope improved it. The chances are that it should be a stronger and more univocal measure of that ability.

As soon as I can obtain a reproduction made for you, I will send it. You may reproduce it for your research purposes.

I have also made a new scoring key, which should be closely adhered to, with the exception noted.

Sincerely,

J. P. Guilford

J. P. Guilford

Enc: Test and scoring key

APPENDIX 3

INSTRUCTIONS FOR STRUCTURE OF INTELLECT TESTS USED IN THIS STUDY

APPENDIX 3

WORD LINKAGE

In this test, you will be given two words, followed by a list of three words. From the list of three words, you are to underline the one that is related to both given words. The word you choose must have a different meaning in its relation to each of the given words. Now look at the example.

Example:

Jewelry - Bell

1. ornament
2. jingle
3. ring

Ring is the right answer. It is associated with the word Jewelry because a ring is jewelry, but is also associated with the word Bell because it is the sound a bell makes. Notice that two different meanings of ring are used. 3 has been blackened to show that ring is the right answer.

Jingle has two different meanings; one meaning is a "sound" and the other meaning is a "rhyme." Jingle is associated with both Jewelry and Bell because they both can jingle. However, jingle would not be chosen since it is associated with the two given words by the same meaning (sound).

Ornament is not chosen because it does not have two different meanings. Choose the word that is associated with the two given words by two different meanings.

This test has 15 items. You will have 4 minutes in which to work. You will be told when 2 minutes remain.

If you have questions, ask them now.

STOP HERE.

WAIT FOR FURTHER INSTRUCTIONS

REMEMBERED RELATIONS

This is a test of how well you can remember given relations. On a study page you will be given sentences, each one expressing a relation. You are to study the relations, then complete statements on a test page. Look at the sample study page:

SAMPLE STUDY PAGE

Gold is more valuable than iron.
Lead is heavier than sand.
Diamonds are harder than coal.
Tar is blacker than cement.

Now look at the sample test page:

SAMPLE TEST PAGE

Lead is C than sand.
A. blacker
B. more valuable
C. heavier
D. none of these.

Coal is A than diamonds.
A. softer
B. blacker
C. less valuable
D. none of these

Sand is D than gold.
A. harder
B. blacker
C. lighter
D. none of these

Notice that the first item appears the same as on the study page, and "C" is marked. The second item, however, is the reverse of an item on the study page, so "A" is marked to show that the relation has still been remembered. The third relation is not found on the study page; therefore, it is marked "D" none of these.

This test has 20 items. You will have 2½ minutes to examine the study page, and 2 minutes to mark your answers on the test page. Avoid wild guessing, as there is a penalty for wrong answers. Do not turn any pages unless you are instructed to do so.

If you have questions, ask them now.
STOP HERE. WAIT FOR FURTHER INSTRUCTIONS

ASSOCIATIONAL FLUENCY I

Form A

By Paul R. Christensen and J. P. Guilford

In this test you are to write words similar in meaning to the given word.

SAMPLE ITEM:

Write words similar in meaning to the word HARD.

HARD:

_____ _____

_____ _____

_____ _____

_____ _____

Notice that the words written above are all somewhat like the word HARD in meaning. In the test you are to write as many words as you can that are similar in meaning to the given word.

WAIT FOR THE SIGNAL BEFORE TURNING THIS PAGE.

Write as rapidly as you can. Avoid using a word more than once. Your score will be the total number of words you write (similar in meaning to the given word).

You will have 2 minutes in which to work.

Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

ASSOCIATIONS III

The items in this test consist of pairs of words. Your task is to think of a single word that has a meaning similar to each of the given words of the pair.

Look at the following example:

nonsense _____ bed

The correct answer is "bunk" since one of its meanings is nonsense and another meaning is bed; therefore, the word "bunk" is written in the space between the two given words.

Try the next sample.

recline _____ deceive

The correct answer is "lie" since it has a meaning similar to both given words.

The remaining items in the test should be answered in the same manner. Work rapidly, but be sure that you answer each item with a word that has a meaning similar to both given words.

This test consists of 15 items. You will have 6 minutes working time. Are there any questions?

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

PART-WHOLE RELATIONS
(Revised)

A. Fulgosi and J. P. Guilford

In each item you will be given a word that stands for a part of something. Your task is to think of and to write the name of the smallest possible whole of which the given thing is a part.

Examples:	Given part	Smallest whole
	leaf	_____
	minute	_____

Credit will not be given unless the answer states the smallest whole. For example, "branch" or "tree" would not be acceptable in response to "leaf."

Credit will not be given for naming classes. For example, "unit of time" or "time" would not be acceptable in response to "minute."

Credit will not be given for naming parts of the given part or other parts like it. For example, in response to "leaf," "stem" is part of a leaf. The response "bud," or "flower," would be a similar part, not a whole that contains a leaf.

Do not give more than one response to each item.

There are 10 items in the test. You will have one minute working time, so work rapidly. Do not spend too much time on any one item. You may come back to it later if there is still time.

If you have questions, ask them now.

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS.

WORD ANALOGIES III

This is a test of your ability to judge relations between words. In each item you will be given a first pair of words which are related in the same way. You are to complete a second pair by choosing one of four given words. The second pair should have a relation similar to that of the first pair. Now look at the example.

Example:

TRAFFIC : SIGNAL as RIVER: B

A. bank
B. dam
C. canal
D. sand bags

Although all four alternatives are related to river, the alternative B, dam, best fits the blank to complete the second pair. Signal controls traffic as dam controls river. The letter "B" is therefore written in the blank.

In the test, select the alternative word which best fits the blank in each item.

This test has 10 items. You will be given 3 minutes in which to work. You will be told when 1 minute remains.

If you have questions, ask them now.

STOP HERE. WAIT FOR FURTHER INSTRUCTIONS

APPENDIX 4

DAILY TESTING SCHEDULE

APPENDIX 4

DAILY TESTING SCHEDULE

Testing day	Time	Subject	Condition	Test Sequence[a]				
1	9:00 am	1	L	$*D_1$	E_2	A_1	$B_2\hat{}$	C_1
	10:00 am	2	C	E_2	$\hat{}B_1$	D_2^*	A_1	C_2
	11:00 am	3	P	C_1	E_2	$B_1\hat{}$	$*D_2$	A_1
	1:00 pm	4	C	E_2	C_1	A_2	D_1^*	$\hat{}B_2$
	2:00 pm	5	P	$*D_1$	A_2	C_1	$B_2\hat{}$	E_1
	3:00 pm	6	L	$\hat{}B_2$	A_1	C_2	D_1^*	E_2
2	9:00 am	7	C	C_1	$*D_2$	A_1	$B_2\hat{}$	E_1
	10:00 am	8	H	C_2	A_1	E_2	$\hat{}B_1$	D_2^*
	11:00 am	9	H	A_1	E_2	B_1^*	$\hat{}D_2$	C_1
	1:00 pm	10	P	E_2	C_1	D_2^*	A_1	$\hat{}B_2$
	2:00 pm	11	H	$B_1\hat{}$	C_2	$*D_1$	A_2	E_1
	3:00 pm	12	C	C_2	E_1	A_2	D_1^*	$\hat{}B_2$
3	9:00 am	13	P	$B_1\hat{}$	$*D_2$	E_1	A_2	C_1
	10:00 am	14	L	A_2	C_1	D_2^*	$\hat{}B_1$	E_2
	11:00 am	15	H	$B_1\hat{}$	$*D_2$	A_1	C_2	E_1
	1:00 pm	16	C	A_2	$\hat{}B_1$	E_2	D_1^*	C_2
	2:00 pm	17	L	A_1	$B_2\hat{}$	$*D_1$	E_2	C_1
	3:00 pm	18	H	E_2	D_1^*	C_2	A_1	$\hat{}B_2$
4	9:00 am	19	H	$B_1\hat{}$	$*D_2$	E_1	C_2	A_1
	10:00 am	20	L	C_2	$\hat{}B_1$	E_2	A_1	D_2^*
	11:00 am	21	L	$B_1\hat{}$	E_2	A_1	C_2	$*D_1$
	1:00 pm	22	P	E_2	$\hat{}B_1$	D_2^*	C_1	A_2
	2:00 pm	23	C	A_1	E_2	C_1	$B_2\hat{}$	$*D_1$
	3:00 pm	24	P	D_2^*	$\hat{}B_1$	A_2	E_1	C_2

[a] *represents position of Part-Whole Relations Test in sequence

^represents position of Digit Symbol Test in sequence

Testing day	Time	Subject	Condition	Test Sequence				
5	9:00 am	25	C	$^{*}D_1$	A_2	E_1	$\hat{B}_2$	C_1
	10:00 am	26	L	A_2	C_1	E_2	$\hat{B}_1$	D^{*}_2
	11:00 am	27	C	$\hat{B}_1$	E_2	C_1	A_2	$^{*}D_1$
	1:00 pm	28	L	C_2	D^{*}_1	$\hat{B}_2$	E_1	A_2
	2:00 pm	29	C	E_1	B^{*}_2	C_1	$^{*}D_2$	A_1
	3:00 pm	30	H	D^{*}_2	C_1	$\hat{B}_2$	A_1	E_2
6	9:00 am	31	H	A_1	E_2	$^{*}D_1$	C_2	$\hat{B}_1$
	10:00 am	32	H	E_2	$\hat{B}_1$	A_2	D^{*}_1	C_2
	11:00 am	33	P	A_1	$^{*}D_2$	E_1	C_2	$\hat{B}_1$
	1:00 pm	34	P	A_2	D^{*}_1	C_2	$\hat{B}_1$	E_2
	2:00 pm	35	L	E_1	A_2	$\hat{B}_1$	$^{*}D_2$	C_1
	3:00 pm	36	H	E_2	C_1	$\hat{B}_2$	A_1	D^{*}_2
7	9:00 am	37	P	C_1	$\hat{B}_2$	E_1	$^{*}D_2$	A_1
	10:00 am	38	L	$\hat{B}_2$	A_1	C_2	D^{*}_1	E_2
	11:00 am	39	C	A_1	C_2	$\hat{B}_1$	E_2	$^{*}D_1$
	2:00 pm	40	L	A_2	$\hat{B}_1$	E_2	C_1	D^{*}_2
8	9:00 am	6	H	$\hat{B}_1$	C_1	$^{*}D_2$	E_1	A_2
	10:00 am	5	C	$\hat{B}_1$	A_1	E_2	D^{*}_2	C_2
	11:00 am	4	H	$\hat{B}_1$	E_1	C_2	$^{*}D_2$	A_1
	1:00 pm	3	H	D^{*}_1	$\hat{B}_2$	C_2	A_2	E_1
	2:00 pm	2	L	A_2	$\hat{B}_2$	E_1	C_1	$^{*}D_1$
	3:00 pm	1	C	$\hat{B}_1$	A_2	C_2	E_1	D^{*}_2
9	9:00 am	12	P	$\hat{B}_1$	A_1	$^{*}D_2$	E_2	C_1
	10:00 am	11	C	E_2	D^{*}_2	$\hat{B}_2$	A_1	C_1
	11:00 am	10	L	$^{*}D_1$	A_2	$\hat{B}_1$	E_2	C_2
	1:00 pm	9	P	C_2	$\hat{B}_2$	D^{*}_1	A_2	E_1
	2:00 pm	8	L	A_2	$^{*}D_1$	$\hat{B}_2$	C_1	E_1
	3:00 pm	7	H	$\hat{B}_1$	E_2	D^{*}_1	A_2	C_2

Testing day	Time	Subject	Condition	Test Sequence
10	9:00 am	18	P	C_1 A_2 $\hat{B_1}$ $*D_2$ E_1
	10:00 am	17	P	A_2 E_1 D_2^* C_2 $\hat{}B_1$
	11:00 am	16	L	$\hat{B_2}$ A_1 E_1 C_1 $*D_2$
	1:00 pm	15	L	$\hat{}B_2$ C_2 A_2 E_1 D_1^*
	2:00 pm	14	C	E_1 C_2 $\hat{B_2}$ A_1 $*D_1$
	3:00 pm	13	L	C_2 A_1 D_1^* $\hat{}B_2$ E_2
11	9:00 am	24	H	E_2 A_1 C_1 $\hat{B_2}$ $*D_1$
	10:00 am	23	P	E_1 $\hat{}B_1$ C_2 A_2 D_2^*
	11:00 am	22	C	$*D_1$ C_2 $\hat{B_2}$ E_1 A_1
	1:00 pm	21	H	C_1 $\hat{}B_2$ A_2 E_1 D_2^*
	2:00 pm	20	P	A_2 $\hat{B_2}$ $*D_2$ C_1 E_1
	3:00 pm	19	C	A_2 E_2 $\hat{}B_2$ C_1 D_1^*
12	9:00 am	30	P	A_2 C_2 E_1 $*D_1$ $\hat{B_1}$
	10:00 am	29	H	D_1^* C_2 E_2 A_2 $\hat{}B_1$
	11:00 am	28	C	$*D_2$ E_2 C_1 A_1 $\hat{B_1}$
	1:00 pm	27	L	C_2 D_2^* $\hat{}B_2$ A_1 E_1
	2:00 pm	26	P	$\hat{B_2}$ A_1 $*D_1$ C_2 E_1
	3:00 pm	25	L	E_2 D_2^* A_1 C_2 $\hat{}B_1$
13	9:00 am	36	P	C_2 $*D_1$ A_2 E_1 $\hat{B_1}$
	10:00 am	35	C	$\hat{}B_2$ A_1 E_2 C_2 D_1^*
	11:00 am	34	H	$\hat{B_2}$ $*D_2$ A_1 E_1 C_1
	1:00 pm	33	C	C_1 A_2 D_1^* $\hat{}B_2$ E_2
	2:00 pm	32	C	C_1 A_1 E_1 $*D_2$ $\hat{B_2}$
	3:00 pm	31	L	C_1 E_1 A_2 D_2^* $\hat{}B_2$
14	9:00 am	40	H	E_1 $*D_1$ A_1 C_2 $\hat{B_2}$
	10:00 am	39	P	C_1 E_1 A_2 $\hat{}B_2$ D_2^*
	1:00 pm	38	L	$*D_2$ C_1 E_1 $\hat{B_1}$ A_2
	2:00 pm	37	L	E_2 A_2 C_1 D_1^* $\hat{}B_1$

Testing day	Time	Subject	Condition	Test Sequence				
15	9:00 am	4	P	C_{1R}	$B\hat{}_{2R}$	A_{2R}	$*D_{1R}$	E_{2R}
	10:00 am	1	P	A_{1R}	$\hat{}B_{2R}$	C_{1R}	D^{*}_{1R}	E_{2R}
	11:00 am	2	H	E_{2R}	C_{2R}	$*D_{2R}$	$B\hat{}_{1R}$	A_{1R}
	1:00 pm	5	H	C_{1R}	E_{1R}	D^{*}_{1R}	A_{2R}	$\hat{}B_{2R}$
	2:00 pm	6	P	E_{2R}	C_{2R}	A_{1R}	$B\hat{}_{2R}$	$*D_{1R}$
	3:00 pm	3	C	D^{*}_{2R}	A_{1R}	E_{2R}	C_{1R}	$\hat{}B_{1R}$
16	9:00 am	10	C	$*D_{2R}$	E_{2R}	A_{1R}	C_{1R}	$B\hat{}_{2R}$
	10:00 am	7	L	D^{*}_{2R}	E_{1R}	C_{1R}	$\hat{}B_{2R}$	A_{1R}
	11:00 am	8	C	C_{2R}	$*D_{2R}$	E_{2R}	A_{1R}	$B\hat{}_{1R}$
	1:00 pm	11	L	A_{2R}	$\hat{}B_{1R}$	C_{2R}	E_{1R}	D^{*}_{1R}
	2:00 pm	12	L	$B\hat{}_{2R}$	C_{2R}	E_{1R}	$*D_{1R}$	A_{2R}
	3:00 pm	9	L	$\hat{}B_{1R}$	D^{*}_{2R}	C_{1R}	A_{1R}	E_{2R}
17	9:00 am	16	P	$B\hat{}_{1R}$	$*D_{1R}$	A_{2R}	C_{2R}	E_{2R}
	10:00 am	13	H	$\hat{}B_{1R}$	E_{1R}	D^{*}_{2R}	C_{1R}	A_{2R}
	11:00 am	14	H	C_{1R}	A_{2R}	E_{2R}	$*D_{2R}$	$B\hat{}_{1R}$
	1:00 pm	17	C	E_{2R}	A_{1R}	$\hat{}B_{2R}$	C_{1R}	D^{*}_{1R}
	2:00 pm	18	C	A_{1R}	$*D_{1R}$	C_{2R}	$B\hat{}_{2R}$	E_{2R}
	3:00 pm	15	P	A_{1R}	D^{*}_{2R}	E_{2R}	C_{1R}	$\hat{}B_{1R}$
18	9:00 am	22	L	C_{1R}	E_{2R}	$B\hat{}_{1R}$	A_{2R}	$*D_{2R}$
	10:00 am	19	P	E_{1R}	$\hat{}B_{1R}$	A_{1R}	D^{*}_{2R}	C_{2R}
	11:00 am	20	H	E_{2R}	A_{1R}	C_{2R}	$*D_{2R}$	$B\hat{}_{1R}$
	1:00 pm	23	H	E_{2R}	A_{1R}	$\hat{}B_{2R}$	D^{*}_{1R}	C_{1R}
	2:00 pm	24	L	C_{2R}	A_{2R}	$*D_{2R}$	E_{1R}	$B\hat{}_{1R}$
	3:00 pm	24	L	C_{2R}	A_{2R}	$*D_{2R}$	E_{1R}	$B\hat{}_{1R}$
19	9:00 am	28	H	E_{1R}	$*D_{1R}$	A_{2R}	$B\hat{}_{2R}$	C_{2R}
	10:00 am	25	H	D^{*}_{1R}	A_{2R}	C_{1R}	E_{1R}	$\hat{}B_{2R}$
	11:00 am	26	C	A_{2R}	$*D_{2R}$	$B\hat{}_{1R}$	E_{2R}	C_{1R}
	1:00 pm	29	P	A_{1R}	E_{1R}	C_{1R}	D^{*}_{2R}	$\hat{}B_{2R}$
	2:00 pm	30	C	$*D_{2R}$	C_{1R}	A_{1R}	$B\hat{}_{2R}$	E_{2R}
	3:00 pm	27	P	A_{2R}	E_{2R}	D^{*}_{1R}	$\hat{}B_{1R}$	C_{1R}

Testing day	Time	Subject	Condition	Test Sequence				
20	9:00 am	34	C	A_{2R}	C_{2R}	$*D_{1R}$	$B\hat{}_{1R}$	E_{2R}
	10:00 am	31	C	D^{*}_{1R}	$\hat{}B_{1R}$	A_{1R}	E_{2R}	C_{2R}
	11:00 am	32	L	C_{2R}	A_{2R}	$*D_{1R}$	E_{2R}	$B\hat{}_{1R}$
	1:00 pm	35	P	C_{1R}	E_{1R}	D^{*}_{2R}	$\hat{}B_{1R}$	A_{2R}
	2:00 pm	36	L	$B\hat{}_{2R}$	C_{1R}	$*D_{2R}$	A_{1R}	E_{2R}
	3:00 pm	33	L	$\hat{}B_{1R}$	E_{1R}	A_{1R}	C_{2R}	D^{*}_{2R}
21	9:00 am	38	C	$*D_{2R}$	A_{2R}	E_{2R}	$B\hat{}_{1R}$	C_{1R}
	10:00 am	40	P	E_{1R}	C_{1R}	D^{*}_{2R}	$\hat{}B_{2R}$	A_{1R}
	1:00 pm	37	H	E_{2R}	$*D_{1R}$	A_{1R}	$B\hat{}_{2R}$	C_{2R}
	2:00 pm	39	L	$\hat{}B_{1R}$	D^{*}_{1R}	E_{2R}	C_{2R}	A_{1R}
22	9:00 am	5	L	$*D_{2R}$	A_{1R}	$B\hat{}_{1R}$	C_{2R}	E_{2R}
	10:00 am	3	L	$\hat{}B_{2R}$	C_{2R}	A_{2R}	D^{*}_{1R}	E_{1R}
	11:00 am	6	C	C_{1R}	E_{1R}	A_{2R}	$B\hat{}_{1R}$	$*D_{2R}$
	1:00 pm	1	H	$\hat{}B_{1R}$	C_{2R}	E_{1R}	A_{2R}	D^{*}_{2R}
	2:00 pm	4	L	C_{2R}	$B\hat{}_{1R}$	$*D_{2R}$	E_{1R}	A_{1R}
	3:00 pm	2	P	D^{*}_{1R}	E_{1R}	$\hat{}B_{2R}$	C_{1R}	A_{2R}
23	9:00 am	11	P	A_{1R}	$*D_{2R}$	E_{2R}	$B\hat{}_{2R}$	C_{1R}
	10:00 am	9	C	C_{2R}	D^{*}_{1R}	E_{1R}	$\hat{}B_{2R}$	A_{2R}
	11:00 am	12	H	$*D_{2R}$	$B\hat{}_{1R}$	E_{2R}	A_{1R}	C_{1R}
	1:00 pm	7	P	E_{2R}	A_{2R}	D^{*}_{1R}	$\hat{}B_{1R}$	C_{2R}
	2:00 pm	10	H	C_{2R}	$B\hat{}_{1R}$	E_{1R}	$*D_{1R}$	A_{2R}
	3:00 pm	8	P	D^{*}_{1R}	C_{1R}	A_{2R}	E_{1R}	$\hat{}B_{2R}$
24	9:00 am	17	H	$*D_{2R}$	$B\hat{}_{1R}$	A_{2R}	C_{2R}	E_{1R}
	10:00 am	15	C	D^{*}_{1R}	$\hat{}B_{2R}$	E_{1R}	C_{2R}	A_{2R}
	11:00 am	18	L	A_{2R}	$*D_{2R}$	C_{1R}	E_{1R}	$B\hat{}_{1R}$
	1:00 pm	13	C	A_{1R}	C_{2R}	D^{*}_{1R}	E_{2R}	$\hat{}B_{2R}$
	2:00 pm	16	H	C_{1R}	A_{1R}	$B\hat{}_{2R}$	E_{1R}	$*D_{2R}$
	3:00 pm	14	P	$\hat{}B_{2R}$	D^{*}_{1R}	C_{2R}	E_{1R}	A_{1R}

Testing day	Time	Subject	Condition	Test Sequence				
25	9:00 am	23	L	$^{*}D_{2R}$	$B\hat{}_{1R}$	C_{2R}	E_{1R}	A_{2R}
	10:00 am	21	P	C_{1R}	D^{*}_{2R}	A_{2R}	E_{1R}	$\hat{}B_{2R}$
	11:00 am	24	C	A_{1R}	C_{1R}	$B\hat{}_{2R}$	$^{*}D_{1R}$	E_{2R}
	1:00 pm	19	L	A_{2R}	C_{1R}	$\hat{}B_{2R}$	E_{2R}	D^{*}_{1R}
	2:00 pm	22	H	E_{1R}	$^{*}D_{1R}$	C_{2R}	$B\hat{}_{2R}$	A_{1R}
	3:00 pm	20	C	C_{1R}	E_{1R}	D^{*}_{1R}	$\hat{}B_{2R}$	A_{2R}
26	9:00 am	29	L	E_{2R}	C_{2R}	$B\hat{}_{1R}$	$^{*}D_{1R}$	A_{2R}
	10:00 am	27	H	D^{*}_{2R}	E_{1R}	$\hat{}B_{2R}$	A_{1R}	C_{1R}
	11:00 am	30	L	$^{*}D_{1R}$	C_{2R}	E_{1R}	$B\hat{}_{1R}$	A_{2R}
	1:00 pm	25	P	E_{2R}	$\hat{}B_{1R}$	A_{1R}	C_{2R}	D^{*}_{2R}
	2:00 pm	28	P	$B\hat{}_{1R}$	E_{2R}	A_{1R}	$^{*}D_{2R}$	C_{1R}
	3:00 pm	26	H	E_{1R}	A_{1R}	D^{*}_{1R}	C_{2R}	$\hat{}B_{1R}$
27	9:00 am	35	H	A_{1R}	C_{2R}	E_{2R}	$B\hat{}_{2R}$	$^{*}D_{1R}$
	10:00 am	33	H	D_{1R}	C_{1R}	$\hat{}B_{2R}$	E_{2R}	A_{2R}
	11:00 am	36	C	C_{2R}	A_{2R}	E_{1R}	$B\hat{}_{1R}$	$^{*}D_{1R}$
	1:00 pm	31	P	C_{1R}	$\hat{}B_{2R}$	D^{*}_{2R}	A_{2R}	E_{1R}
	2:00 pm	34	L	E_{1R}	$^{*}D_{2R}$	C_{1R}	A_{1R}	$B\hat{}_{2R}$
	3:00 pm	32	P	A_{1R}	C_{1R}	D^{*}_{2R}	E_{1R}	$\hat{}B_{2R}$
28	9:00 am	39	H	C_{1R}	E_{1R}	$B\hat{}_{2R}$	$^{*}D_{2R}$	A_{2R}
	10:00 am	37	C	$\hat{}B_{1R}$	A_{2R}	C_{2R}	E_{2R}	D^{*}_{1R}
	1:00 pm	40	C	$^{*}D_{1R}$	A_{1R}	E_{1R}	C_{2R}	$B\hat{}_{2R}$
	2:00 pm	38	P	A_{2R}	D^{*}_{2R}	$\hat{}B_{1R}$	C_{1R}	E_{1R}

APPENDIX 5

SUBJECTS' COMMENTS, AND SELF-RATINGS OF THEIR INTOXICATION LEVELS, ON A 0 - 100 RATING SCALE

APPENDIX 5

SUBJECTS' COMMENTS, AND SELF-RATINGS OF THEIR INTOXICATION LEVELS, ON A 0 - 100 RATING SCALE[a]

Subj. no.	Test day[b]	Dose	Self-rating	Subjects' Comments[c]
1	4	H	40	-(R) Lighter than last time, but still very good.
	1	L	75	-(R) Pleasantly high - air conditioner too loud.
	3	P	0	-(R) It wasn't - no effect.
	2	C	-	
2	3	H	70	-(I) Pleasantly high. (R) Less than last time, but OK. A good mild high.
	2	L	80	-(I) Stoned. (R) Nice light grass stone - really ripped.
	4	P	90	-(I) The best yet. (R) Great - best so far - really ripped - very relaxed.
	1	C	-	
3	2	H	80	-( ) More stoned than last time. (R) Good heavy stone - came on slow, then hit pretty hard.
	4	L	60	-(R) Pretty good - better than first time - worse than last time.
	1	P	45	-(R) A light stone.
	3	C	-	
4	5	VH	75	-(R) Good stuff - positively got off - strong.
	2	H	60	-(R) Enjoyable - close to a social stone.
	4	L	35	-(R) Between former two effects - OK but not great.
	3	P	10	-(R) No high
	1	C	-	

[a]where 0 - "the worst (weakest) grass I ever had," and
100 - "the best (strongest) grass I ever had."

[b]Test day - The occasion on which each condition was administered. Important because many subjects described their reactions relative to how they felt on previous test occasions.

[c]Letters in brackets (I), (T), (R) indicate comments were made, respectively, in the Intake, Testing, or Recovery rooms.

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
5	5	VH	90	-(R) Riproaring high - very much more than a social stone.
	3	H	85	-(I) High, good grass. (R) Really wiped - great grass.
	4	L	75	-(I) Quite relaxed - pretty well wiped. (R) Less than last time, but still a pretty good stone.
	1	P	70	-(R) Pleasantly high.
	2	C	-	
6	5	VH	55	-(R) Really pleasant - good social stone - not really ripped.
	2	H	0	-(I) Tough to smoke. (R) No high - bitter taste - I think I got a placebo.
	1	L	65	-(R) Good grass - I would refuse any more.
	3	P	65	-(I) Relaxed. (R) Light but nice - came on fast.
	4	C	-	
7	5	VH	60	-(I) One joint is really enough. (R) Good grass - much better than last time.
	2	H	35	-(I) High - good grass. (R) Slow, subtle, weak, easy to come down. (Later reported that he got high on way home.)
	3	L	40	-(I) Pleasantly high. (R) Better than before - good social stone - very relaxed - almost floating.
	4	P	20	-(R) Poor - enjoyable but not very strong.
	1	C	-	
8	1	H	40	-(R) Enjoyable experience.
	2	L	65	-(R) Good social stone - higher than last week.
	4	P	20	-(I) Higher on two previous occasions. (R) Not exactly nothing - but not much.
	3	C	-	
9	1	H	80	-(R) Pleasantly high.
	3	L	90	-(I) Best yet. (R) Slow but very good - really high.
	2	P	85	-(R) Social high - better than last week.
	4	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
10	4	H	90	-(R) Very good - quick stone - heavy abstraction - seeing meaning in things.
	2	L	55	-(R) Relaxed - sleepy - I have a cold.
	1	P	55	-(R) Very relaxed - quiet - content - abstraction - facts not important.
	3	C	-	
11	1	H	65	-(I) Air conditioner bothers me. (R) Speech hesitant (not obvious to E).
	3	L	10	-(R) No effect - taste was putrid.
	4	P	40	-(I) Relaxed - slight effect. (R) Very light stone - very relaxed.
	2	C	-	
12	4	H	25	-(R) Very low high - just got relaxed.
	3	L	30	-(I) Relaxed pleasant feeling. (R) High - got more than last time.
	2	P	40	-(I) Some effect - equivalent of one joint. (R) Very nice - mellow to heavy stone.
	1	C	-	
13	3	H	70	-(I) Pleasantly high. (R) Feel tired so did not feel as good as last time - but good grass.
	2	L	70	-(I) Lose my train of thought. (R) Great!
	1	P	30	-(R) Grass was harsh - little effect.
	4	C	-	
14	3	H	70	-(I) High - good grass. (R) Came on slowly, then it was really good grass.
	1	L	60	-(I) Good grass. (T) I'm pretty stoned. (R) Quick - good high - long-lasting.
	4	P	80	-(I) A heavy stone. (R) Good dope - got quite giddy - best yet.
	2	C	-	
15	1	H	40	-(R) Smooth easy high.
	2	L	5	-(R) Very little high - just a bit at the beginning.
	3	P	0	-(R) A bummer - nothing.
	4	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
16	4	H	80	-(R) Got the maximum this time - both head and body stone.
	2	L	30	-(R) Light stone - floaty feeling - relaxed feeling helps in doing tests.
	3	P	5	-(R) Very light - almost no effect.
	1	C	-	
17	5	VH	65	-(R) Got pretty stoned - more than last time after only one joint.
	4	H	75	-(R) Pretty good - a fine stone.
	1	L	45	-(R) Low smooth high - no rush.
	2	P	55	-(I) Higher than last time. (R) A little better than last time - not yet a social stone.
	3	C	-	
18	1	H	85	-(R) A very good high.
	4	L	75	-(R) Nice and gradual, and then wham - second best of three
	2	P	15	-(R) Not much - less than last week.
	3	C	-	
19	1	H	70	-(R) Light easy high - typical grass high.
	4	L	60	-(R) Milder than last time - an OK stone just about down the middle.
	3	P	40	-(R) Not as ripped as first time - quite mild.
	2	C	-	
20	3	H	50	-(R) Less than a social stone but not bad.
	1	L	80	-(I) Pleasant effect. (R) Subtle, did not notice till I quit then surprised by a very good high.
	2	P	10	-(I) Less effect than last time. (R) Very light if any at all.
	4	C	-	
21	2	H	60	-(I) More effect than last time - don't like grass. (T) More stoned than last time. (R) Less effect - not really stoned.
	1	L	60	-(I) Grass is poor. (T) Stone is great. (R) Grass is no good - worse than usual high - slow gradual effect.
	4	P	55	-(R) As good as second dose, but not as good as first - I am not really stoned.
	3	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
22	5	VH	90	-(R) Got very stoned - second strongest I ever had - didn't want any more.
	4	H	90	-(R) Good high - best yet - a mind high - got insight into things.
	3	L	80	-(I) Good grass. (R) Reasonably stoned - good stuff.
	1	P	5	-(T) Did not get high. (R) Almost no high- very low dose - little effect.
	2	C	-	
23	3	H	98	-(I) Relaxed high. (R) Great! - perceptual enhancement of all stimuli.
	4	L	45	-(R) Not as good as last time - an early rush that's all - pleasant body sensation.
	2	P	20	-(I) Little effect, have had better. (R) Just a little light-headed and relaxed.
	1	C	-	
24	2	H	70	-(I) Relaxed - high. (R) A nice stone - last week's was stronger.
	3	L	70	-(R) Above average.
	1	P	40	-(R) Very little effect - mostly relaxation - one or two dissociation rushes.
	4	C	-	
25	5	VH	80	-(I) Quite considerably stoned. (R) So happy after first joint I wouldn't have asked for more.
	3	H	80	-(I) Highest I've ever been on dope. (R) Really good stone - a couple of rushes - forgot about time on the tests.
	2	L	60	-(I) Enjoyable - pleasant effect - time perception affected. (R) Really good stuff - nice social high.
	4	P	20	-(R) Low social high - nothing much happened.
	1	C	-	
26	4	H	40	-(R) Had a very tough day - grass relieved the tension, but didn't get high.
	1	L	40	-(I) Slight effect - have had better grass. (R) Light, smooth, no rush - less than usual.
	2	P	10	-(R) Very little effect.
	3	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
27	4	H	40	-(R) Enough to make tests bearable.
	2	L	40	-(I) Terrible ghastly dope - terrible music - little effect. (R) Terrible grass.
	3	P	20	-(T) Poor pot - I feel pissed off. (R) terrible!
	1	C	-	
28	3	H	80	-(R) Really good stone - up very quickly - started to come down while doing tests.
	1	L	40	-(R) Nice stone - social high - good start, but not very strong.
	4	P	5	-(R) I would have complained to the pusher if I had bought it.
	2	C	-	
29	2	H	65	-(I) High, happy, relaxed. (R) Very nice light high - a little less than usual social stone.
	4	L	70	-(R) Fast, gentle - time distortion.
	3	P	10	-(I) Very light effect. (R) Very little.
	1	C	-	
30	5	VH	60	-(R) Definitely up - as high as I typically get, or more - a comfortable high.
	1	H	80	-(I) I'm stoned. (T) I'm really high. (R) Strange, subtle at first - second room really set me off.
	4	L	40	-(R) Usual medium high - got off on drawings.
	2	P	10	-(T) Grass was poor - I'm not stoned at all. (R) Didn't get off.
	3	C	-	
31	1	H	40	-(I) I've tasted better grass. (R) No high at all - that's normal for me.
	2	L	30	-(R) Did not get high.
	4	P	0	-(R) No effect. (Subject later reported, "It hit me after I got back to the office.")
	3	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
32	1	H	50	-(I) Distortion of time - relaxed stone - slightly less than usual. (R) Slow - crept up to an OK high.
	3	L	5	-(R) How good was it? - It wasn't!
	4	P	0	-(R) Nothing at all.
	2	C	-	
33	4	H	75	-(R) Really good grass - I'm not into drawing - got involved in tests - mostly just very relaxed.
	3	L	65	-(I) A little better than first time. (R) Nice social stone.
	1	P	55	-(I) Relaxed, pleasant. (R) Comfortable - less than usual.
	2	C	-	
34	2	H	70	-(R) Pretty good social high.
	4	L	10	-(R) Seems like nothing, but I'm not sure.
	1	P	50	-(R) Mild, not too strong. (Later reported got high while going home in taxi - said he should have given a higher rating.)
	3	C	-	
35	5	VH	85	-(R) Quite thoroughly stoned - a lot more than last time.
	4	H	40	-(R) It produced an effect but that's all - fairly good - relaxed.
	1	L	35	-(R) Slow - very little effect.
	3	P	0	-(R) Camel dung!
	2	C		
36	5	VH	65	-(R) Good -a bit more than a social stone - I feel others could tell I was stoned.
	1	H	70	-(I) Anxious - dry mouth - photo sensitive - slight nausea. (R) A good high - physical reactions first - then OK.
	3	L	40	-(R) Pleasant - a party high - can still function - but feels good.
	2	P	5	-(R) Light effect for 2 or 3 minutes - otherwise nothing.
	4	C	-	

Subj. no.	Test day	Dose	Self-rating	Subjects' Comments
37	3	H	80	-(R) Good, but not as good as last time.
	2	L	75	-(I) Higher than last time. (R) Really nice - came on fast - feel really stoned.
	1	P	55	-(R) OK - mild - do not feel too high.
	4	C	-	
38	2	H	60	-(I) Pleasantly high - relaxed. (R) Came on quietly - nice social high.
	1	L	50	-(R) Good high - not enough to really fly - good grass. (Later reported, "Really got high after I went home.")
	4	P	40	-(R) Pleasant quiet stone - feels good, but it's not strong.
	3	C		
39	4	H	65	-(R) Between the other two - better than average high.
	3	L	75	-(R) A reasonable stone - heavier than last time.
	2	P	40	-(R) A good high after 3 to 5 tokes - having to smoke all of it was a downer - would have stopped at a social high after a few tokes.
	1	C	-	
40	2	H	100	-(I) Relaxed happy high. (R) Quicker than last time - best high I ever had.
	1	L	could not say	-(T) I feel high. (R) This is the third time I ever smoked - best high ever.
	3	P	0	-(R) Felt no effect.
	4	C	-	

APPENDIX 6

HEART-PULSE RATES, BEFORE AND AFTER SMOKING MARIJUANA AT FOUR DOSAGE LEVELS, AND UNDER A CONTROL (NO-DRUG) CONDITION

APPENDIX 6

HEART-PULSE RATES, BEFORE AND AFTER SMOKING MARIJUANA AT FOUR DOSAGE LEVELS, AND UNDER A CONTROL (NO-DRUG) CONDITION

	Dosage Levels														
	Very High			High			Low			Placebo			Control		
Subj.	B	A	C[a]	B	A	C	B	A	C	B	A	C	B	A	C
1				64	88	24	88	96	8	72	76	4	68	76	8
2				68	88	20	84	80	-4	72	72	0			
3				68	96	28	84	106	22	104	104	0	96	80	-16
4	64	104	40	88	104	16	80	76	-4	80	84	4			
5	92	104	12	92	104	12	80	88	8	80	80	0	76	76	0
6	100	96	-4	80	72	-8	84	96	12	92	80	-12	80	80	0
7	76	144	68	100	116	16	76	92	16	76	82	6			
8				96	128	32	108	120	12	94	94	0	72	88	16
9				60	68	8	72	100	28	60	80	20	92	84	-8
10				76	88	12	96	92	-4	84	92	8	80	84	4
11				92	104	12	88	112	24	92	88	-4	80	84	4
12				76	88	12	60	68	8	80	72	-8			
13				72	100	28	72	96	24	76	72	-4	92	72	-20
14				60	88	28	72	96	24	62	64	2	60	64	2
15				84	124	40	84	96	12	72	84	12	76	80	4
16				96	112	16	100	116	16	88	96	8			
17	100	140	40	76	100	24	96	100	4	92	92	0	92	80	-12
18				85	100	15	68	92	24	92	76	-16	76	80	4
19				68	112	44	62	68	6	74	76	2	68	68	0
20				100	116	16	88	120	32	80	80	0	70	76	6
21				88	84	-4	68	82	14	72	68	-4	76	76	0
22	80	96	16	88	96	8	72	88	16	76	68	-8	54	56	2
23				80	92	12	68	70	2	88	76	-12			
24				60	80	20	80	72	-8	84	88	4	78	80	2

[a]where A = After
B = Before
C = Change

	Dosage Levels														
	Very High			High			Low			Placebo			Control		
Subj.	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C
25	76	104	28	72	88	16	68	76	8	72	72	0			
26				72	88	16	68	88	20	84	100	16	64	82	18
27				80	88	8	108	128	20	84	94	10			
28				104	144	40	96	112	16	96	86	-10	104	96	-8
29				58	100	42	84	104	20	72	88	16			
30	72	84	12	68	92	24	76	84	8	72	80	8	80	76	-4
31				84	84	0	96	88	-8	84	84	0	96	80	-16
32				108	140	32	120	116	-4	88	96	8	80	92	12
33				80	76	-4	76	68	-8	56	62	12	56	56	0
34				94	92	-2	96	108	12	80	88	8	72	72	0
35	108	128	20	96	104	8	108	130	22	108	104	-4	96	92	-4
36	80	108	28	96	120	24	99	112	13	88	96	8	92	80	-12
37				100	120	20	96	124	28	108	100	-8			
38				96	104	8	104	96	-8	76	88	12	88	84	-4
39				68	92	24	84	96	12	88	76	-12			
40				92	116	24	100	124	24	88	80	-8	100	76	-24
N	10			40			40			40			29		
M	B	84.80		B	82.13		B	95.23		B	82.15		B	79.40	
	A	110.80		A	99.90		A	96.90		A	83.45		A	78.28	
	C	26.00		C	17.77		C	11.67		C	1.30		C	-1.12	
σ	B	13.60		B	13.63		B	14.29		B	11.51		B	12.92	
	A	18.25		A	17.00		A	12.38		A	10.65		A	9.03	
	C	18.95		C	12.47		C	11.17		C	8.62		C	10.14	

APPENDIX 7

SCORES ON STRUCTURE OF INTELLECT TESTS AND DIGIT SPAN TEST

SCORES ON STRUCTURE OF INTELLECT TESTS AND DIGIT SPAN TEST

Very High Dose

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal. III	Digit Span Forward	Digit Span Reverse
4	5	14	2.3	8	3	8	9	5	4
5	5	14	20	11	7	15	7	8	5
6	5	15	2.3	6	3	8	6	8	6
7	5	15	13.3	4	4	6	10	8	5
17	5	14	5.3	10	9	5	8	6	3
22	5	13	5	8	4	6	5	9	7
25	5	14	11	10	8	6	5	9	8
30	5	12	13.3	16	9	15	5	8	7
35	5	14	9.6	13	9	15	9	9	4
36	5	13	9.3	7	5	11	7	6	6
M		13.8	9.14	9.4	6.1	9.5	7.1	7.6	5.5
σ		0.87	5.31	3.29	2.43	3.93	1.76	1.36	1.5

High Dose

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
1	4	15	8.3	8	7	13	5	8	7
2	3	14	13	7	1	10	7	7	7
3	2	13	9.3	10	5	4	5	5	5
4	2	14	3.6	4	4	10	4	5	4
5	3	13	18.6	7	9	13	8	7	5
6	2	15	0	8	3	7	6	8	3
7	2	14	9.6	5	8	10	8	7	6
8	1	14	8.3	6	8	12	8		
9	1	13	11	7	5	8	10		
10	4	15	5.3	7	4	10	8	6	5
11	1	12	5.6	7	4	13	9		
12	4	15	11.6	3	4	8	8	8	4
13	3	14	14	6	4	12	5	9	8
14	3	14	9.3	13	6	10	7	9	8
15	1	12	4.6	5	2	7	9		
16	4	15	3.6	13	4	11	8	9	6
17	4	14	10.6	8	7	12	6	6	3
18	1	13	15.3	8	2	5	5		
19	1	13	10.6	12	4	9	7		
20	3	12	13.6	6	4	9	8	7	6
21	2	14	6.3	4	2	6	5	9	4
22	4	13	8	6	6	10	5	7	7
23	3	13	8.3	6	8	10	7	6	3
24	2	14	9	8	6	10	9	7	7

High Dose (Cont'd.)

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
25	3	14	15	9	7	10	5	9	7
26	4	14	12	10	3	12	6	9	8
27	4	13	11.6	6	7	12	6	8	5
28	3	15	8.6	5	7	8	7	9	7
29	2	15	11.6	7	8	10	8	6	5
30	1	12	2.6	9	5	3	8		
31	1	14	4	11	8	8	8	5	7
32	1	11	13.3	9	6	10	8	6	5
33	4	14	3.6	9	0	12	8	9	6
34	2	13	6	13	6	13	8	9	7
35	4	14	12	12	10	15	8	9	8
36	1	9	4.3	7	0	12	8	6	5
37	3	15	10.6	10	7	9	5	8	5
38	2	14	5.3	6	3	6	8	8	7
39	4	15	3.3	11	5	11	6	9	6
40	2	14	7.3	9	4	7	7	8	5
M		13.60	8.71	7.93	4.93	9.68	7.03	7.52	5.24
σ		1.24	4.08	2.55	2.39	2.62	1.44	7.37	1.46

Low Dose

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
1	1	14	6.3	5	4	7	8		
2	2	15	11.6	5	7	9	6	6	6
3	4	11	5.3	9	7	5	6	7	5
4	4	14	7.3	8	3	9	8	5	6
5	4	14	20	14	4	15	8	8	7
6	1	14	0.6	10	7	4	9		
7	3	12	14.6	5	4	9	9	7	7
8	2	15	8	7	5	13	7	5	5
9	3	13	12	10	9	10	8	7	6
10	2	15	7	7	6	6	9	8	4
11	3	14	2.6	8	5	15	8	8	8
12	3	13	6	3	6	5	5	8	4
13	2	13	7.6	12	8	9	9	9	8
14	1	15	12	13	6	9	8		
15	2	12	11	3	4	6	8	6	7
16	2	13	6.3	11	1	6	8	9	8
17	1	14	11.3	8	9	6	8		
18	4	12	8	8	6	3	6	8	7
19	4	14	11.3	12	8	8	9	9	8
20	1	13	9.3	5	2	7	8		
21	1	14	8	6	5	10	7		
22	3	15	12	10	4	12	5	9	6
23	4	15	18.6	8	5	10	7	6	4
24	3	12	14.3	9	6	13	8	7	6

Low Dose (Cont'd.)

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Annal.III	Digit Span Forward	Digit Span Reverse
25	2	13	17.3	9	4	12	10	9	8
26	1	15	11	12	3	14	9		
27	2	11	11.3	7	5	10	7	7	4
28	1	15	11	8	7	7	7		
29	4	13	13.3	6	9	11	8	8	6
30	4	13	4	11	4	8	7	7	7
31	2	13	4.3	10	3	8	7	6	7
32	3	14	17.3	6	7	4	7	7	7
33	3	14	6.3	11	6	8	8	8	5
34	4	12	14.6	11	6	14	8	7	8
35	1	14	16	11	7	14	9	7	7
36	3	12	10.6	12	1	12	8	6	6
37	2	14	12.6	10	6	13	9	8	5
38	1	12	7	7	2	10	8	8	6
39	3	11	5.6	11	8	4	5	9	6
40	1	11	5.6	8	5	9	6	8	5
M		13.33	9.97	8.65	5.35	9.10	7.63	7.40	6.19
σ		1.25	4.45	2.68	2.07	3.26	1.20	2.16	1.28

Placebo

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb Anal.III	Digit Span Forward	Digit Span Reverse
1	3	14	6.6	6	6	9	8	8	8
2	4	14	16	7	6	7	7	8	7
3	1	11	2.3	8	3	5	8		
4	3	14	7	8	8	10	8	7	7
5	1	12	12	8	8	12	9		
6	3	14	5.6	9	8	6	9	8	8
7	4	14	10	6	9	10	9	7	7
8	4	14	9.3	10	5	13	9	5	4
9	2	15	10.6	9	9	11	8	6	5
10	1	14	8.3	6	1	6	7		
11	4	14	2.6	7	6	15	9	9	8
12	2	15	13.3	6	7	6	9	6	4
13	1	14	17	9	3	12	7		
14	4	14	10.6	13	8	12	8	9	7
15	3	10	6	8	6	10	8	6	6
16	3	15	7.6	7	6	7	7	9	7
17	2	14	9	5	4	7	6	5	3
18	2	15	11.6	6	5	4	6	7	8
19	3	14	14.6	12	5	12	6	8	7
20	2	14	14.6	9	8	10	9	8	7
21	4	15	6.6	4	3	6	7	9	5
22	1	14	5.6	9	0	10	10		
23	2	15	14.6	8	4	11	6	5	3
24	1	14	12.3	10	7	10	7		

Placebo (Cont'd.)

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
25	4	14	18.6	12	7	6	10	9	8
26	2	14	10.6	7	4	12	7	9	7
27	3	14	14.3	9	8	10	8	7	4
28	4	13	10	8	3	8	10	9	7
29	3	13	8.3	15	5	11	9	6	6
30	2	14	9.3	6	9	8	6	9	6
31	4	14	3.6	10	3	7	4	6	6
32	4	12	12	6	3	8	8	5	5
33	1	11	13.3	9	6	10	8	9	5
34	1	14	8	7	5	12	9	9	6
35	3	14	13.3	9	7	15	8	9	8
36	2	12	6.6	8	4	10	8	7	5
37	1	15	13.3	9	4	9	6	9	5
38	4	13	16.6	9	7	10	7	8	6
39	2	14	4.6	9	7	9	5	9	8
40	3	14	8	10	5	12	7	9	6
M		13.70	10.10	8.33	5.55	9.45	7.68	7.62	6.15
σ		1.14	4.03	2.16	2.18	2.60	1.37	1.46	1.48

Control (No Drug)

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
1	2	15	7.3	8	5	10	8	7	6
2	1	13	8	7	0	5	8		
3	3	11	13	7	4	6	8	7	6
4	1	15	6	8	6	6	6		
5	2	13	18.6	11	4	11	7	5	4
6	4	14	3	6	4	9	5	9	8
7	1	12	18.6	8	6	6	9		
8	3	14	13.6	10	3	12	9	5	7
9	4	15	7.6	8	9	11	7	7	6
10	3	14	6.3	9	4	7	7	7	3
11	2	14	4	8	5	14	8	8	7
12	1	15	9	9	3	3	3		
13	4	14	k0.6	5	8	10	9	9	8
14	2	14	14.6	11	5	12	6	7	4
15	4	14	3.3	4	6	8	8	7	7
16	1	15	6.3	7	6	3	9		
17	3	14	8	9	9	9	9	5	3
18	3	14	3.6	7	6	5	9	7	7
19	2	13	14.6	9	8	6	9	8	7
20	4	14	12.3	8	7	11	8	9	8
21	3	15	5.3	7	8	12	8	9	5
22	2	13	9	7	8	7	6	9	6
23	1	14	9.3	7	6	6	7		
24	4	13	11	8	8	13	8	8	6

Control (No Drug) (Cont'd.)

Subj.	Test day	CMR Word Link.	MMR Remem. Rels.	DMR Assoc. Flu. I	NMR P-W Rels.	NMR Assoc. III	EMR Verb. Anal.III	Digit Span Forward	Digit Span Reverse
25	1	13	14.6	6	8	11	7		
26	3	15	10.6	15	0	15	8	8	8
27	1	14	8	8	7	11	7		
28	2	13	8	8	3	7	9	9	7
29	1	13	13	8	3	9	7		
30	3	13	7.3	11	5	8	7	8	7
31	3	15	7	11	8	9	6	7	6
32	2	11	14.6	7	2	5	8	6	7
33	2	14	13.3	10	1	11	6	9	8
34	3	12	8	7	6	11	9	7	6
35	2	14	9.3	9	10	12	10	9	5
36	4	14	12.6	8	4	12	8	7	7
37	4	14	16	8	7	13	9	8	5
38	3	14	15	7	4	8	9	8	6
39	1	11	6.6	7	6	5	8	9	5
40	4	13	6	11	8	10	8	9	6
M		13.62	9.82	8.23	5.50	8.98	7.68	7.65	6.16
		1.09	4.07	1.93	2.43	3.02	1.35	1.25	1.39

APPENDIX 8

SCORES ON OTIS SELF ADMINISTERING TEST OF MENTAL ABILITY, HIGHER EXAMINATION, FORMS A AND B, 20-MINUTE TIME LIMIT

APPENDIX 8

SCORES ON OTIS SELF ADMINISTERING TEST OF MENTAL ABILITY, HIGHER EXAMINATION, FORMS A AND B, 20-MINUTE TIME LIMIT

	Form A (No Drug)			Form B (High Dose)		
Subj.	Attempted	Correct	IQ	Attempted	Correct	IQ
1	58	55	125	62	57	126
2	59	57	126	58	53	123
3	47	44	114	45	43	113
4	63	61	129	55	44	114
5	66	60	128			
6	61	54	124	70	64	130
7	75	66	131			
8	58	57	126	65	61	129
9	66	57	126	74	66	131
10	51	49	120	58	53	123
11	73	69	132			
12	56	48	119			
13	75	71	133	67	61	129
14	49	40	109	55	45	116
15	67	51	122	69	45	116
16	59	55	125	54	52	122
17	58	53	123	58	45	116
18	75	55	125			
19	60	56	126	46	43	113
20	74	68	132	74	67	132
21	49	45	116			
22	42	42	112	37	28	94
23	56	52	122	61	50	121
24	74	73	133	74	66	131
25	72	66	131	75	61	129
26	71	69	132	75	66	131
27	62	52	122	61	52	122
28	48	43	113	61	51	122

Subj.	Form A (No Drug) Attempted	Correct	IQ	Form B (High Dose) Attempted	Correct	IQ
29	56	48	119	63	54	124
30	42	41	111	47	45	116
31	50	42	112	57	55	125
32	75	71	133	59	47	118
33	71	63	130	75	61	129
34	72	67	132	65	60	128
35	75	69	132			
36	59	57	126	63	49	120
37	72	70	133	68	60	128
38	64	61	129	61	56	126
39	66	55	125			
40	53	43	113			
N = 31:						
M	61.00	56.29	124.19	61.68	53.55	122.48
σ	9.69	9.73	7.25	9.46	8.85	7.81
N = 40:						
M	61.98	56.37	124.28			
σ	9.86	9.68	7.13			