EFFECTS OF DRUG DEPENDENCE ON MEMORY PROCESSING

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CHAPTER I

INTRODUCTION

For most of the twentieth century, drug dependence has been a persistent, although fluctuating problem. Except for the late years of the great depression and the periods during the two world wars, the number of drug dependent people has been sufficient to attract national attention. In the past five years, the drug problem has begun to approach the significance it achieved at the turn of the century when the first narcotics laws were passed (Drug Takers, 1965). When any social problem reaches such proportions, the government and society react in predictable fashion with outpourings of publicity and concern. In some instances there may even be a considerable outpouring of money in order to stem the tide. Such has been the case in recent years with drug abuse.

In the last twenty-five years there appears to have been a neglect of research investigating the capabilities of drug dependent individuals in the area of cognitive processing. During the late 1930's and early 1940's several researchers (Dimmick, 1938; Spragg, 1940; Brown and Partington, 1942; Partington, 1940; Brown, 1946) studied several facets of drug dependence. These included intelligence, incidence of psychosis, intelligence and potential for addiction, and the presence of mental deterioration. In general, their conclusions showed few significant differences between the drug dependent and control subjects.

Today, in light of new theoretical developments and invention of more sensitive indicators of cognitive abilities, research in this area deserves new attention. An important theoretical development has been the postulation of two types of memory processing (Adams, 1967). A short duration, limited capacity, short-term memory, and a memory of much larger capacity and longer duration called long-term memory. This concept utilization also included the assumption that items in long-term memory have been transferred there from short-term memory. Any impairment in this transfer process will presumably result in memory difficulties, thus impairing learning ability. This is probably what happens in cases involving certain lesions of the mammillary bodies, bilateral lesions of the hippocampus, Korsakoff's syndrome, head injuries, brain tumors, and some psychotic syndromes (Barbizet, 1963). Medically this is referred to as anterograde amnesia, without marked retrograde amnesia, although the longer the situation exists the more reterograde amnesia will occur. Patients are able to remember previously learned skills, but are unable to acquire new skills, because of the inability to transfer items into long-term memory from short-term memory.

The possibility exists that much of the difficulty experienced by drug dependents in acquiring new work and social skills might be explained by memory difficulties. The learning of most skilled tasks will involve a combination of the transfer of new input from the short-term memory to the long-term memory, as well as the retention of previously presented material (Posner, 1966). The development of an experiment to investigate the relation between short-term memory and the transfer of information to long-term memory provides a means of determining if some learning deficiencies exist with drug dependent

persons. / The implication of drugs as a causal factor in the interruption of this process could be viewed in the following way. The use of drugs might result in a poor orienting response. Memory deficiencies would be present if the orienting response didn't occur or if it does not adapt, because the ability to attend to new stimuli would be impaired in the former case, or the stimulus cannot be selectively attended to in the latter case. There is also the possibility that a decrement in the level of arousal develops after a cycle of drug dependence. This could be linked with the individual's hyper-emotional state, which is a usual condition found after a prolonged use of drugs.

The experimental design of the present study was to determine whether or not differences exist between previously drug dependent individuals and non-drug dependents in short-term memory processing and the transfer of material to long-term memory. The design was derived from experiments previously developed by Sternberg (1969) and Sanders (1961). The high-speed scanning process in short-term memory using reaction time as the response measure was examined first. This was done by loading up the short-term memory with varying lists of digits (1, 4, or 7) and probing these lists with a positive or negative probe (see page 25) a short time later. The subjects' reaction time response to the probe decision was the response measure used to examine the short-term memory process. Immediately following the probe, the varied-set lists (lists were always different) were signalled for recall at either a 0-second rehearsal or 20-seconds rehearsal period. Using the proportion of digits incorrectly recalled as a response measure in this task, it was possible to get an idea of the transfer rate from short-term memory to long-term memory. In addition, some of the 20-

second rehearsal periods contained an interference task, which enabled the examination of the effects of interference on recall rates.

In brief summary, with this type of design the drug dependent and non-drug dependent were compared on several variables: (a) the time taken to encode the stimulus items, (b) short-term memory processing time, (c) proportion of items correctly recalled, (d) and the effects of interference on the items recalled.

Drug Dependence

Attempts to find a universally acceptable definition of addiction have for a number of years occupied many meetings and conferences. Arguments have often centered over the attempts to differentiate addiction from habituation, and psychological (psychic) from physical dependence. Further problems arose, because as new drugs and compounds were introduced their effects would not fit the terminology due to unique pharmacological profiles. Also, well known drugs seemed to develop changing patterns (Eddy, Halbach, Isbell, Seevers, 1965).

In 1964, the World Health Organization (WHO) committee on addiction producing drugs (1964, 13th Report) recommended the substitution of the term "drug dependence" for both of the terms drug habituation and drug addiction. A drug dependent person would be in a state of psychological or physical dependence or both following repeated administration of a drug on a periodic or continuous basis (Drug Takers, 1965). The characteristics of such a state could vary according to the agent involved. So, in the classification of drug dependence one refers to dependence of the morphine type, amphetamine type, barbiturate type, etc.

Psychological dependence implies a strong desire, drive or compulsion to continue taking a drug or chemical substance either for pleasure or to avoid some discomfort. Psychological dependence is sometimes evidenced by such intense drives that it persists even when there are no known physiological effects from the drug administered.

Physical dependence usually implies an adaptive state characterized by intense physical disturbances when administration of the drug is either discontinued or counteracted by a specific antagonist.

Drug Dependence of the Morphine Type

The subjects (Ss) used in this experiment classified as drug dependent did not clearly fall into one type of drug dependence. They would be more clearly classified as multiple drug users or poly-users. However, it was still possible to find two drugs that were fairly dominant in the drug dependents' past drug history. One drug which had been used by all of the Ss in the experimental group was meth-amphetamine (Methedrine) and will be described in the section on drug dependence of the amphetamine type. The second drug, which was used by about one-half of the Ss was heroin, an opiate, and is described in this section.

In 1964, in conjunction with the new definition of drug dependence, the World Health Organization Scientific Group on Evaluation of Dependence-Producing Drugs reported the following characteristics of dependence of the morphine type:

(a) Strong psychological dependence, which manifests itself as an overpowering drive (compulsion) to continue taking the drug and to obtain it by any means for pleasure or to avoid discomfort;

(b) Development of tolerance, which requires an increase in dose to maintain the initial pharmacodynamic effect;

(c) An early development of physical dependence, which increases in intensity, paralleling the increase in dosage. This requires a continuation of drug administration in order to prevent the appearance of the symptoms and signs of withdrawal; withdrawal of the drug, or the administration of a specific antagonist precipitates a definite, characteristic and self-limiting abstinence syndrome (WHO Scientific Group on the Evaluation of Dependence Producing Drugs, 1964).

With morphine or other opiate derivatives or synthetics (heroin, meperidrine, methadone, codeine, hydromorphone, et cetera) the abstinence syndrome appears within a few hours after the last administration of drug and usually subsides in 7-14 days, with the peak intensity of the syndrome occurring between 48 and 72 hours (Vogel, 1967). This is referred to as the acute withdrawal phase, as actual physiological changes persist for months longer but are not so overtly displayed. The time, onset, peak intensity, and the duration vary with the degree of dependence on the drug, as well as the type of drug used. Use of a morphine antagonist (nalorphine) will almost immediately precipitate the abstinence syndrome, which in this case is more intense but of shorter duration.

Clinically, abrupt withdrawal results in distinct changes of all major areas of nervous activity. General behavior is altered distinctly, and both divisions of the autonomic nervous system are excited simultaneously. Some of the signs and symptoms include: anxiety, restless-

ness, insomnia, yawning, lacrimation (tears), rhinorrhoea (runny nose), perspiration, mydriasis (dilation of the pupil), piloerection, hot flashes, nausea, emesis (vomiting), diarrhoea, elevation of body temperature, respiratory rate and systolic blood pressure (Isbell and White, 1953).

Recent evidence (Eisenman, 1967; Wikler, 1967; Eisenman, Sloan, Martin, Jasinski, Brooks, 1969; Martin and Jasinski, 1969) indicates that individuals need much longer than the seven to fourteen days of detoxification to regain the pre-drug dependent physical status. Martin and Jasinski (1969) feel that on the basis of physiological changes the morphine abstinence syndrome consists of two distinct phases: an early phase, and a secondary phase. The early phase, or primary abstinence is characterized by increased blood pressure, pulse rate, body temperature, and sensitivity of the respiratory center to CO_2 (carbon dioxide). The secondary phase, or protracted abstinence syndrome, is marked by decreased blood pressure, pulse rate, body temperature, and sensitivity of the respiratory center to CO_2. All measurements were based on pre-dependence levels, and the transition between primary abstinence and protracted abstinence took place from six to nine weeks after complete withdrawal of administration of morphine. The secondary phase can last up to 30 weeks for some signs, but the average is about 20 weeks.

In Martin and Jasinski's (1969) experiments, the acute phase of withdrawal was not so pronounced because the Ss were gradually withdrawn from their dependence on morphine, thus eliminating many of the symptoms present in abrupt withdrawal. A previously cited study (Eisenman et al., 1969) reported increased urinary epinephrine levels

at 7, 17, and 24 weeks after withdrawal in human Ss. This seems to be the reverse of what would be expected from Martin and Jasinski's (1969) results, unless the body has adapted to the increased catecholamine secretion during protracted abstinence. Unfortunately, evidence supporting increased catecholamine excretion as indicative of signs of abstinence and hyperactivity in man has not been demonstrated (Eisenman et al., 1969). The difference in results may be due to the higher doses of morphine used to induce drug dependence in animals.

Obviously, the post-withdrawal period after use of morphine in man is represented by several distinct physiological and psychological changes and suggests the possibility of either permanent or temporary changes in the general operational level of post-drug dependents. This might be manifested by changes in the memory processing abilities of these individuals.

Drug Dependence of the Amphetamine Type

Unlike the previous drug implicated in a type of dependence (morphine), which is classified as a central nervous system (CNS) depressant, amphetamine-type drugs are called CNS stimulants. These drugs include amphetamine, d-amphetamine sulfate, and methamphetamine hydrochloride (Methedrine). Administration of the drug results in both peripheral and central nervous system changes. Prominent among the peripheral changes are increases in blood pressure, heart rate, pupillary dilation and other sympathetic nervous system (SNS) effects. Amphetamines are often referred to as sympathomimetics, because they mimic sympathetic-like stimulation. The marked and consistent CNS effect is production of a state of arousal or wakefulness. This is

probably due to direct stimulation of the midbrain reticular formation (Kalant, 1966). The reticular formation has also been implicated as the locus for the facilitation of sensory perception that is reported by many users of amphetamines. In some cases, these effects are reported as hallucinations (Kalant, 1966).

It is the central stimulatory effects of the drug which probably lead to its abuse, as the reported subjective effects of such stimulation include increased self-confidence, better decision making, and feelings of well being and euphoria. It is in these latter two effects that the drug becomes very similar to the subjective effects produced by morphine and other opiates. The usual route of administration for meth-amphetamine abusers is the intravenous route, which is also the preferred route of many opiate users. However, with some amphetamine users, the oral route and even the subcutaneous route is preferred.

The World Health Organization Expert Committee has described drug dependence of the amphetamine type as follows:

(a) A desire or need to continue taking the drug;

(b) Consumption of increasing amounts to obtain greater excitatory and euphoric effects or to combat fatigue, accompanied in some measure by the development of tolerance;

(c) A psychic dependence on the effects of the drug related to a subjective and individual appreciation of the drug's effects; and

(d) General absence of physical dependence so that there is no characteristic syndrome of abstinence

when the drug is discontinued (WHO Expert Committee on Addiction-producing Drugs, 1964).

The important difference between morphine-type drug dependence and amphetamine-type is the lack of physical dependence and a clear characteristic withdrawal syndrome in amphetamine-type dependence. However, it would be inaccurate to state that withdrawal from very large doses or prolonged use of amphetamines is not without noticeable symptoms. Most frequently reported are instances of depression and disruption of sleep patterns. Oswald and Thacore (1963) studied withdrawal of amphetamines in six women patients. They reported disruption of nocturnal sleep patterns which disappeared immediately if the drugs were readministered, or if the drugs were not taken again for a period of 3-8 weeks. Overall, amphetamine withdrawal does occur, but it does not compare in magnitude with the symptoms that occur in morphine, barbiturates, alcohol, and other drugs that create physical dependence. Withdrawal of drugs of the amphetamine type is never threatening to life and requires psychological rather than physical therapy (Eddy et al., 1965).

Kalant (1966) offers an interesting suggestion for the marked difference in withdrawal syndromes between morphine and amphetamines, suggesting there are two points that should be taken into consideration. First of all, the base line for withdrawal is the morphine type syndrome which occurs very abruptly and overtly, with many obvious external symptoms. This may very well be the most extreme type of withdrawal syndrome, and other drugs may have withdrawal syndromes where the effects are more internal and less obvious. Amphetamine withdrawal may be an example of this latter type. The second point Kalant makes is that the differences might be due to the rate of excretion of the

drug from the body. Morphine is excreted much faster than amphetamine from the body. This could mean that the amphetamine user undergoes a gradual withdrawal while the morphine user undergoes abrupt withdrawal.

While these last two sections have pointed up the differences in the type of drug dependence stemming from the use of morphine or amphetamines, the fact still remains that the multiple drug user seems to be able to switch quite readily from one drug to another, with the choice often being based on the availability of a certain drug. The important point to be remembered is that with both types of drug dependence there is evidence of a considerable disruption of the general physiological milieu both during the administration of the drug and on withdrawal of the drug. The main purpose in this study was to determine whether the drug dependent person manifests memory deficiencies during the post-withdrawal period and whether these deficiencies are due to drug usage which has altered the general physiological state of the individual. The fact that multiple drug users in the study limited the identification of drugs which may be more damaging than others, as it was not realistically possible to compare the amphetamine user with the morphine user.

CHAPTER II

A SELECTED REVIEW OF THE LITERATURE

Most of the research involving drugs on human subjects has been conducted while the subject was under influence of the drug. Administration of morphine, a CNS depressant, has usually resulted in performance impairments in simple reaction time tasks (Hill, Belleville, and Wikler, 1957) and in tests of immediate and delayed recall (Brown, 1946). Amphetamines, which are CNS stimulants and have attracted considerably more research attention than the opiates, seem, in general, to facilitate motor and intellectual tasks (Weitzner, 1965; Holliday, 1966; and Cole, 1967). However, there is some disagreement as to the true effects of amphetmaines as the so-called improved performances are much greater in fatigued subjects (Dews and Morse, 1961; Holliday and Devery, 1962) and in competitive situations (Weiss and Laties, 1962). It should be noted that in studies of this type the experimental procedure, the task involved, and the dosage administered are important in determining the outcome, as so many of the results have been disputed.

Review of the available literature revealed no research involving the multiple drug user, either taking drugs or after having taken drugs. In the section that follows, some studies are cited that are pertinent to the present research. Most of these studies involved post-narcotic addicts, which means the subjects were probably drug dependent on one

or more of the opiates. However, this point is not always made clear, so the possibility exists that some of the subjects in these studies were multiple drug users.

Most of the pertinent studies relating the mental capabilities of the drug dependent as compared to the non-drug dependent or controls were conducted in a 15-year period starting around 1935. This date corresponds closely with the opening of the U. S. Public Health Service Hospital at Lexington (Kentucky) in 1935 for the treatment of narcotic addicts. A similar hospital was opened in Fort Worth, Texas in 1938 (Maddux, 1965). Although much research was devoted to classifying the clinical characteristics of addiction and withdrawal as well as the education and socio-economic levels of the drug dependent, there were some studies done on post-drug dependent individuals.

Spragg, in a 1940 review article, summarized most of the research up to that point and concluded there was no evidence relating intelligence and proneness to addiction. The studies that did indicate such differences were dismissed because of inadequate sampling. Brown and Partington (1942) administered the Wechsler-Bellevue Intelligence Scale to 371 white admissions at the Lexington hospital and compared their sample to the population sample on the scale. They found no differences in the intelligence ratings between the narcotic drug addicts and the general population sample.

Brown and Partington (1942b) also made a psychometric comparison between institutionalized post-narcotic addicts and hospital attendants. After being matched for intelligence (Wechsler-Bellevue Scale), age, race, and nationality, the subjects were given a series of psychometric tests which included Ferguson Form Boards, mazes, number series com-

pletion, Knox Cubes, memory for names and faces, block counting and distributed attention. Tests which were primarily indicators of intelligence revealed no differences between the post-drug dependents and hospital attendants. The addicts proved to be superior to the hospital attendants on tests involving speed of performance. These tests included cancellation of forms, distributed attention, and speed of adding, subtracting, and multiplying. However, the addicts took more time to complete mixed addition, subtraction, and multiplication problems than when the problems were not mixed. This was labeled "perseveration tendency" by the authors.

Brown (1946) studied two narcotic addicts throughout a complete cycle of addiction lasting almost two years. Both psychometric and physiological measures were taken on the subjects. There was an initial six to seven months period when base-line measurements were recorded, followed by four to seven months of morphine injections until a constant plane of physical addiction was reached. The last period was a post-drug or withdrawal phase and lasted either six or twelve months, depending on the patient. Measurement included Johnson Code Learning, steadiness, tapping speed, continuous subtraction, immediate and delayed recall of nonsense syllables, and voice-hand response time. Because of the extremely small sample and lack of adequate controls, the results have to be interpreted primarily on an individual basis, thus limiting the conclusions. Both subjects showed a reduction in efficiency under the drug conditions. There appeared to be no significant changes in any of the measurements during the withdrawal period. In fact, both subjects showed some improvement on one or more tests during the withdrawal period.

Wikler, Haertzen, Chessick, Hill, and Pescor (1965) in a study comparing chronic schizophrenics, post-addicts, and controls found the controls had longer mean reaction times than the post-addicts using an irregular presentation procedure.

Two studies deserve mention that have studied the effects of morphine, including intellectual changes. Pfeffer and Ruble (1946) studied the incidence of psychosis and mental deterioration in morphine users. There was considerable disagreement at that time as to whether or not chronic morphine use would result in a Korsakoff-type syndrome similar to that associated with chronic alcohol use. Memory weaknesses are a dominant symptom in Korsakoff's syndrome, especially the retention of new material. The incidence of psychosis was found to be no higher for the drug dependents than in a comparable group of non-drug dependents. Examination of a determined psychotic group of addicts (6 patients) using the Rorschach and the Shipley-Hartford Retreat Scale (a vocabulary and abstract thinking test for measurement of mental deterioration) revealed no unique features that could be attributed to drug (morphine) dependence. In other words, there was no difference between a psychotic addict and a non-addict psychotic in mental deterioration. The authors also administered the Shipley-Hartford Retreat Scale to 25 non-psychotic post-addicts and 25 hospital attendants. The subjects were matched for age and education. Although the addicts had a lower mean score on the Retreat scale (83.6 to 85.6), it was not considered significant, leading the authors to conclude there was no organic type of intellectual deterioration.

Partington (1940), using the Revised Babcock Examination for the measurement of mental deterioration, did find significant differences

between addicts and non-addicts. The Examination consists of twenty tests which measure such parameters as immediate and delayed recall, quick perception in substitution, and learning paired associates. Deficiencies in learning ability and motor ability were indicated for the drug dependents. Older drug dependents seemed to do worse than younger drug dependents, but this proved to be an age factor and not attributable to duration of drug use. The author felt the data indicated some deficiency in the ability to form new associations or reproduce new material beyond the length of the simple memory span as opposed to not being able to attend to new material or to hold new impressions. This could be interpreted as representing a deficiency in transfer of information from short-term memory to long-term memory. Unfortunately, this aspect was never followed up, as the author felt the deficiency probably existed prior to drug use and might have contributed to the drug habit.

The Two-Stage Memory Process

Another area highly relevant to the present research is the theory and evidence for a separate short-term memory (STM) and long-term memory (LTM). Subject to much theoretical argument, there now appears to be two distinct types of memory. Variously labeled primary memory (Waugh and Norman, 1965), short-term memory (Adams, 1967), short-term memory store (Atkinson and Shiffrin, 1968; Sternberg, 1969) and active memory (Sternberg, 1969), STM is of short duration, small capacity, and subject to rapid decay unless some sort of active retention process is maintained. LTM is of much larger capacity and more permanent. It has also been called inactive memory (Sternberg, 1969), long-term store

(Atkinson and Shiffrin, 1968), and secondary memory (Waugh and Norman, 1965). Adams (1967) from pages 37 to 44 presents a good example of the proposed dichotomy of short-term memory (STM) and long-term memory (LTM):

> A to be remembered event, like a series of letters, numbers or words is presented to a subject for later recall after a few seconds or minutes. With one or a few reinforcements, the event is assumed to be in STM and operating according to its laws. After a number of reinforcements, however, the event is considered transferred to LTM and subject to a different set of laws. Depending on the nature of the material, the event in STM may or may not be independent of LTM. If the event in STM has well learned associations from past experience it can draw on these mediated connections and relate then to the memory task at hand.

Instead of "reinforcement," rehearsal is probably the more commonly used term to denote the active process that not only keeps items in short-term memory, but transfers them to long-term memory. This rehearsal process is estimated to have an approximate maximum rate of from three to seven items per second (Landauer, 1962).

Adams (1967) cites three lines of evidence supporting the dichotomy of STM and LTM. One line of evidence is the apparent difference in capacity between LTM and STM. The estimated capacity in LTM is unknown, but perfect recall in an experiment involving brief presentation of letters or numbers deteriorates at about seven items (Woodworth, 1938). This is presumed to represent the estimated capacity of STM.

A second line of evidence involves the effects of interference. Adams (1967) states that interference affects both LTM and STM, but the results are different. In STM it is interference along a dimension of acoustic similarity, while in LTM the effect is one of semantic interference. In other words, items interfering with STM are those that

sound alike, while those that interfere in LTM have similar meanings. In addition, information not well rehearsed will be affected more by interference, so items in long-term memory should be less affected than items in STM because more practice or rehearsal is required to transfer information to long-term storage. Stanners and Meunier (1969) have shown how the number of correct items recalled can be increased in short-term memory by increasing the rehearsal periods before an interference task is presented. Allowing the subject 10 seconds rehearsal after the presentation of trigrams followed by an interference task (counting backwards) improved the number correct by recall over allowing only 0 seconds and 5 seconds of rehearsal.

Some of the most convincing arguments for two separate memory processes are provided by physiological evidence. Clinical cases where people have suffered damage to the mammillary-hippocampal region suffer loss of immediate memory, but well established associations are still intact, and there is not much loss of general intelligence (Milner, 1969). Barbizet (1963) presents a review of clinical cases resulting in loss of immediate memory. Such cases include head injuries, brain tumors, some psychotic syndromes, bilateral lesions of the hippocampus, and certain lesions in the mammillary bodies. There does not seem to be a deficit in actual short-term memory per se, because individuals retain certain items by intense concentration or continuous repetition. However, as soon as another item or event, either related or unrelated is presented, retention is lost. The disability seems to be an inability to transfer information from STM to LTM. Papez's circuit, which includes the hippocampus, mammillary bodies, anterior thalamic

nuclei, and the singular cortex has been proposed as responsible for the immediate memory function (Barbizet, 1963).

There is not complete agreement on the dichotomy of STM and LTM. Melton (1963) feels memory is a continuous process with retention dependent on the frequency of repetition. One trace is enough for permanent fixation. Melton believes the evidence that interference affects both the so-called STM and LTM process supports a continuous process better than a dichotomous process. Underwood (1964) has also been critical of the research supporting separate memory processes because of the problem of measuring forgetting when the degree of initial learning has not been properly equated.

Another important structural feature of the memory system is stimulus encoding (Sternberg, 1969), or sensory register (Atkinson and Shiffrin, 1968) or iconic memory (Neisser, 1966). This structure represents the amount of time necessary for the registration of a stimulus and the preparation of a response to that stimulus to take place. For example, in visual presentation the stimulus leaves a photographic trace which decays in a period of several hundred milliseconds and is subject to masking and replacement by repeated stimulation (Atkinson and Shiffrin, 1968). Sperling (1960) estimates the trace lasts about one second, as his subjects' reports did not improve in accuracy after one second. However, Neisser (1966) states that the duration can be influenced by visual variables like intensity, exposure time, and post-exposure illumination. The post-exposure field appears especially important as a dark field will extend the storage legibility over a bright field. Sternberg (1969) has demon-

strated that numbers superimposed on a checker board pattern increases the stimulus encoding period over numbers presented in clear form.

At present, the only sensory modality evidencing a register is vision. Work has been done on the auditory system (Atkinson and Shiffrin, 1968), but a registration mechanism hasn't been isolated. However, Crowder and Morton (1969) cite research supporting their system for a precategorical storage of acoustic information. The system is called PAS (precategorical acoustic storage) and the authors propose it (PAS) as qualitatively similar to the sensory register (see preceding paragraph) system in vision. The PAS is presumed to have a slightly longer persistence (three seconds) than the visual register (one second) and subject to overwriting or displacement by subsequent auditory events, and decay with passage of time.

Problems for Investigation

Although there has been some memory research done using post-drug dependents, it was conducted several years ago using less sensitive indicators than are available today. The idea of two memory processes, an STM and an LTM process, is relatively recent.

The experiment conducted in this paper used a much more sensitive indicator than the previous methods, namely the use of reaction time as a measure of the short-term memory search process. On the other hand, the recall measure (proportion of digits correctly recalled) is similar to the response measures used in other studies. Only Partington's (1940) study seems to suggest anything like a deficiency in transfer from short-term memory to long-term memory as a result of a cycle of drug dependence. If significant differences in memory pro-

cessing could be indicated between drug dependent and non-drug dependents, it might be a start to providing an explanation other than lack of motivation or disinterest for the marked work and social skill deficiencies of drug dependent persons. Of course, there is the question of whether or not the memory condition existed before the cycle of drug dependence.

In the short-term memory part of the experiment the following questions were investigated:

a. Are there differences between the two groups (drug dependent and non-drug dependent) in the time it takes to encode and prepare a response to the stimulus items? This would be indicated by the zero-intercept from the linear least squares equation of reaction times to the probe as a function of the memory set size (Sternberg, 1969). Differences here would be the result of differing reaction times, response preparation differences, or both. The drug dependent and non-drug dependent were not expected to differ on this aspect, although there were no data to support a prediction one way or the other.

b. Are there differences in short-term memory processing between the two groups? Short-term memory processing differences were examined by comparing the mean reaction times required to respond to a probe of lists of varying length. If the drug dependent are deficient in short-term memory processing, the reaction time-set size function should show a steeper slope with increasing list length.

In the transfer of memory items from short-term memory to long-term memory part of the experiment, the following questions were investigated:

a. Are there differences in the proportion of digits (memory items) correctly recalled between the drug dependent and non-drug dependent? This facet was examined by adding two periods of rehearsal before signalling for recall of the memory items after the presentation of the probe item. A zero-second rehearsal period was used to determine whether the two groups were retaining the same number of items in short-term memory. A rehearsal period of 20 seconds was used to give some indication of the transfer of items from STM to LTM.

b. Are there differences in the effects of interference with rehearsal between the two groups? This was determined by adding an intereference task in one half of the 20 second rehearsal periods. If interference should affect the drug dependent more, this would indirectly indicate that the consolidation of the memory trace is more prone to interference and has been less efficient, or that more rehearsal is needed to transfer the items to LTM.

CHAPTER III

METHODOLOGY

Subjects

A total of 36 subjects (Ss), 18 post-drug dependent and 18 non-drug dependent were tested in the experiment. All Ss were Caucasian males. The post-drug dependents were in-patient residents of the Oklahoma City Veterans Administration Hospital and were classified as multiple drug users, although amphetamines and opiates were the dominant drugs used by these patients. The Ss were drug free for one month prior to testing, and this was verified by a weekly urinalysis. The post-drug dependent Ss ranged in age from 18 to 41.

The control group or non-drug dependent were selected from a group of Oklahoma State University students who had previously indicated by a survey that they had never used any drugs, except for medical reasons. These control Ss were selected and matched with the experimental Ss on the basis of age and I.Q. Age-matching for Ss under 30 was within one year and for Ss over 30 was within four years. I.Q. matchings were on the basis of the nearest standard deviation (see Experimental Task and Design). The age of the control Ss ranged from 18 to 37.

All Ss were screened for any pathological deficiencies (epilepsy, organic brain damage, motor disabilities, etc.) and any acute illnesses present such as a common cold or the flu. In no case was any member of

the experimental group tested if it was felt by the ward therapist that it would not be in his best interests, as the experimental task was fairly difficult and required considerable concentration. In addition, no S was forced to take the experiment if he did not wish to.

All Ss, both the experimental and control, were paid three dollars for their participation in the experiment, which lasted 80 to 90 minutes. Ss were told by the experimenter that they would not be paid if they did not follow instructions or demonstrate consistent motivation during the experiment.

Apparatus

The basic apparatus consisted of a table specially constructed for the experiment and several other pieces of standard experimental equipment. The table was 18 x 32 in. and 31 in. high. A panel, 22 x 36 in., was mounted on the back of the table to limit the S's view. Two two-way toggle switches were mounted in the top of the table about 15 in. apart. These switches were placed so that one could be used by the left hand and one by the right hand.

A Realistic tape recorder, Model 909, was used to record and present the stimulus materials to the Ss. A Hunter Model 120A Klockounter was used to measure the Ss' reaction times to the probe stimulus. This Klockounter was activated by a Gerbrands electronic voice key. In addition, a small panel containing four telephone relays and four lights (15 watts) was constructed to indicate the Ss's probe responses to the experimenter. The wiring for the relay panel was separate from the wiring for the Klockounter, so there would be no interference or delay in the recording of the reaction time response. The voice key,

tape recorder, Klockounter, relay panel and a one amp. power supply were on a separate table and controlled by the experimenter.

The Ss heard the stimulus materials over a set of Koss Headphones and were also provided with a two page answer sheet and two pencils which they used to write down the digits they could recall for each trial.

The experimental Ss were tested in a standard hospital room in the Oklahoma City V. A. Hospital. They were tested during the period 4:30 P.M. to 10:00 P.M. This period was used to minimize interruption of the patients' daily routine and to avoid interference with the hospital staff. The control Ss were tested in a similar isolated room on the Oklahoma State University campus. These Ss were also tested in the same time period.

Stimulus Materials

The first nine monosyllable digits were randomly arranged into lists of one (1), four (4), and seven (7) digits each. A probe digit was paired with each list presented. A positive probe was the same as one member of the list, and a negative probe was not. In the lists containing one digit, the single position was probed 36 times, 18 positive and 18 negative. For the digit lists containing four digits, only the first and fourth positions were probed, 9 positive and 9 negative. With the digit lists of seven items, only the first, fourth, and seventh positions were probed, 6 positive and 6 negative for each position.

Immediately following the response to the probe there was a rehearsal period before the S was required to recall the previously

presented digits. Two rehearsal times, a zero-second period and a 20-second period were used. During one half of the 20-second rehearsal periods, a letter followed by a clicking sound occurring at one-second intervals was presented auditorially over the tape to the Ss at the start of the period. This was to signal and pace the Ss during the interference task required in these periods. The interference task consisted of having the Ss go forward in the alphabet, skipping one letter at a time and making their response in time with the click. The end of all rehearsal periods were signalled over the tape by the word "recall."

With three lists or set sizes (1, 4, and 7), two probe types (positive and negative), and three rehearsal periods (0-sec., 20-sec., and 20-sec. with interference), there were 18 possible experimental combinations with the set size first, then the probe, and finally the rehearsal period. The stimulus materials were constructed with a random recombination every 18 lists, with one list corresponding to one trial (see Appendix A). The multiple chosen that would result in an even number for each level and also give enough measures on each level was 108. Thus, 108 lists of digits and probes, divided into six periods or recombinations, were recorded on a mster tape using a Standard Electric Timer for the item spacings. The same procedure was repeated to construct another randomly ordered series of trials for a second tape.

Experimental Task and Design

Fundamentally, the experiment was divided into two parts. Ss were first presented with the varying lists of digits (1, 4, and 7) and

required to perform a STM search task (see Experimental Procedures below), followed by a second task requiring a recall of these digits in correct serial order. The STM search task consisted of throwing a toggle switch to either the right or left in response to a probe of the digit lists. The second task consisted of writing down as many digits as could be remembered in correct serial order from the previously presented lists.

In the STM search task, the basic design involved the factorial combination of one between-Ss variable and three within-Ss variables. The between-Ss variable was the type of subject, either experimental (post-drug dependent) or control (non-drug dependent). The within-Ss variables were the size of the memory sets or lists (1, 4, and 7), whether the probe digit was in the previous list or not (positive or negative), and the particular period in which the memory set occurred (one through six).

In the recall task, one more within-Ss variable was added in combinatnion with the variables in the STM task. This was the rehearsal period and consisted of either 0-sec. rehearsal, 20-sec. rehearsal, or 20-sec. rehearsal with an interference task.

Another important design factor in this experiment was the matching of the subjects. The Ss were matched for age in an attempt to control for reaction time differences due to age, and they were also matched for I.Q. The latter matching was used more as a screening device than a matching variable. There were two reasons for this. As a test of general intelligence, digit memory-span tests are very poor and correlate low with other tests of intelligence (Wechsler, 1958). It appears to have usefulness only in discriminating the lowest

levels of intelligence or as a diagnostic tool for some memory defects (Wechsler, 1958). In other words, digit-span tests are poor discriminators of I.Q. differences except at the lower levels of intelligence (I.Q.'s less than 80). A second reason was the difficulty in getting all Ss to take the same intelligence test. For the experimental group, I.Q. scores were available on three different tests: the Wechsler Adult Intelligence Scale (WAIS), the General Aptitude Test Battery (GATB), and the Otis-Lennon. Furthermore, only a few Ss had scores on more than one test. The situation was more favorable for the control group, as all the Ss took the Otis-Lennon test before being selected for the experiment.

The following procedure was used to match the subjects on I.Q. scores. Each S's I.Q. score was converted to the standard deviation (Z score) for the test which they had taken, and the Ss were then matched on the basis of a standard-deviation range. For example, Ss having a standard deviation score between -1 and +1 (I.Q. range = 84-116) were considered eligible for a match. Other matching groups included -1 through -2 (I.Q. range less than 84) and +1 through +2 (I.Q. range 117 to 131). There were no matched pairs which included Ss above +2 standard deviations, and there was only one matched pair below a standard deviation of -1. Most of the matched pairs fell between standard deviations of -1 and +1.

Experimental Procedures

Stimulus materials were presented to the Ss auditorially on a tape recorder over headphones. Ss were randomly assigned to one of the two tapes used in the experiment. Each S was seated in front of a table

with two toggle switches (left and right) mounted on the surface. The S was given the choice of which toggle switch he wanted to use throughout the experiment. In the center of the table an answer sheet and two pencils were provided.

The left channel of the stereo recorder was used to record the memory sets, and the probes were recorded on both the right and left channels. The Ss heard only the left channel, while the right channel probe simultaneously activated an electronic voice key (Gerbrands) when the Ss heard the probe in the left channel. The activated voice key fired the Hunter Klockounter which ceased when the S made his response to the probe by moving one of the two toggle switches mounted on the table. Reaction time in milliseconds was recorded by the experimenter after each trial.

Ss were instructed (see Appendix B) to try and remember the memory sets for later recall, so after the probe item the rehearsal period began and was terminated by the word "recall" at either 1.5 seconds or 21.5 seconds after the probe. On trials where the interference task was required, immediately after the probe item (1.5 seconds), a letter was presented on the tape, and this was the signal to start going forward in the alphabet starting with that letter and skipping each letter until the word "recall" was heard over the tape. They were given a different letter each time, and if the S ended on the letter z before he heard "recall," he was instructed to continue through the alphabet starting with the letter b and skipping each letter until he heard "recall." If the S ended on y, he was to start over with the letter a, and continue as above until he heard "recall."

Each trial was initiated by the words "ready start," followed two seconds later by the memory sets. There was a one-second interval between each digit in the memory set, and one-second after the last item in the set a 6,500 Hz tone sounded followed 1.5 seconds later by the probe digit. Ss were allowed 1.5 seconds for response to the probe items before the start of the rehearsal periods. The 1.5 was the time allowed on the tape to separate the probe response time from the start of the rehearsal periods. If a subject ran longer than 1.5 seconds to make his probe response, he ran into the rehearsal period. Since there was no actual signal to the subject for the start of the rehearsal period, long responses to the probe stimulus posed no problem in the experiment. The end of the rehearsal periods was signalled over the tape by the word "recall" and the Ss had 10 seconds to write down their responses before the start of the next trial. The 108 trials were divided into six periods, with a different arrangement of trial-combinations in each period. There was a five minute break between periods three and four, and the whole experiment took from 80 to 90 minutes, depending on the S and tape used.

There were four practice trials presented to the Ss before the experiment began and no S was allowed to begin until it was evident he understood the directions. This sometimes required a second and third run through of the practice trials for some Ss.

CHAPTER IV

RESULTS

Reaction Time Response

The basic statistical design in this study involved the factorial combination of one between-Ss factor and several within-Ss factors. The between-Ss factor was the type of subject (drug dependent or control) and was present in both the reaction time and recall response measures. The within-Ss factors included the type of probe (positive or negative), set size (1, 4, and 7), periods (periods of repeated trial combinations), and rehearsal-periods (0-sec., 20-sec., and 20-sec. with interference). The rehearsal-periods factor was not in combination with the other within-Ss factors for the analysis of the reaction times.

The first response measure analyzed was the reaction-time response to the probe stimulus of the memory sets. Mean reaction times for each S were calculated for each set size and probe type within a period. This produced six mean reaction times for each set size and probe type combination (3 x 2), giving 36 data points for each S (6 mean reaction times x 6 periods). For example, in set size one, there were two mean reaction times for each period, one under the positive probe condition and one under the negative probe condition. Over six periods, this totaled 12 mean reaction times, six positive and six

negative. The same held true for set sizes four and seven. Any reaction time (RT) accompanied by the incorrect probe response was discarded from the data.

A four-factor analysis of variance was initially performed on the RT data to see if there were any differences between the two tapes used in the experiment. With type of tape as a between-Ss factor and set size (1, 4, and 7), probe (positive versus negative), and periods (1-6) as within-Ss factors, no significant differences were obtained for either the between-Ss factor or any of the interactions containing the between-Ss factor. It was assumed, therefore, that the tapes were not different, and the data were collapsed across tapes for subsequent analysis.

A four-factor analysis of variance with one between-Ss factor (subject type) and three within-Ss factors (set size, probe, and periods) was carried out on the reaction time data (see Table I). The between-Ss factor was significant, and within-Ss factors significant were set size and periods. The probe type was not significant. Significant interactions involving the between-Ss factor were set size by subject type and probe by period by subject type. The set size by subject interaction is represented in Figure 1 (see page 34) and shows a greater increase in reaction time with increase in number of items in the memory set for the post-drug dependent as compared to the controls. Figure 2 (page 35) shows the three-factor interaction (PTC). It appears that the controls had a sharp drop in the first three periods and leveled off in periods four and five with a slight upturn in period six. The drug dependents showed a steady decrease in

TABLE I

AOV OF REACTION TIMES OF DRUG DEPENDENTS AND CONTROLS

Source	df	MS	F
Total	1295	121,550	
Between Ss	35	1,382,213	
C (subject type)	1	15,326,135	15.77**
Ss w. Grps.	34	972,098	
Within Ss	1260	109,120	
S (set size)	2	18,778,864	149.45**
SC	2	507,822	4.04*
Ss w. Grps. x S	68	125,656	
P (probe)	1	23,316	.38
PC	1	34,896	.57
Ss w. Grps. x P	34	60,701	
T (periods)	5	1,433,837	20.64**
TC	5	133,626	1.92
Ss w. Grps. x T	170	69,464	
SP	2	90,350	1.70
SPC	2	21,576	.41
Ss w. Grps. x SP	68	53,107	
ST	10	72,114	1.78
STC	10	64,239	1.58
Ss w. Grps. x ST	340	40,619	
PT	5	90,595	2.44*
PTC	5	104,379	3.82*
Ss w. Grps. x PT	170	37,055	
SPT	10	36,072	.92
SPTC	10	22,844	.59
Ss w. Grps. x SPT	340	39,034	

Note: Significance levels are represented in all tables by the following: * = $p < 0.05$; ** = $p < 0.01$; n.s. = not significant at the 0.05 level.

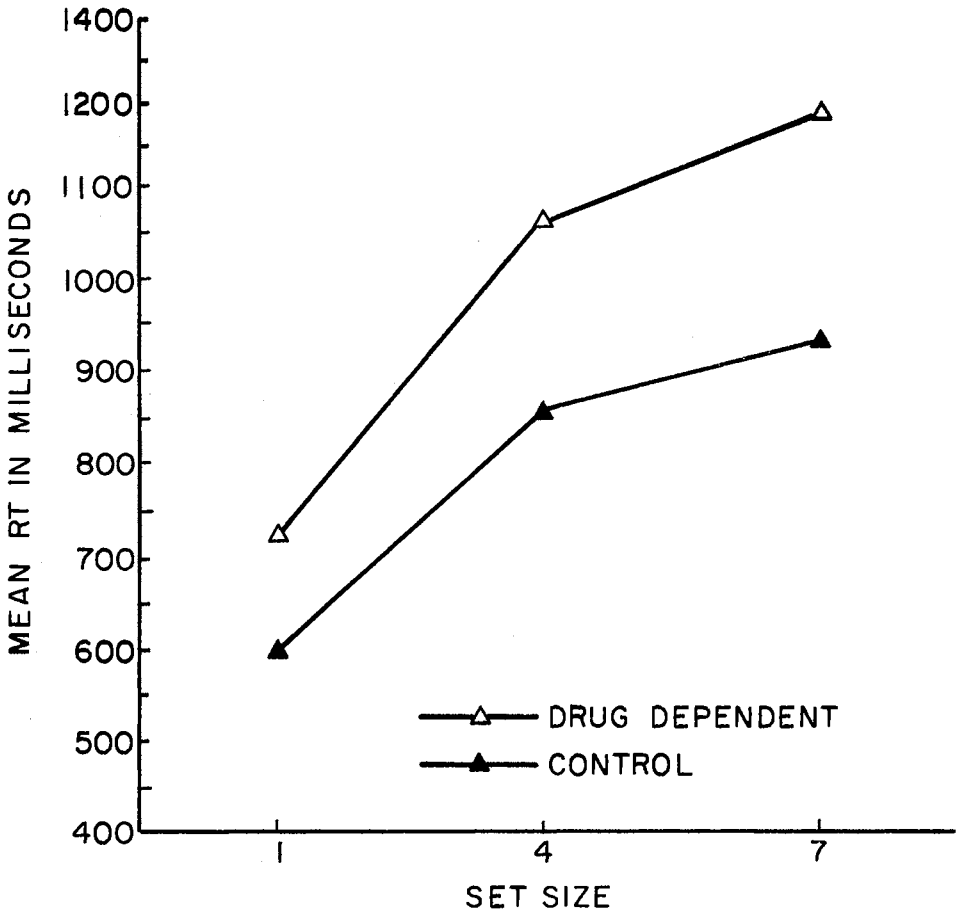

Figure 1. Set Size by Subject Type Interaction

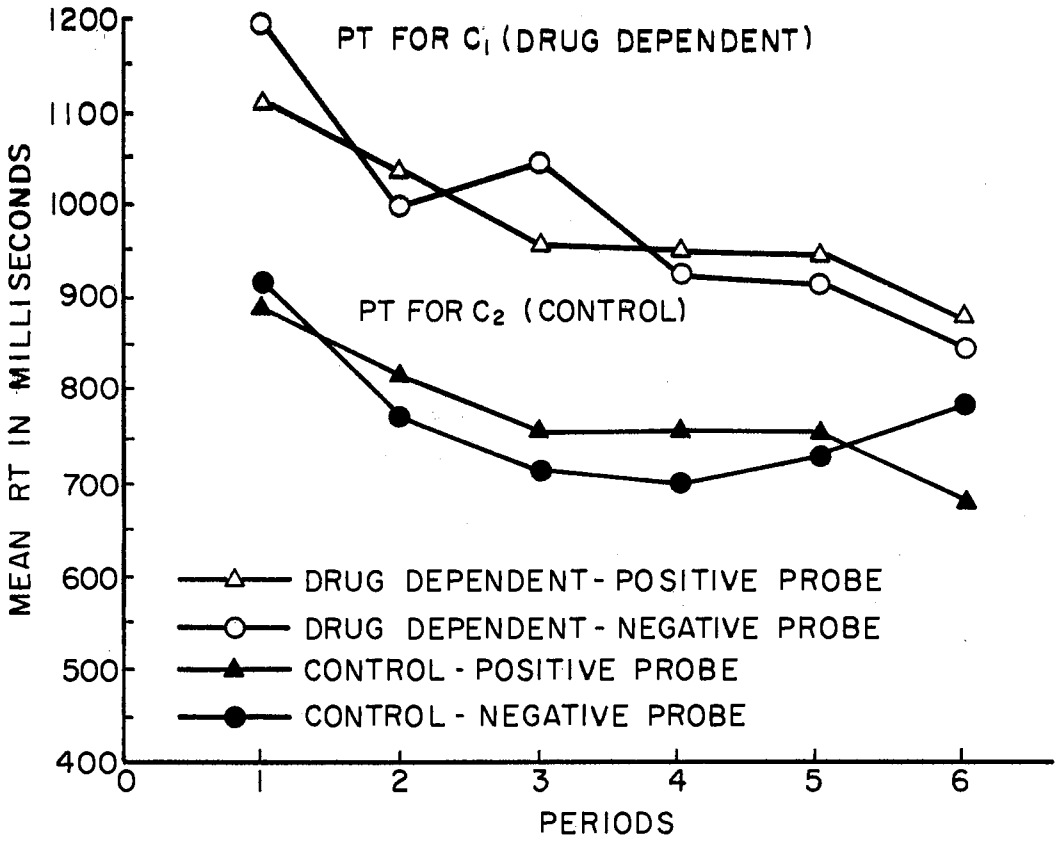

Figure 2. The Probe (P) by Periods (T) by Subject Type (C) Interaction of the Reaction Time Response

reaction time over all periods. The probe type on the other hand showed no consistency as it "flip-flopped" from period to period for both groups.

A three-factor within-Ss analysis of variance was performed on the data of the drug dependent and control Ss separately. The three within-Ss factors were set size, probe, and periods. Tables II and III present a summary of the results, which were consistent except for one reversal: the set size by periods interaction was significant for the drug dependent and not for the controls, while the probe by periods interaction was significant for the controls and not for the drug dependent Ss. The drug dependent showed more variation from set size to set size on the periods factor than the controls (Figure 3), while the controls had a large reversal on the probe response in period six (Figure 2).

Regression analysis on the set size RT data with periods collapsed indicated a scanning rate of 86 milliseconds (msec.) per item on the positive probe and 71 msec. per item on the negative probe for the drug dependents, with intercepts of 457 msec. and 561 msec. respectively. The linear regression factor was significant for both the positive and negative probe (Table IV). For the controls the scanning rates were 59 msec. per item for the positive probe and 52 msec. per item for the negative probe. The intercepts were 415 msec. and 457 msec., respectively, for the positive and negative probes. The linear regression factor was also significant and is presented in Table V. Figure 4 (see page 41) presents a graph of the least squares equations for the positive and negative probes.

TABLE II

AOV OF REACTION TIMES OF DRUG DEPENDENTS

Source	df	MS	F
Total	647	149,005	
Subjects	17	1,122,177	
Within Ss	630	120,047	
S (set size)	2	12,663,336	74.44**
Ss w. Grps. x S	34	170,120	
P (probe)	1	57,630	.68
Ss w. Grps. x P	17	85,749	
T (periods)	5	1,111,454	12.91**
Ss w. Grps. x T	85	86,087	
SP	2	83,550	1.06
Ss w. Grps. x SP	34	79,148	
ST	10	116,861	2.07*
Ss w. Grps. x ST	170	56,558	
PT	5	108,319	1.86
Ss w. Grps. x PT	85	58,155	
SPT	10	44,341	.71
Ss w. Grps. x SPT	170	62,210	

TABLE III

AOV OF REACTION TIMES OF CONTROLS

Source	df	MS	F
Total	647	70,595	
Subjects	17	722,018	
Within Ss	630	53,018	
S (set size)	2	6,623,373	81.58**
Ss w. Grps. x S	34	81,191	
P (probe)	1	582	.02
Ss w. Grps. x P	17	36,654	
T (periods)	5	456,008	8.63**
Ss w. Grps. x T	85	52,842	
SP	2	28,376	1.05
Ss w. Grps. x SP	34	27,066	
ST	10	19,492	.79
Ss w. Grps. x ST	170	24,681	
PT	5	86,654	5.43**
Ss w. Grps. x PT	85	15,958	
SPT	10	14,574	.92
Ss w. Grps. x SPT	170	15,856	

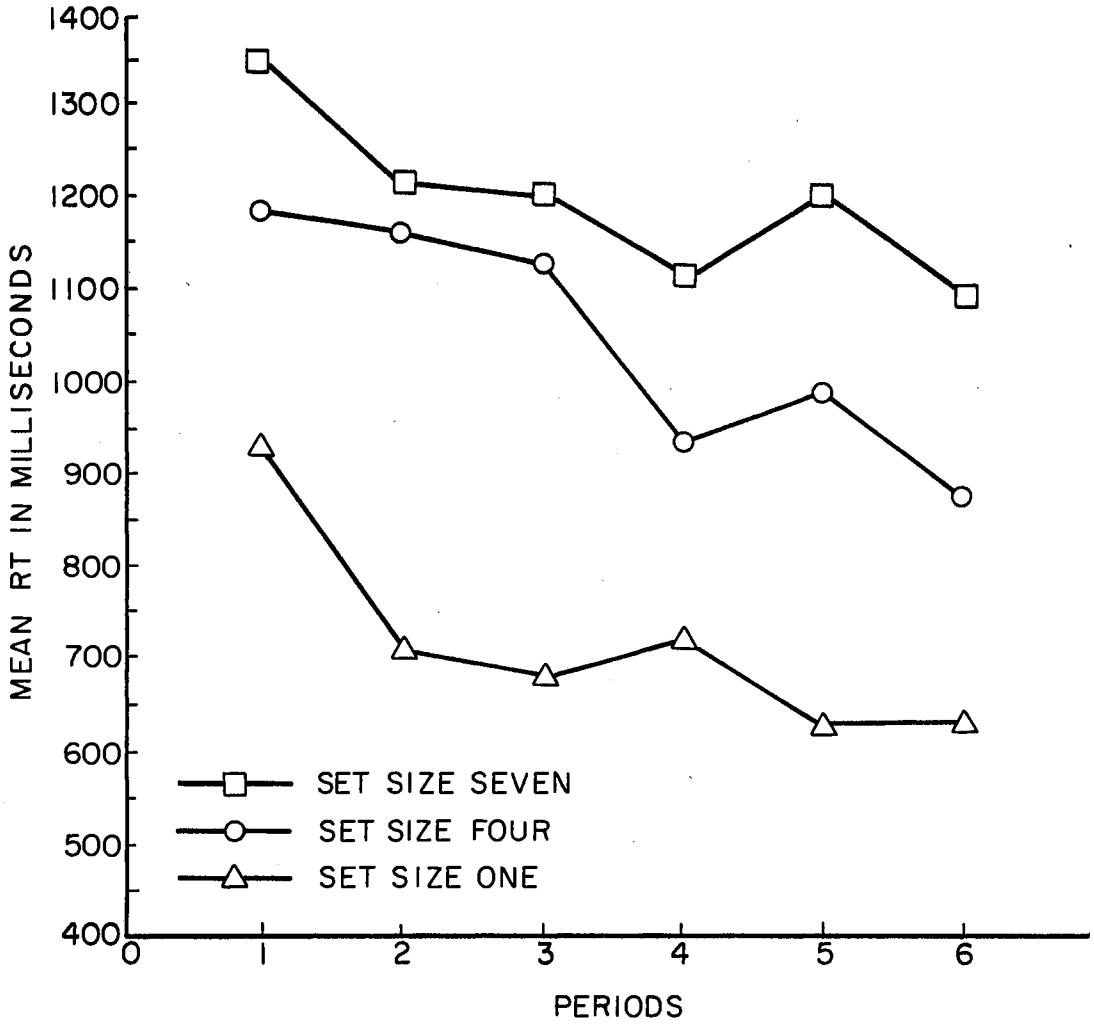

Figure 3. The Set Size (S) by Periods (T) Interaction for the Drug Dependent Ss

TABLE IV

AOV OF REACTION TIME OF DRUG DEPENDENTS FOR LINEAR REGRESSION

Source	df	MS	F
Total (positive probe)	53	92,071	
Linear regression	1	2,410,774	50.77**
Error	52	47,481	
Total (negative probe)	53	87,040	
Linear regression	1	1,641,388	28.72**
Error	52	57,148	

TABLE V

AOV OF REACTION TIME OF CONTROLS FOR LINEAR REGRESSION

Source	df	MS	F
Total (positive probe)	53	45,363	
Linear regression	1	1,117,601	45.16**
Error	52	24,743	
Total (negative probe)	53	47,548	
Linear regression	1	875,160	27.67**
Error	52	31,632	

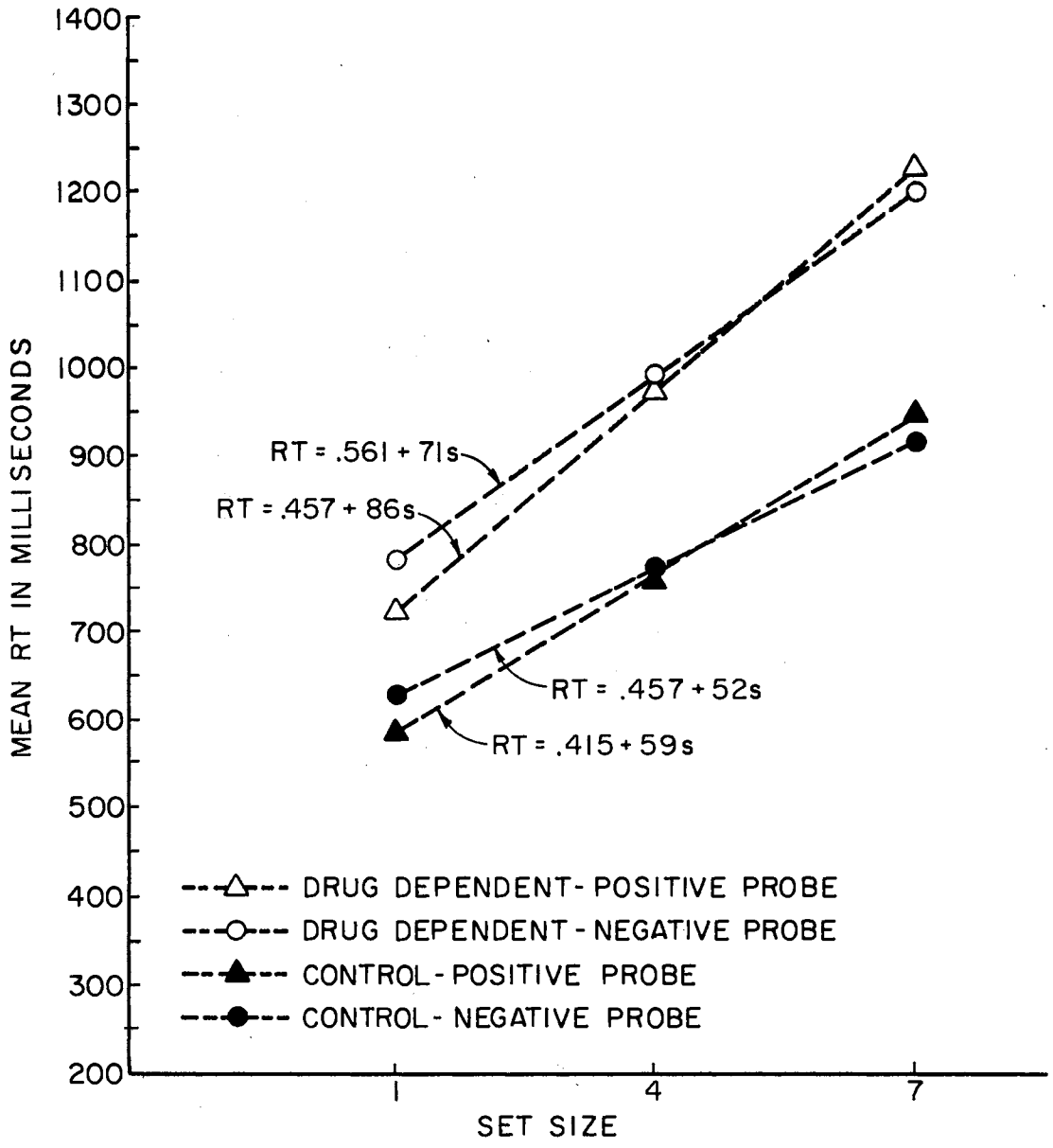

Figure 4. Regression Lines Using Mean RT Across Set Sizes as a Function of Probe Type

Because the overall F test for the set size by subject interaction was significant (Table I), t tests were used to test intercept differences and set size differences by subject type and probe type. Probe differences were tested, although the F test on the probes was not significant, because it is the usual procedure in designs of this type to analyze the probe separately. Intercept differences were not indicated for either the positive or negative probe. Using matched-groups t tests, because the Ss were matched in the experimental design, significant differences were found at all set sizes between drug dependents and controls on the positive and negative probes. These results indicate that the drug dependents and controls can encode and prepare a response at about the same rate, but scanning the memory sets results in differences between the two groups. Tables VI and VII present a summary of the results.

The reaction-time response was also analyzed for serial position effects on the positive probes. For the data of set size seven, a two-factor analysis of variance was performed with type of subject as a between-Ss factor and serial position as the within-Ss factor. Table VIII, which summarizes the results, shows the subject factor was significant, as was the serial position factor. Separate analysis of the drug dependent and control data with single-factor within-Ss analyses of variance showed the serial position factor to be significant for both groups (Table IX). Multiple-comparison tests were then used to determine probe position differences. These tests are summarized in Table X and reveal that probe positions one and seven, and four and seven, were different for both groups, but positions one and four did not differ for either group. This indicates that the serial position

TABLE VI

SUMMARY TABLE OF SLOPES, INTERCEPTS, t TESTS AND HO:B=0 FOR DRUG DEPENDENTS (DD) AND CONTROLS (C)

Intercept	Slope	t for HO:B=0	p
Positive probe			
(DD) 456.69 msec.	258.78 msec.	7.13	0.0001
(C) 414.89 msec.	176.19 msec.	6.72	0.0001
Negative probe			
(DD) 560.93 msec.	213.53 msec.	5.36	0.0001
(C) 457.24 msec.	155.92 msec.	5.26	0.0001

Note: Two tailed t tests were used in Tables VI and VII.

TABLE VII

SUMMARY TABLE OF t TESTS FOR INTERCEPT DIFFERENCES AND SET SIZE DIFFERENCES FOR DRUG DEPENDENTS (DD) AND CONTROLS (C)

Test comparison	t value	df	p
Intercept			
(DD) + vs. (C) +	.74	34	n.s.
(DD) - vs. (C) -	1.14	34	n.s.
Set size 1			
(DD) + vs. (C) +	2.23	17	.05
(DD) - vs. (C) -	2.90	17	.01
Set size 4			
(DD) + vs. (C) +	3.66	17	.01
(DD) - vs. (C) -	2.60	17	.05
Set size 7			
(DD) + vs. (C) +	4.72	17	.01
(DD) - vs. (C) -	4.08	17	.01

Note: + = positive probe and - = negative probe.

TABLE VIII

AOV ON REACTION TIME TO POSITIVE PROBE IN SET SIZE SEVEN FOR DRUG DEPENDENTS AND CONTROLS

Source	df	MS	F
Total	107	116,186	
Between Ss	35	196,154	
C (subject type)	1	2,290,753	17.03**
Ss w. Grps.	34	134,548	
Within Ss	72	77,299	
S (serial position)	2	476,218	7.61**
SC	2	179,227	2.86
Ss w. Grps. x S	68	62,583	

TABLE IX

AOV'S ON REACTION TIME TO POSITIVE PROBE IN SET SIZE SEVEN FOR DRUG DEPENDENTS AND CONTROLS

Source	df	MS	F
Drug Dependent			
Total	53	154,656	
Subjects	17	178,091	
Within Ss	36	143,590	
S (serial position)	2	617,058	5.33*
Ss w. Grps. x S	34	115,738	
Control			
Total	53	36,387	
Subjects	17	91,004	
Within Ss	36	11,037	
S (serial position)	2	38,387	4.07*
Ss w. Grps. x S	34	9,428	

TABLE X

SUMMARY TABLE OF MULTIPLE COMPARISON TESTS FOR PROBE POSITION DIFFERENCES FOR DRUG DEPENDENTS AND CONTROLS

Test comparison	t or q_r value	r,df	p
Drug Dependent			
Set size 4			
Position 1 vs. position 4	1.26[a]	17[a]	n.s.[a]
Set size 7			
Position 1 vs. position 7	3.48	2,34	.05
Position 1 vs. position 4	.90	2,34	n.s.
Position 4 vs. position 7	4.38	3,34	.05
Control			
Set size 7			
Position 1 vs. position 7	3.62	3,34	.05
Position 1 vs. position 4	.31	2,34	n.s.
Position 4 vs. position 7	3.33	2,34	.05

[a]Matched groups t test used in this comparison, while other comparisons use the Newman-Keuls test.

TABLE XI

SUMMARY TABLE OF t TESTS FOR PROBE POSITION DIFFERENCES BETWEEN DRUG DEPENDENTS (DD) AND CONTROLS (C)

Test comparison	t value	df	p
Set size 1			
(DD) vs. (C)	1.96	17	n.s.
Set size 4			
(DD) vs. (C) position 1	2.57	17	.05
(DD) vs. (C) position 4	3.71	17	.01
Set size 7			
(DD) vs. (C) position 1	7.81	17	.01
(DD) vs. (C) position 4	2.65	17	.05
(DD) vs. (C) position 7	1.85	17	n.s.

Note: Two tailed t tests were used in Tables X and XI.

effect was primarily a recency effect, and that the primacy effect was not present. As revealed in Figure 5 (see page 46), only the drug dependent show any sign of a primacy effect, and this was not significant. A matched-groups t test was also run to see if the drug dependent showed any recency effect in set size four. The test proved non-significant and is presented in the first part of Table X.

The serial position data were pursued on step further to see where the differences were between the drug dependent and control according to set size and position. Matched-groups t tests were used and the results as summarized in Table XI show that the drug dependent and control did not differ in set size one, differed on both positions in set size four, and on positions one and four only in set size seven. It is interesting to note the lack of a difference in position seven of set size seven.

Recall Responses

Per cent error rates on the digits recalled from the memory sets were calculated for each S by recall or rehearsal period (0-sec., 20-sec., and 20-sec. with interference), probe type (positive or negative), set size (1, 4, and 7) and periods (1 through 6). There were 18 possible combinations of recall period, set size, and probe type (3 x 3 x 2) within each time period, so with six time periods this gave 108 data points for each S. An arc sine transformation (Steele and Torrie, 1960) was administered on the data before they were subjected to statistical analysis. This is a standard procedure in dealing with percentage data in order to guard against heterogeneity

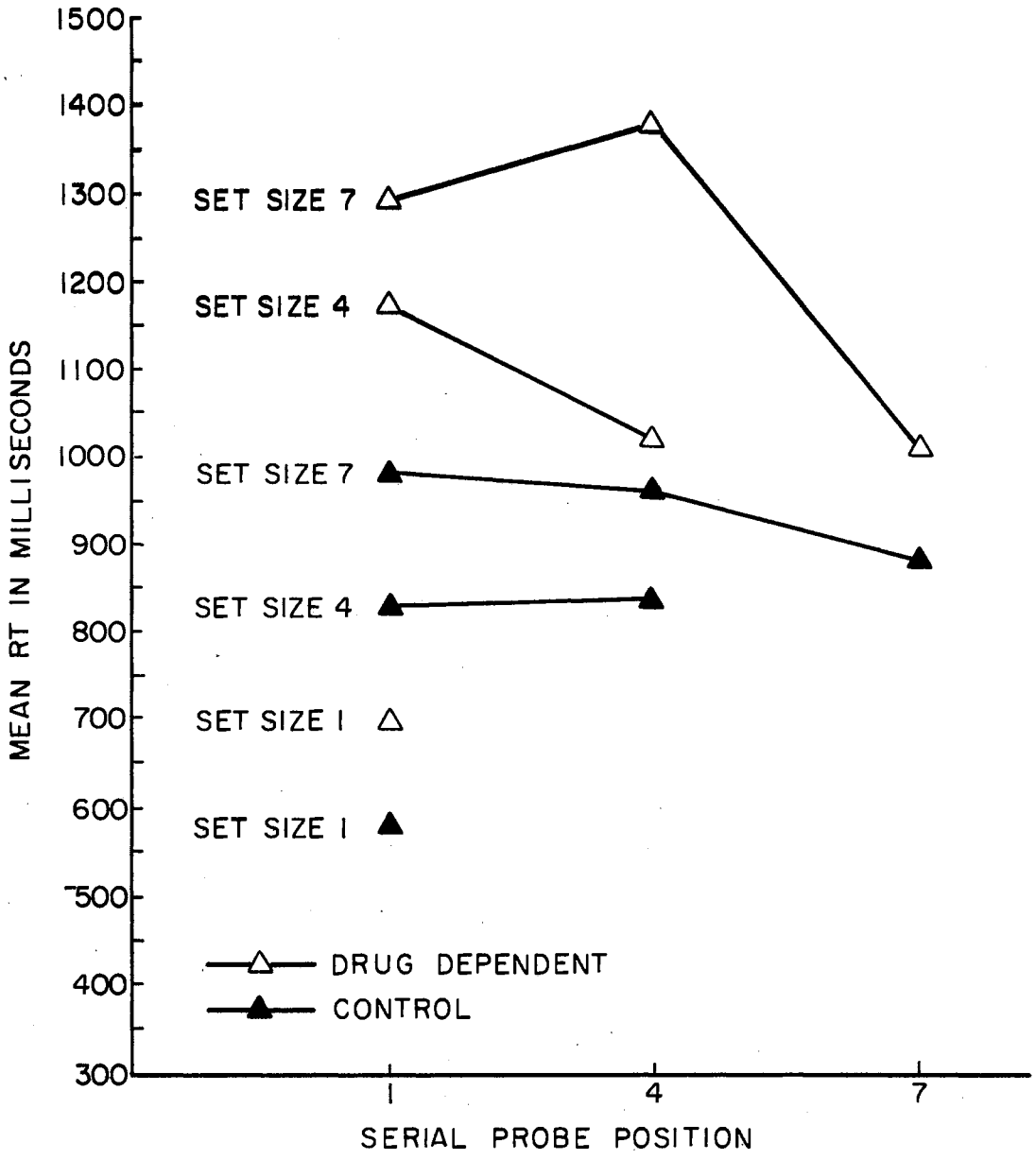

Figure 5. Serial Position Curves on Mean Reaction Times to Positive Probes for Drug Dependents and Controls

of error variances and to obtain normality of within-cell distributions (Winer, 1971). An error was any digit not correctly recalled, or recalled but not in correct serial order.

The per cent error response was also tested for tape differences. Using a five-factor analysis of variance with tapes as the between-Ss variable and rehearsal period, set size, probe, and periods as within-Ss variables, separate analyses were carried out on the drug dependent and controls. There were nine controls and nine drug dependents for tape one, and also nine of each for tape two. Although the between-Ss factor did not approach significance (Appendix C), there were some three- and four-factor interactions involving the tapes factor which were barely significant for each group. It was felt that this was primarily due to some unique characteristics of the data: of the 18 treatment combinations, only lists of set size seven and set size four with the interference task have a range of values other than primarily zero. There is also unequal weight in the amount of "information" contained in some cells. For example, in set size one cells, the data could only receive one of two values, zero per cent or 100% error. A 100% error score in set size one, where the task required recalling only one digit was then equivalent to 100% error in set size seven, where the task required recalling seven digits. Because the numbers of errors for set size one and for set size four with zero-second and 20-second rehearsal were extremely low, it is probable that the tape differences were due to random variations in error percentages occurring in these cells. Therefore, the lists were considered to be equivalent and the data were collapsed over tapes.

TABLE XII

AOV OF RECALL RESPONSE OF DRUG DEPENDENTS AND CONTROLS

Source	df	MS	F
Total	3887	1,222	
Between Ss	35	5,324	
C (subject type)	1	30,962	6.78*
Ss w. Grps.	34	4,570	
Within Ss	3852	1,185	
I (recall interval)	2	456,971	386.08**
IC	2	655	.55
Ss w. Grps. x I	68	1,182	
S (set size)	2	748,413	526.68**
SC	2	591	.42
Ss w. Grps. x S	68	1,421	
T (periods)	5	2,590	4.21**
TC	5	377	.61
Ss w. Grps. x T	170	615	
P (probe)	1	14,931	26.38**
PC	1	3,615	6.39*
Ss w. Grps. x P	34	566	
IS	4	45,371	49.48**
ISC	4	979	1.01
Ss w. Grps. x IS	136	917	
IT	10	529	1.17
ITC	10	522	1.15
Ss w. Grps. x IT	340	454	
IP	2	7,920	12.57**
IPC	2	196	.31
Ss w. Grps. x IP	68	630	
ST	10	540	1.55
STC	10	437	1.25
Ss w. Grps. x ST	340	349	
SP	2	5,740	11.96**
SPC	2	267	.55
Ss w. Grps. x SP	68	480	

TABLE XII (Continued)

Source	df	MS	F
TP	5	601	1.31
TPC	5	224	.49
Ss w. Grps. x TP	170	459	
IST	20	524	1.28
ISTC	20	445	1.08
Ss w. Grps. x IST	680	410	
ISP	4	5,856	13.91**
ISPC	4	752	1.78
Ss w. Grps. x ISP	136	421	
ITP	10	586	1.34
ITPC	10	313	.71
Ss w. Grps. x ITP	340	438	
STP	10	759	1.64
STPC	10	282	.61
Ss w. Grps. x STP	340	463	
ISTP	20	528	1.18
ISTPC	20	430	.98
Ss w. Grps. x ISTP	680	442	

A single main analysis was carried out on the recall data and this was a five-factor analysis of variance with one between-Ss factor (subject type) and four within-Ss factors (rehearsal period, set size, probe, and periods). Table XII presents a summary of the results. The subjects factor is significant and the two-factor interaction of type of probe by type of subject is also significant. As expected, the set size, probe type, rehearsal period, and periods main effects are also significant, but there are no differences between drug dependents and controls on any of these factors except probe type. Figure 6 shows the mean per cent error rate over periods for the drug dependents and controls. The drug dependents show little improvement over periods, while the controls evidence some improvement after the second period. In general the results indicate that the drug dependent had higher error rates for each set size following a rehearsal period than the controls (Figures 7, 8, 9). In addition, both groups missed more digits under the negative probe condition than the positive probe condition (PC interaction), with the drug dependent missing a significantly greater percentage of digits under the negative probe (PC interaction; Figure 10).

Examination of Figures 7, 8, and 9 (see pages 54 and 55), which show per cent error rates for each set size by rehearsal period and probe type, gives some interpretation for the significant three factor interaction involving these factors. Greater differences on the rehearsal periods factor occurred in the lower set sizes (one and four) than in the largest set size (seven). Also greater differences between positive and negative probes occurred in the lower set sizes than in

set size seven. Set size seven also reveals greater "change over" on the probe factor (for the 20-sec. rehearsal period) than any of the other set sizes.

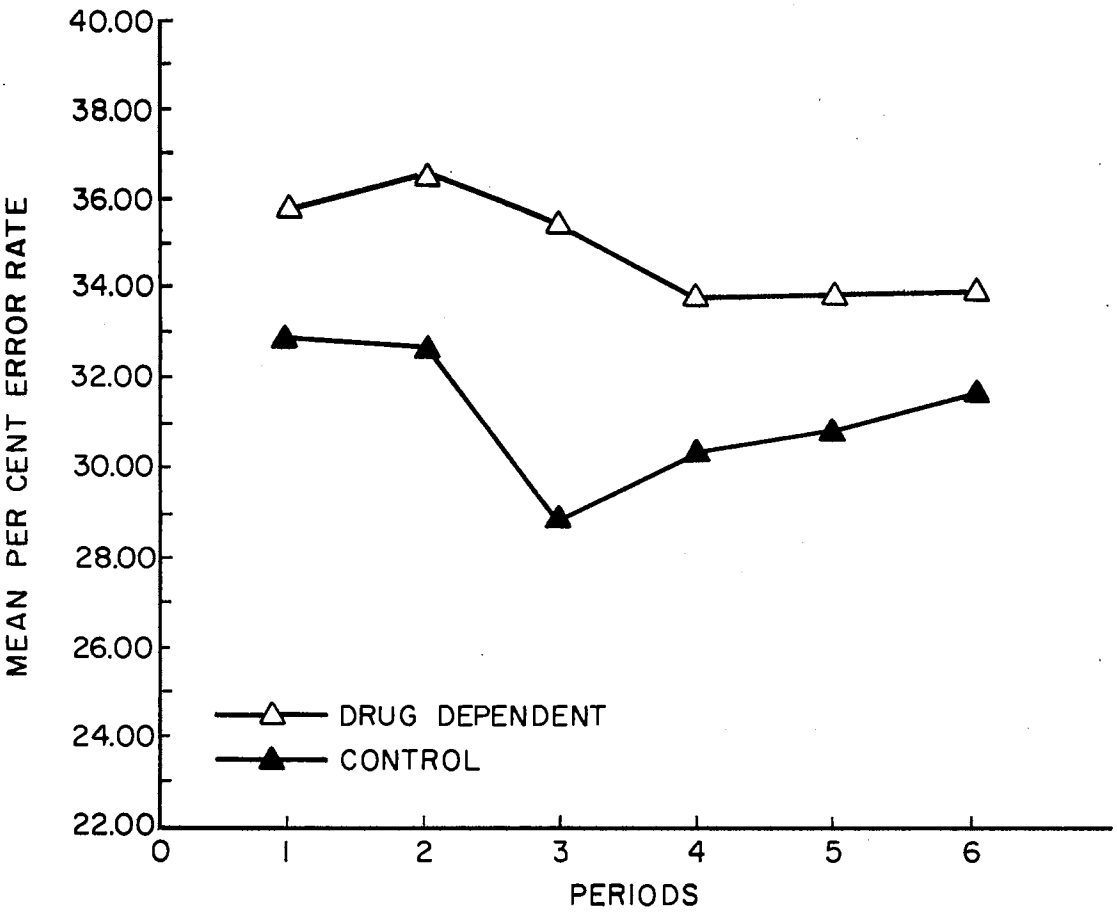

Figure 6. Error Rates by Periods for Drug Dependents and Controls

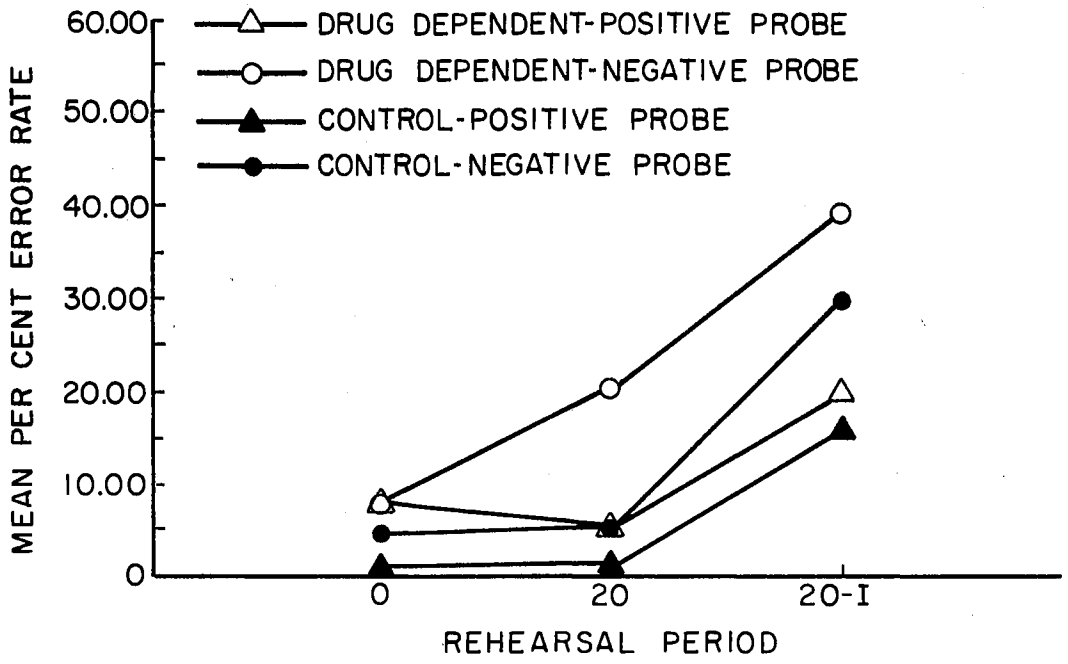

Figure 7. Error Rates by Rehearsal Period in Set Size One

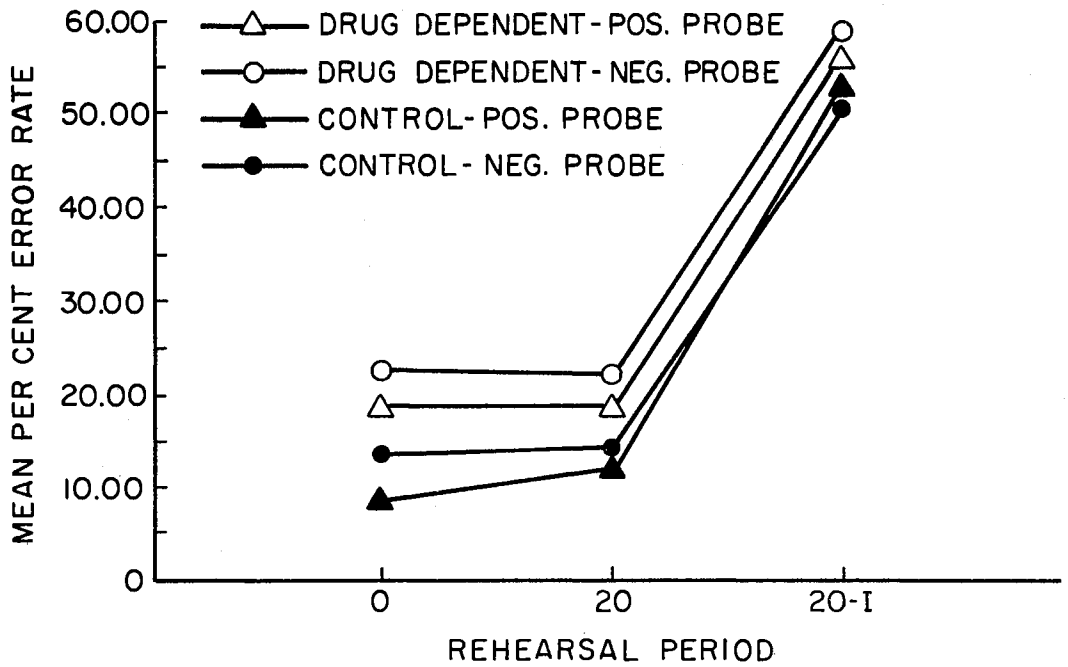

Figure 8. Error Rates by Rehearsal Period in Set Size Four

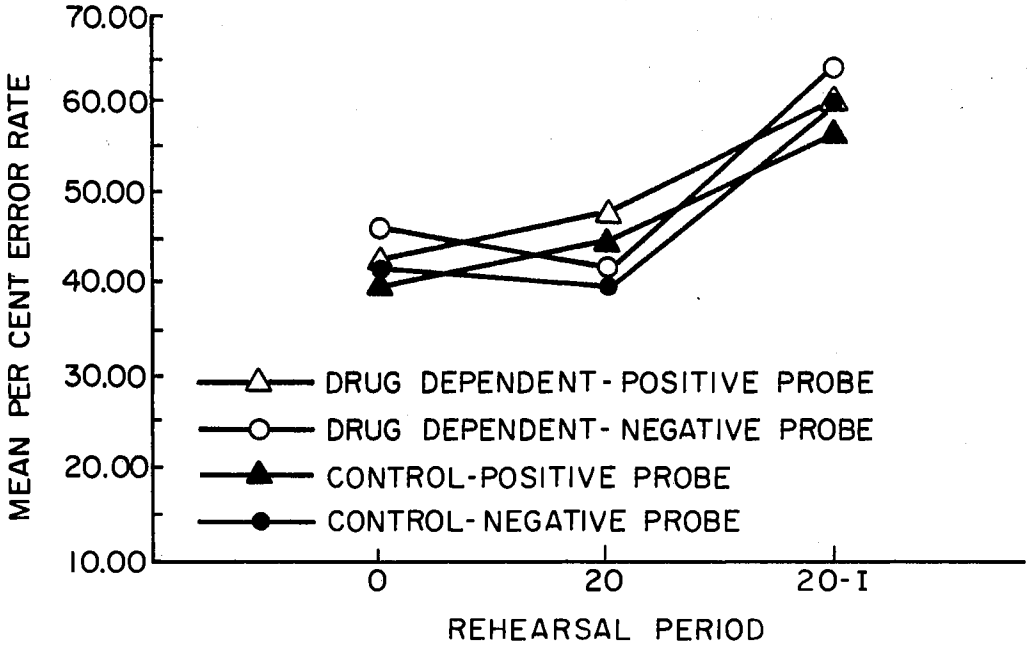

Figure 9. Error Rates by Rehearsal Period in Set Size Seven

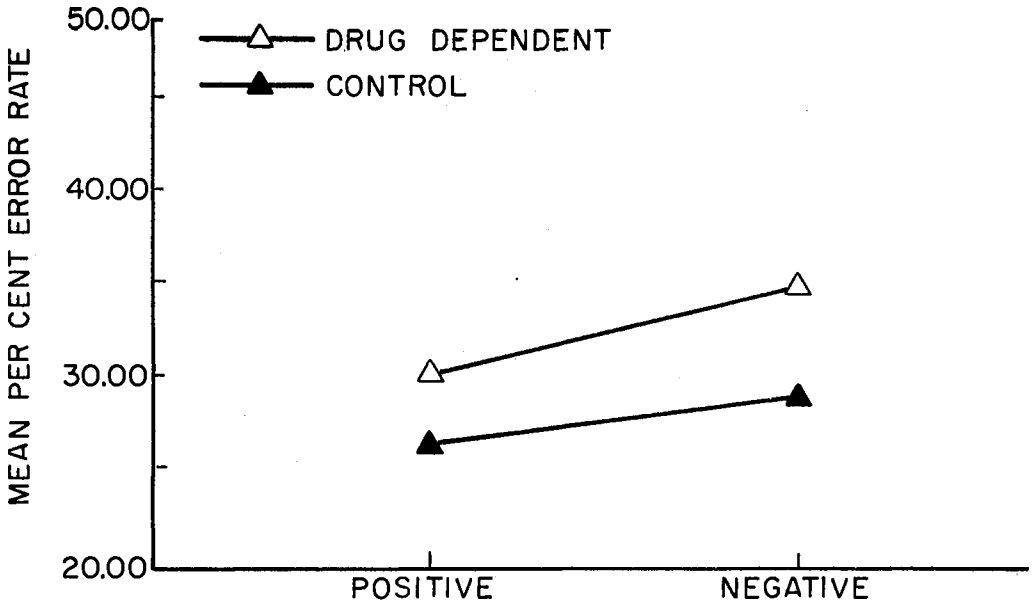

Figure 10. The Probe (P) by Subjects Type (C) Interaction of the Error Rate During the Rehearsal Period

CHAPTER V

DISCUSSION

It appears the results support one of the propositions of this experiment, namely, that post-drug dependent inviduals show short-term memory search differences when compared to non-drug dependent individuals. The differences were not in the stimulus encoding stage, as the y-intercepts of the least squares equations for each group of Ss were not different, but in the scanning rates. The post-drug dependents' scanning rates increased at a greater rate for each item scanned than the controls' scanning rates. The overall differences in scanning rates between the drug dependent and control were approximately 27 msec. per item on the positive probe (86 msec. - 59 msec.) and 19 msec. per item on the negative probe (71 msec. - 52 msec.), although there were actually no differences indicated between the probe types.

Possible explanations for the difference in scanning rates can only be hypothetical, but a couple of guesses may be made. Deficiencies in the orieting response can probably be ruled out because the post-drug dependent were able to respond to new stimuli as fast as the controls, though it is possible that the post-drug dependent showed relatively weaker orienting responses than the non-drug dependent, i.e., showed somewhat weaker attention to the stimuli. More-

over, there was no evidence that the orienting response was habituating for the post-drug dependent, since this group showed a consistent improvement in performance over periods.

The scanning rate difference possibly occurred because of differences in arousal mechanisms between the post-drug dependent and the controls. Kahneman, Tursky, Shapiro, and Crider (1969) have shown that differences in general level of arousal, or marshalling of sympathetic activity, are indicated by performance levels in problem-solving experiments. Some of the problem-solving experiments included mental arithmetic tasks of adding digits. If the post-drug dependent Ss in the present experiment had a longer latency for arousal, a more variable latency than the controls, or a lower level of arousal, this would probably affect the scanning rate for the drug dependent. The effect would most likely be an increase in the scanning rate. Previous research (Clark, 1970) has indicated that larger set sizes result in greater puillary dilation for non-drug dependent Ss, which reflects greater sympathetic stimulation. In the present research, the greatest differences in search times occurred in set size seven, followed by set size four, and were nearly non-significant in set size one.

Evidence of differences between the experimental group and the controls on autonomic nervous system functioning was not directly available. However, Martin and Jasinski (1969) have shown considerable changes in sympathetic nervous system functioning in post-morphine dependents lasting for 30 weeks (see section on Morphine-type Dependence above). Furthermore, collateral research done on some members

of the experimental group has indicated marked variability in the general level of arousal after 30 days of drug abstinence (Krug, 1972).

One proposition that was not directly supported by the results was that transfer of items from short-term memory to long-term memory would be poorer for the drug dependent than the non-drug dependent. Although the proportion of items transferred was greater for the controls at every set size and rehearsal period, there was no appreciable increase in the rate of transfer from the 0-sec. rehearsal period to the 20-sec. rehearsal period. Zero-sec. rehearsal periods were used to indicate the number of items in STM, while recall after 20-sec. of rehearsal was used to indicate the number of items transferred into LTM. It is possible, of course, that the 20-sec. rehearsal period was too short, and should have been extended. Sanders (1961) has found that 40-sec. rehearsal times are more resistant to interference than 20-sec. or 12-sec. rehearsal times. This indicates that the "permanence" of the trace is not complete at 20 seconds. However, the controls also showed no appreciable change from the 0-sec. period to the 20-sec. period, so apparently the rate of transfer was relatively equal for both groups.

It seems more plausible to propose that the difference in the recall rates between the drug dependent and controls was either in the STM, or in the stimulus encoding phase. The fact that the experimentals and controls can encode and prepare a response at the same rate seems to argue against the stimulus encoding hypothesis, although there is the possibility that the sensory trace in the encoding phase

was weaker for the drug dependent. A weaker trace would mean that items would be lost due to decay faster than if a stronger trace was present.

Perhaps a more promising argument would be that the post-drug dependent were not retaining as many items in STM as the controls. Items in STM decay rapidly and have to be maintained by constant rehearsal, so if there were a deficiency in the arousal mechanisms of the drug dependent, they may not have been able to rehearse as many times as the controls, and more items would have been lost. Another possibility is that the drug dependent were not retaining as many distinctive features of the stimulus array as the controls. There is some experimental evidence from the data to support this contention. The probe response, which is a recognition task, would require less features to perform, and the drug dependents and controls did not differ on error rates to the probe response; but they did differ on error rates to the recall of the items, which is a recall task and would require the use of more features. A possible cause for a difference in retention of distinctive features is not readily evident, but the level of arousal could affect it, as well as the historical nature of the individuals' perceptual-learning process. Crowder and and Morton (1969) point out that what is unique to human learning is its dependence on language, and the highly overlearned modes individuals have for dealing with language. It is quite possible that the two groups used in this experiment may have differed considerably in the development of their respective modes of articulatory representation.

These results do not tend to support Partington's (1940) contention that post-drug dependents are not able to recall new material beyond the simple memory span. Instead, the data seem to indicate that the drug dependent are not able to maintain a new impression as well as the non-drug dependent. A related possibility may be that the drug dependent are not able to extract as much, i.e., features from a new impression as the non-drug dependent.

It is also interesting to note the lack of difference between the drug dependent and control Ss on the interference task. In set size seven, both groups had an error rate of about 60%. In set size four, this error rate dropped to about 50% for both groups. Only at set size one was there any indication of a difference between the groups, and this was primarily limited to items recalled with a negative probe. Apparently the interference task had a fairly equal effect of producing a high error rate for both groups. The interference task may have come too soon after the probe to detect any differences between the two groups, because it had such a devastating effect on the memory trace for all Ss. A further experiment might allow a short five-second rehearsal period before the interference task in order to allow better consolidation of the memory trace. Stanners and Meunier (1969) have demonstrated increases in number of correct items recalled by allowing short rehearsal periods (five and ten seconds) before an interference task is required (see page 18 above).

Analysis of performance over periods showed some differences between the drug dependent and controls. In the STM task this was indicated by the significant subject by periods interaction. The drug dependents showed steady improvement over all periods with

decreases in their mean reaction times, while the controls reached their lowest RT's in period three, leveled out over period four and five, and showed a slight increase in period six. This might be interpreted to give further support for the hypothetical difference in arousal levels between the two groups of Ss, as it seems to be taking longer for the drug dependents to adapt to the experimental task. However, the difference was probably more of a learning difference, as it apparently took the drug dependent longer to learn how to perform the task. Since the controls reached their best performance level much quicker than the drug dependent, it is possible that if the experiment had been extended to include several extra periods, the drug dependents might have reached the performance levels of the controls. A further experiment should be conducted to determine if the drug dependent could reach the performance level of the controls, and how many trials it would take.

On the recall response measure, the period variable was not a critical factor. Subanalysis indicated periods were not a significant factor for the drug dependent, as they had a fairly even error rate over all periods, showing some slight improvement after the short break. The factor was significant for the controls and they showed their greatest improvement in the period before the break. The only notable difference between the two groups on the periods factor was a qualitative one: the post-drug dependent showed some slight improvement after the break, while the controls did not.

It may also be important to briefly discuss the significance of the probe factor. On the reaction time response measure in the STM task, neither the experimental group nor the control group showed any

differences on reaction times to the positive or negative probe. However, on the recall response measure, both groups of Ss recalled proportionately less digits under the negative probe conditions than the positive probe conditions, with the drug dependents recalling significantly less digits under the negative probe condition than the controls. This was indicated by the significant subject by probe interaction. Apparently the positive probe facilitates recall to some extent, probably by helping to consolidate the memory trace for at least the one digit the positive probe matches. The possibility also exists that the negative probe causes some sort of interference, and the drug dependent Ss do not recognize wrong responses as well as the control Ss.

The serial position analysis on the positive probes revealed no primacy effect for either group, but only a recency effect for both groups. One interesting result was the lack of a difference between the drug dependent and non-drug dependent on position seven in set size seven. This seems to indicate that the recency effect was relatively stronger for the post-drug dependent than the controls.

Of course, there is always a possible explanation for the results in terms of motivational differences between the post-drug dependent and controls. Some steps were taken to institute some control over this factor, most notably the use of paid volunteers. There is also some evidence from the data that the motivational levels were relatively equal for both groups: both groups of Ss encoded the stimulus items and prepared to respond at approximately the same rate. There were also non-significant differences in the errors to the probe responses for both groups. In addition, the steady improvement the

drug dependents showed in reaction times over periods suggests they were properly motivated. Their consistent response over periods on the recall response also supports this contention.

There seemed to be one procedural problem in this experiment that should be avoided in any repetition of the procedure in future research. For a few subjects the presentation of the stimulus items apparently came at too fast a rate, so they devoted most of their efforts to the scanning part of the experiment and sacrificed the recall part. This was noticed mainly by personal observation, and in some cases the reverse was true. This might explain why the recall results were so disappointing and, consequently, why the proposed deficiency in the transfer of items from STM to LTM was not detectable. A possible correction might be to lengthen the time between the presentation of the last item in the memory list and the probe item to five seconds instead of two seconds. This would give the Ss more time to rehearse the sets before the probe and recall responses. It may also be that the probe responses came so quickly that it interfered with the consolidation of the memory trace.

Another disappointing result was the failure to find large scale differences between the drug dependents and the controls on recall error rates in set size seven. Seven digits is near the upper limit of the short-term memory capacity, so both groups were probably operating on a relatively equal basis in this set size. A replication of this procedure would do well to use five or six digits as the upper limit. This might reduce the error rates for the controls and leave the drug dependent error rate the same, thus creating a situation where differences might be detectable.

The important conclusions from this study can be summarized as follows. Both non-drug dependents and post-drug dependent individuals can encode and prepare to respond to stimulus items in approximately the same amount of time. However, the scanning rates for both groups differs, with the drug dependent having a slower scanning rate than the non-drug dependent. Although the drug dependent recall less items than the controls, this does not appear to be due to a deficiency in transfer from STM to LTM, since the drug dependent do not retain as many items in STM as the controls, or they may retain enough of the features for recognition, but not recall. There are also learning differences between the two groups of Ss on the STM task. In the present experiment the controls reached their maximum performance levels after about 40 trials, while the drug dependent still show improved performance after 108 trials.

CHAPTER VI

SUMMARY

The purpose of this study was to examine the effects of drug dependence on memory processing. The 36 Ss (18 post-drug dependent and 18 non-drug dependent) were all paid volunteers, matched for age and I.Q. The Ss were presented 108 trials to test their short-term memory processing and transfer of items to long-term memory. The Ss were presented auditorially over headphones by a tape recorder, varying lists of monosyllable digits (1, 4, and 7) at one-second intervals, followed 1.5 seconds later by a single probe digit. There were equal numbers of trials for each digit list, as well as an equal number of positive and negative probes. Ss indicated the condition of the probe (positive or negative) by moving a two-way toggle switch. A positive probe was a member of the previously presented list and a negative probe was not. Ss were also required to recall the digit lists after three different periods of rehearsal: 0-seconds, 20-seconds, and 20-seconds with an interference task. The interference task consisted of going forward in the alphabet skipping each letter. The interference task was paced by a series of clicks at one second intervals.

Two response variables were measured. Reaction time to the probe digit toggle response was measured first on each trial to the nearest millisecond, followed secondly by the number of digits correctly recalled.

The major results of the study were as follows: first, the drug dependent and controls Ss did not differ in the time taken to encode the stimulus and prepare a response. This was taken as evidence against a deficiency in the orienting response and also as an indication of comparable motivation levels for the drug dependent and controls.

Second, the drug dependent and control Ss differed on scanning rates in STM, with the drug dependent showing increased scanning rates with increases in the number of items scanned. The possibility of differences in level of arousal, latency of arousal, and variability of level of arousal were offered as possible explanations for the results.

Third, although the drug dependent had higher error rates on the recall response than the controls, the results failed to support the proposition that the drug dependent would not transfer as many items from STM to LTM. Instead, the results seemed to indicate that the difference was in the STM. Two explanations were offered: deficiencies in arousal mechanisms for the drug dependent resulted in poorer maintenance of the memory items, which would probably result in faster decay of the memory trace. A second alternative explanation was that the drug dependent were not retaining as many stimulus features as the controls, which hampered them more on the recall task. On the recognition task (probe response), the drug dependent and controls did not differ. A possible cause for this difference was discussed in terms of past experience with articulatory representation.

Fourth, learning differences seemed to be indicated between the drug dependent and controls. The controls reached an asymptote of per-

formance during the third period on the reaction time task, while the drug dependent were still showing improvement on the sixth and final period.

Other less important results included: (a) Only a recency effect for both the drug dependent and control Ss (shown by a serial position analysis) was found. (b) On the recall task, only the controls showed any improvement over the course of the trials, while the drug dependent maintained a fairly even per cent error rate. (c) There were no differences between the positive and negative probes for either the drug dependent or non-drug dependent on the reaction time response measure, but both groups missed more digits in the negative probe condition on the recall task. The drug dependents missed significantly more digits on the recall task in the negative probe condition than the controls. Apparently the facilitatory effect of the positive probe benefited the controls more than the drug dependents. (d) The drug dependents and the controls did not show large differences on the interference task in per cent error rates, nor did they show large differences in per cent error rates in set size seven. The interference task apparently wiped out the memory trace fairly evenly for both groups. Lack of marked differences in set size seven was probably due to the fact that seven items is near the capacity for STM, and both groups were probably evenly affected.

No actual conclusion can be made pinpointing any one drug as the cause of these deficiencies, as the Ss in this experiment were multiple drug users. No conclusion can be made, either, about the permanence of these effects, or whether or not these differences might exist prior to drug usage. It is suspected that drug usage and the resultant life

style, which included everything from poor nutrition to extreme physiological reactions, are the causative factors in what is probably a temporary state.

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APPENDIX A

FLOW CHART REPRESENTATION OF STIMULUS MATERIALS PRESENTATION

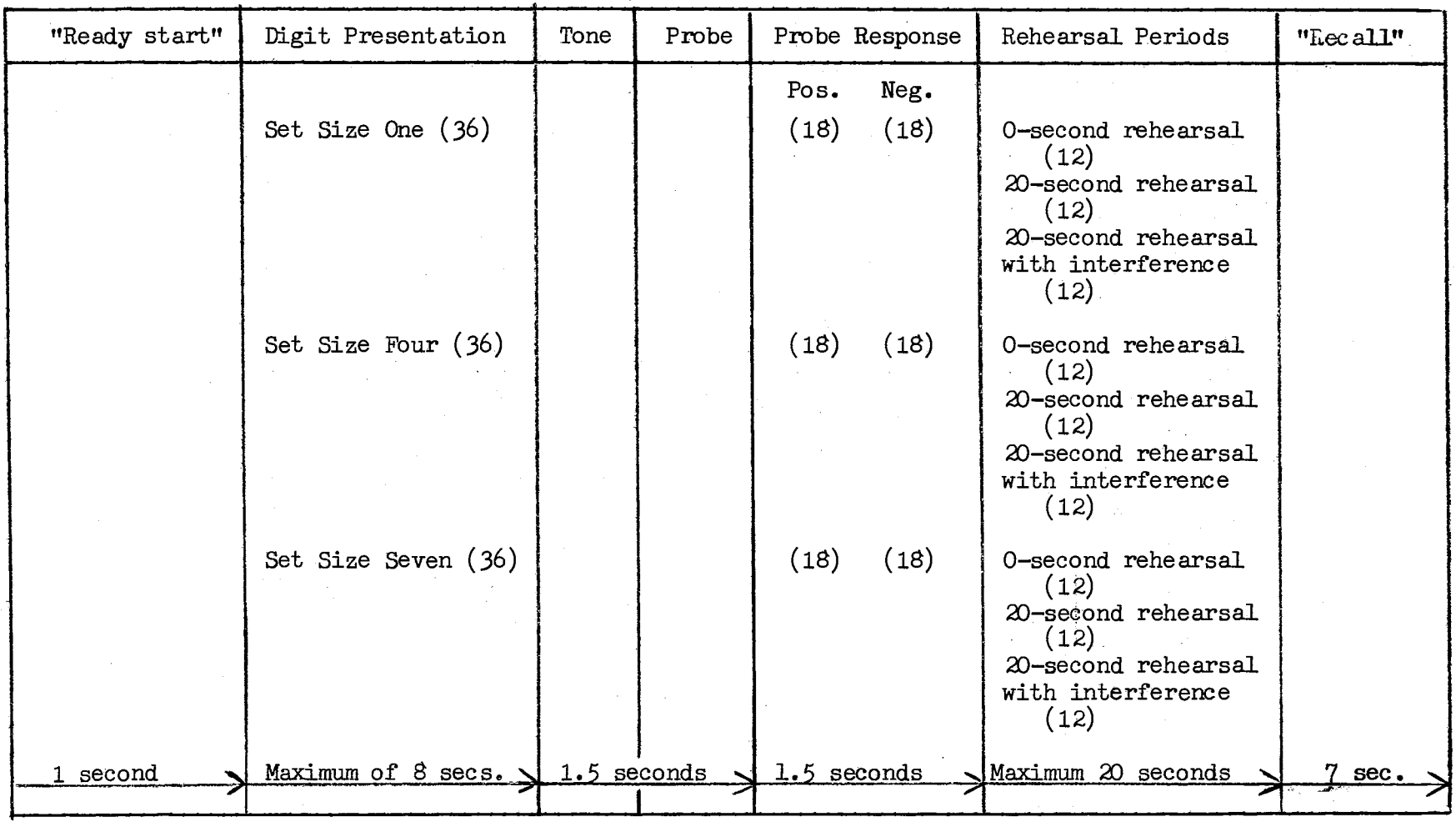

Figure 11. Sequence of Stimulus Presentation and the Number of Trials Under Each Condition

APPENDIX B

INSTRUCTIONS TO SUBJECTS

INSTRUCTIONS TO SUBJECTS

The following instructions were heard by all Ss over the tape-recorder before the start of the experimental trials.

a) You will be presented with varying digit lists of one, four, and seven in length;

b) After the presentation of the lists there will be a short bleep sound followed by another digit. If the digit after the bleep is the same as the one in the list, flip the toggle switch towards yes. If the digit is different, flip the toggle switch towards no. This is a reaction time task, so try and respond as fast and accurately as possible;

c) After the probe digit there will be a rehearsal period, where you will retain the digits and try and recall them later. The three rehearsal periods are 0-seconds, 20-seconds, and 20-seconds with an interference task. As soon as you hear the word "recall" over the tape, write down the digits in correct serial order on the sheet provided in front of you. On one-third of the trials, immediately after the probe digit there will be a letter presented on the tape. As soon as you hear the letter, start going forward in the alphabet, starting with that letter, and skip each letter until you hear the word "recall." If you end on the letter Z, go back and start with B, or if you end on Y, start with A;

d) Each trial will be preceded by the words "Ready Start" and there will be about ten seconds interval between each trial;

e) Here are some practice trials.

The following practice trials were presented to every S before the experimental trials began.

1. Digits presented: 1-4-7-9, Probe-9, Rehearsal Period-0-seconds.
2. Digits presented: 3-1-6-4, Probe-5, Rehearsal Period-20-seconds with interference.
3. Digits presented: 4, Probe-3, Rehearsal Period-20-seconds.
4. Digits presented: 1-6-3-9-2-8-5, Probe 9, Rehearsal Period-20-seconds with interference.

In addition, Ss were asked if they had any further questions before the experiment began. Ss were also told that the three dollar payment was contingent on following instructions.

APPENDIX C

AOV'S OF RECALL RESPONSE FOR TAPE DIFFERENCES

TABLE XIII

AOV OF CONTROLS RECALL RESPONSE FOR TAPE DIFFERENCES

Source	df	MS	F
Total	1943	1,125	
Between Ss	17	3,962	
L (tape type)	1	749	.179
Ss w. Grps.	16	4,162	
Within Ss	1926	1,099	
I (rehearsal period)	2	211,507	202.40**
IL	2	2,152	2.06
Ss w. Grps. x I	32	1,045	
S (set size)	2	381,479	232.75**
SL	2	1,348	.82
Ss w. Grps. x S	32	1,639	
T (periods)	5	1,784	5.14**
TL	5	633	1.83
Ss w. Grps. x T	80	347	
P (probe)	1	1,926	3.28
PL	1	5	.01
Ss w. Grps. x P	16	588	
IS	4	28,406	39.73**
ISL	4	421	.59
Ss w. Grps. x IS	64	715	
IT	10	559	1.56
ITL	10	1,021	2.84**
Ss w. Grps. x IT	160	359	
IP	2	3,523	7.09**
IPL	2	42	.09
Ss w. Grps. x IP	32	497	
ST	10	414	1.30
STL	10	648	2.04*
Ss w. Grps. x ST	160	319	
SP	2	1,798	4.28*
SPL	2	289	.69
Ss w. Grps. x SP	32	420	

TABLE XIII (Continued)

Source	df	MS	F
TP	5	401	1.29
TPL	5	272	.88
Ss w. Grps. x TP	80	310	
IST	20	366	1.13
ISTL	20	598	1.84*
Ss w. Grps. x IST	320	325	
ISP	4	2,110	5.51**
ISPL	4	1,111	2.89*
Ss w. Grps. x ISP	64	384	
ITP	10	264	.64
ITPL	10	225	.54
Ss w. Grps. x ITP	160	414	
STP	10	160	.44
STPL	10	240	.66
Ss w. Grps. x STP	160	354	
ISTP	20	417	1.18
ISTPL	20	376	1.06
Ss w. Grps. x ISTP	320	354	

TABLE XIV

AOV OF DRUG DEPENDENTS RECALL RESPONSE FOR TAPE DIFFERENCES

Source	df	MS	F
Total	1943	1,304	
Between Ss	17	5,178	
L (tape type)	1	10,897	2.26
Ss w. Grps.	16	4,821	
Within Ss	1926	1,270	
I (rehearsal period)	2	246,120	199.94**
IL	2	826	.65
Ss w. Grps. x I	32	1,281	
S (set size)	2	367,526	314.39**
SL	2	2,024	1.73
Ss w. Grps. x S	32	1,169	
T (periods)	5	1,183	1.37
TL	5	913	1.05
Ss w. Grps. x T	80	863	
P (probe)	1	16,621	27.25**
PL	1	51	1.08
Ss w. Grps. x P	16	610	
IS	4	17,945	16.34**
ISL	4	1,735	1.05
Ss w. Grps. x IS	64	1,099	
IT	10	492	1.00
ITL	10	605	1.23
Ss w. Grps. x IT	160	492	
IP	2	4,593	5.92**
IPL	2	1,068	1.38
Ss w. Grps. x IP	32	773	
ST	10	562	1.60
STL	10	503	1.44
Ss w. Grps. x ST	160	351	
SP	2	4,208	7.29**
SPL	2	70	.12
Ss w. Grps. x SP	32	578	

TABLE XIV (Continued)

Source	df	MS	F
TP	5	423	.69
TPL	5	661	1.09
Ss w. Grps. x TP	80	608	
IST	20	603	1.33
ISTL	20	807	1.77*
Ss w. Grps. x IST	320	455	
ISP	4	4,497	10.43**
ISPL	4	169	.39
Ss w. Grps. x ISP	64	431	
ITP	10	636	1.37
ITPL	10	632	1.37
Ss w. Grps. x ITP	160	464	
STP	10	881	1.69
STPL	10	1,290	2.48**
Ss w. Grps. x STP	160	522	
ISTP	20	541	1.03
ISTPL	20	600	1.14
Ss w. Grps. x ISTP	320	524	

VITA

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