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Cognitive, Perceptual and Motor Learning After Spontaneous
Recovery from Severe Traumatic Closed Head Injury:
A Microcomputer Approach

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A Thesis

in

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Arts at
Concordia University
Montréal, Québec, Canada

August 1987

Abstract

Cognitive, Perceptual and Motor Learning After Spontaneous
Recovery from Severe Traumatic Closed Head Injury:
à Microcomputer Approach

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This study was based on the hypothesis that learning occurs in
computerized cognitive-perceptual rehabilitation of closed head injured
(CHI) individuals past spontaneous recovery (i.e., beyond one year). A
second question involved what type of exercises (attention,
visuospatial, memory, auditory, or problem solving) promote learning
most. A third question involved whether learning improves as a function
of practice condition (massed or spaced). Twenty two CHI individual (19
males and 3 females) ranging in age between 19 and 50 years were
selected with level of education ranging from 5 to 19 years and interval
sincetrauma-to-project between 20 and 204 months. Prior to
rehabilitation central nervous system dysfunctions were assessed with a
battery of standardized neuropsychological tests. Rehabilitation
procedures involved cognitive-perceptual stimulation two hours twice
weekly for a period of six months, using 37 computerized exercises
selected from the Psychological Software Services Cognitive Perceptual
Remediation package. These exercises were designed to train speed of
response, visuospatial functioning, memory, audititory discrimination,
and problem solving skills. Results illustrated that performance
improved with practice on most exercises, and that massed practice was
not clearly superior to a spaced practice schedules. In descending
order the largest improvements were found on exercises involving
audition, visuospatial, problem solving, memory, and speed of response.

Trend analyses illustrated that a linear function best represents the trial main effect for auditory exercises but more complex functions explain the learning curves of the other exercises. Slope analyses illustrated that exercises for which the slope was in the right direction were equal for each practice condition. Performance slopes of 10 exercises in the massed condition and 6 in the spaced condition were in the unexpected direction. Analyses of variance demonstrated several significant effects of 6 practice, 17 trial, and 3 interaction effects. Analyses of covariance demonstrated that coma attributed significantly to 22% of the dependent measures, age to 9%, interval since trauma to 7%, and education to 4%. Coma, age, education, and interval since trauma were significant covariates which affected results on F5, F9, VS1, VS9, M1 (moves and steps), PS2 (moves and time), PS5 (wrong moves). These analyses confirmed two significant practice condition main effects, two interactions as well as multiple trial main effects. The results imply that this remediational package can result in amelioration without stagnation in CHI.

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A. Closed Head Injury

1. Epidemiology and socioeconomic importance of CHI

Historically, head injuries have resulted from war wounds. Road traffic accidents now account for approximately one-half of all CHI and 70 % of the head injuries that result in coma (Kalsbeek, McLaurin, Harris, & Miller, 1980). The prevalence of severe head injury corresponds to an estimated incidence of 200 cases per 100,000 persons (Kalsbeek et al., 1980). The estimated economic cost associated with each injury in 1980 was $4,114 (U.S.) per injured person (Kalsbeek et al., 1980). The long term cost, however, for severe cases may be staggering and presents a major public health problem.

The victims of these accidents are mostly men between the ages of 15 and 24 years (Annegers, Grabow, Kurland, & Laws, 1980; Fields, 1976).

The relationship between low socioeconomic class and head injury due to road traffic accidents has clearly been demonstrated (Kerr, Kay, & Lassman, 1971). Furthermore, alcohol consumption just prior to the injury is a predisposing factor in CHI (Field, 1976; Kerr et al., 1971).

2. Primary neuropathological sequelae of CHI

There is now little interest in the psychological symptomatology that accompanies focal lesion effects in CHI. Focal damage may be localized anywhere in the brain depending on the site of impact and contre-coup effects (Alexander, 1982). Research is now turned toward diffuse brain damage after CHI due to car accidents. Purely focal

lesions most often result from missile wounds, gunshot wounds or lesions at the point of "impact" (coup). On the other hand CHI can be considered to be a syndrome of diffuse brain damage. The term closed head injury is interchangebly used with "blunt" head injury (Rosenbaum, Lipsitz, Abraham & Najenson, 1978). The interaction between focal and diffuse damage produces neuropsychological profiles which may contradict the findings that focus primarely on one area of the brain (i.e., focal lesions).

Closed head injury may produce some regions of localized cortical contusion on the crests of the gyri and there are microscopic lesions and small haemorrhages spread throughout the brain (Miller, 1984), most frequently on the under-surfaces of the frontal lobes and around the pole of the temporal lobe (Alexander, 1982; Teasdale & Mendelow, 1984). Careful examination of subcortical areas also demonstrates macroscospic or sometimes microscopic lesions of the corpus callosum and upper brainstem (Strich, 1979) but these lesions are always associated with lesions in the cerebral hemispheres (Teasdale & Mendelow, 1984).

Closed head injury represents a family of craniocerebral injuries that result either from removal of momentum consequently leaving the skull relatively stationary, or imparting energy to the head in the form of momentum (Trexler, 1982). The physical forces that deform the skull and/or brain at the time of injury are: acceleration; deceleration; and rotation (Lezak, 1983). Acceleration occurs when there is an imparting of movement through space to the head. Deceleration occurs if there is a stoppage of movement; and rotation occurs when the head moves on its axis (i.e., rostral/caudal) (Trexler, 1982). Acceleration-deceleration mechanisms of CHI causes the greatest amount of brain damage (Alexander,

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1982). Sufficient stress may cause the skull to fracture which complicates matters due to possible infection and additional tissue damage (Lezak, 1983). Bone fragments can penetrate the brain tissue if the skull is depressed (Levin, Benton & Grossman, 1982).

The movement of the brain within the skull may further damage nerve fibers and blood vessels that sometimes stretch to the point of shearing. These are often in the form of microscopic lesions occurring throughout the brain. Significant lesioning occurs, when the moving brain strikes the skull, sustaining damage due to the inwardly projecting rugged ridge of the sphenoid bone (anterior temporal lobe), orbital plate (orbitofrontal areas), crysta galli or any skull irregularities (Alexander, 1982; Teasdale & Mendelow, 1984). The cortical areas mostly affected in this way are the frontal and temporal lobes.

Rotational velocity plays a significant role in producing loss of consciousness (Lezak, 1983). Loss of consciousness can occur at the time of injury due to the stress imparted on the reticular formation. Varying durations of unconsciousness reflect varying degrees of diffuse brain injury (Teasdale & Mendelow, 1984). Loss of consciousness beyond a day indicates elevated intracranial pressure on the reticular formation and consequently other brain structures sustain damage due to this elevation of pressure (Plum & Posner, 1980).

Levin, et al. (1982) claim that length of coma may serve as an index of the severity of brain damage. In 1000 patients where coma persisted for several hours the mortality was almost 50% (Teasdale & Mendelow, 1984). Coma therefore, may be a reliable indicator of severe

brain damage. For a more detailed discussion of the aforementioned mechanisms responsible for primary brain damage see Jennett and Teasdale (1981).

3. Secondary neuropathological sequelae of CHI

In addition to the mechanism responsible for primary damage to the brain, cerebral ischaemia, intracranial haematoma, brain swelling, and extracranial factors are responsible for further damage to the brain (Teasdale & Mendelow, 1984). Ischaemia, an interruption of glucose and oxygen to the brain, reduces the energy supplied to the brain. This leads to a deterioration in neuronal functioning and in severe or prolonged cases, permanent damage to the brain. Intracranial haematoma, bleeding within the skull, leads to clotting which in turn compresses the brain. Regardless of the type of haematoma (e.g., extradural or subdural) if it is not removed almost immediately its compressive effects on the brain will lead to pathological conditions (e.g., nerve deformation, brain distortion).

Brain swelling occurs when there is an increase in the volume of the brain itself. This may be a result of intra- or extracellular fluid elevation (oedema) or an increase in cerebral volume (engorgement). Brain shift and/or raised intracranial pressure may result as a consequence of brain swelling.

Extracranial factors involve injuries sustained to other parts of the body. Such factors may affect brain tissue through hypotension or hypoxia. A reduction in oxygen available in the lungs leads also to a reduction of the oxygen available in the arterial blood going to the brain. Hypotension on the other hand may result due to substantial blood

loss which leads to a fall in blood pressure and in extreme cases can lead to shock. Early management of secondary damage is crucial it outcome from head injury is to improve (Langfitt & Gennarelli, 1982). A more comprehensive and complete view of the body's physiological response to acute brain damage is given by Jennett and Teasdale (1981).

4. Neuropsychological sequelae of CHI

Beyond healing of secondary brain damage, recovery is not fully understood. Previous research has demonstrated that psychological impairments following CHI have a more deleterious effect on activities of daily living (adjustment) than any physical impairments (Bond, 1975; McKinlay, Brooks, Bond, Martinage & Marshall, 1981). In general, individuals with diffuse damage demonstrate numerous relatively poor performances. These include tasks requiring concentration and mental tracking such as sequential arithmetic and reasoning problems which require mental performance (Gronwall & Wrightson, 1981), information processing tasks (Wilson, Brooks & Phillips, 1982; see Benton, 1986 for a review), tasks of sustained, effortful or controlled attention (Little, Goldstein, Klisz & Rosembaum, 1985). The CHI individual may manifest chronic confusion and uncertainty of response, distractibility, and fatigue (Lezak, 1983). Memory problems are also major complaints (Brooks & Aughton, 1979; Levin, Grossman, Rose & Teasdale, 1979; McKinlay et al., 1981; Squire, 1986). Long after their injury patients often complain about dizziness, headaches and mental or emotional stress (e.g., anxiety, irritability) (Lishman, 1978). It is important to note that most severe CHI, individuals demonstrate more

than one pattern of impairment (Lezak, 1983). That is, they have symptoms of diffuse impairment, focal damage and some temporal and frontal lobe deficits. Secondary to CHI, the patient may have deficits in sensation, perception, conception, language and speech skills, visuospatial skills, memory, emotions, social skills, motor programming and response.

B. Theory of brain functioning and rehabilitation models

1. The neuropsychological model of A. Luria

Closed head injury results in very complex functional disturbances. As we saw above, the central nervous system damage in most cases encompasses lesions in the cortex, subcortex, and the interconnections between them. Any given theoretical model which attempts to explain brain functioning in CHI must make very fine distinctions of brain functioning and the interrelationships between various zones of the nervous system.

In the works of Luria there exists an all encompassing model of the functional organization of the brain (Braun, 1987). Luria's (1973) theoretical formulations of brain functioning include three brain areas which he called functional units. Only a brief summary can be presented here. The first includes brain stem and other subcortical areas and is involved in regulating tone. Level of arousal is accomplished by the reticular activating system (RAS) located in the brain stem. This structure has both activating and inhibiting mechanisms that can influence, in a general or specific way, the entire nervous system. The RAS has both ascending and descending neuronal tracts. Injury of this

area can greatly affect the functioning of other brain areas leading to decreased ability in responding, analyzing, recalling, et cetera.

The second unit consists of the surface of the brain which extends over the top to the side (temporal) area and over the posterior areas. These areas are involved in receiving, analyzing, and storing information. The primary sensory areas receive information. The secondary areas organize this information and process this information further. The tertiary zones integrate and combine information received from different areas.

The last unit includes the frontal areas of the brain and is involved in programming of actions, regulating behavior in relation to a program and verifying that the behavior is adequate for the program and meets the demands of the task. The motor cortex is the primary area of the third unit and serves in the transmission of motor impulses to the periphery (i.e., the final output rather than the motor programs). The premotor area is considered as the secondary zone and serves in programming and organizing movement. The tertiary (prefrontal) zone of the frontal lobe "play(s) a decisive role in the formation of intentions and programs, and in the regulation and verification of the most complex forms of human behavior" (Luria, 1973, p. 84). Mental activity according to Luria is a complex functional system which works through the combined efforts of all three brain units with each unit making its own contribution. A disturbance in the basic processes that hinders the working of a functional system may result in changes in behavior. These changes can be profound affecting one's ability to interact or function or can be very subtle or almost unnoticeable.

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2. Luria's model of cognitive-perceptual rehabilitation

In the area of neuropsychological rehabilitation, three models are commonly used (see Trexler, 1982 for a review). These are Luria's model, that of the New York University Institute of Rehabilitation Medicine (NYUIRM), and the Hawaii State Hospital model. We shall briefly review each one, a more comprehensive view being provided elsewhere (Braun, 1987; Horton & Miller, 1984; Trexler, 1982; Luria 1963, 1973).

According to Luria (1973) complex human behavior involves the orchestrated action of the three basic functional units of the brain. The term function in these instances refers to what Luria (1973) termed 'complex functional systems'. This emphasizes the dependence of complex activities (e.g., visual-motor coordination) on the operation of various smaller units. These smaller units are of necessity at various locations in the central nervous system and not strictly localized to one part of the brain. For example, visual perception encompasses retinal cells, optic tract transmission, operation of the visual cortex, of the tertiary visual cortex in the temporal lobe of hippocampal circuits for encoding, and so on. In order for an individual to accomplish a goal all the specific components of the functional system must be operational. However, Luria claims that individual systems can be flexible to a certain degree so that they can accomplish another system's goal. This 'anatomical reorganization' assumes that a previously uninvolved brain area can take over the lost function which was previously accomplished by the damaged center. According to this view the creation of new functional systems may be achieved by finding novel ways to implicate intact structures. One can adopt different

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approaches to accomplish such a goal (Luria, 1963). Luria (1963) recommended three different ways to accomplish this. 1) A region in one hemisphere could assume the role of its counterpart located in the other hemisphere, 2) an elementary system can substitute for a higher cortical system, 3) a higher brain area can subserve a lower brain system.

The first approach may be implicated when the injury completely destroys a functional system (e.g., loss of speech due to left hemisphere damage). The deranged system may be restored by having other systems (e.g., in the right hemisphere) assume the new role. This type of reorganization requires maximum conscious participation of the patient. For example, melodic intonation therapy applied to the aphasic patient was derived from this insight (Horton & Miller, 1984). In such a therapy the patient is asked to sing an overlearned song (presumably using his/her right hemisphere). The song is shaped into alternate lexical forms, and the melody is gradually faded out from overt phonation but is used by the patient covertly (presumably because his/her left hemisphere language centers are permanently destroyed) (Miller, 1980a).

The second approach for reorganization of functional systems implicates the involvement of elementary neurological systems to take over the function of a higher cortical area. Horton, Wedding, and Phay (1981) had a patient who was unable to discriminate phonemes (e.g., "b" and "p"). They trained him to utilize tactile feedback (e.g., putting his finger on his windpipe) to master an acceptable level of performance.

The third approach suggests that higher cortical areas may take

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over the function of a lower brain area. For example, if a patient is unable to finger tap on command, increasing the intellectual complexity of the task by asking him to count out loud, may enable him to accomplish the task (Horton & Miller, 1984). It is quite clear from Luria's suggestions that behaviors may be accomplished by reorganizing functional systems.

In addition to providing a remediational model Luria also proposed medical strategies to get around various dysfunctions. The one which he explained in greatest detail is called "De-Inhibition". This strategy assumes that some neurons involved in a function are not destroyed but in a state of inactivity or "diaschisis". Temporarily inhibited functions due to brain injury may recover spontaneously. In the period immediately following blast injury from a pressure wave, for example, the individual may experience a severe form of traumatic aphasia. After 6-7 months post injury what was initially a profound language disorder may now be cleared. Chemical mechanism (e.g., synaptic acetylcholine disturbance) may be altered temporarely due to oedema and may contribute to the inhibition syndrome. In some cases, relief may be achieved through drug administration (e.g., prostigmine) . Luria (1963) cites the case of a patient named Chern who received a head wound over the upper premotor area with a depressed skull fracture and subdural haematoma. Secondary symptoms post coma demonstrated a left-sided hemiparesis with the inability to carry out continuous sequential movements smoothly 2 1/2 months post injury. After six weeks of attempts to get Chern to move his hand a prostigmine injection was administered whereby more normal movements were achieved.

De-inhibition may sometimes, be accomplished by trying to change

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the individual's mental orientation. The inhibition in such a case is a cause of the person's attitude. For example, a patient appeared to be suffering from deafness and was asked to answer some questions which were written on a form but were also repeated verbally. The written legibility was slowly altered until the writing was totally illegible while keeping the auditorily presented questions constant. The patient kept answering the questions accurately in spite of the complete illegibility.

3. The New York model of cognitive-perceptual rehabilitation

Members of the NYUIRM have developed a systematic intervention program in the perceptual, cognitive, and interpersonal realms (Ben-Yishay, 1981) which puts emphasis on presenting tasks hierachically according to the level of difficulty. Their inspirations were derived from Luria's hierarchical brain organization. This intervention programme for cognitive remediation comprises five training modules administered in the following order: (1) orientation remedial module (ORM); (2) eye-hand integration with finger dexterity task hierarchy (DEX); (3) perceptual-cognitive integration "constructional" task hierarchy (CON); (4) visual information processing task hierarchy (VIP); (5) verbal, logical reasoning task hierarchy (LOG) (Horton and Miller, 1984). The number of modules are tailored to the individual's need and presented at a rate to maximize mastery (i.e., reach plateau). The above five modules are individually administered uniformly over a period of 20 consecutive weeks. NYUIRM patients are not limited to these five modules but are also involved in social skills-training, personal counseling,

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and community activities (see Ben-Yishay, 1981 for a detailed discussion). The NYUIRM patients have sometimes been referred to as an "elite" group for rehabilitation (Horton & Miller, 1984) since selection criteria include such things as: IQ > 80; independent self-care and ambulation; 12 months post trauma; no premorbid history of psychiatric problems, alcohol and drug abuse and many others (Ben-Yishay & Diller, 1981), and the program is extremely expensive.

4. The Hawaii Model of cognitive-perceptual rehabilitation

At the Hawaii State Hospital the staff of the neuropsychological service have systematized a rehabilitation procedure designed for cognitive retraining which they call "neurotraining". Neurotraining is the "... systematic application of psychological and neurological principles for the purpose of enabling individuals to overcome or compensate for deficits that result from central nervous system dysfunction" (Crain, 1982, p.85). Crain (1982) presents eight principles inspired by neurological and psychological theory: 1) there is plasticity of function within the central nervous system – due to the observation that varying amounts of recovery take place subsequent to brain damage; 2) cerebral cortical functioning may be halted or slowed as a result of injury – since the nervous system is highly maleable and adaptive, adaptation may be achieved through stimulation provided by the training program; 3) learning results from repeated activity which results in it being organized into a functional system of behavior – consequently, relearning pertaining to rehabilitation occurs through repeated practice of a task; 4) training must recapitulate the patient's original acquisition of a skill – rehabilitation efforts should

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therefore, emphasize developmental methods; 5) complex higher cortical functions involve multiple sensory modalities - pairing an intact modality with an impaired modality to accomplish a skill will eventually help re-develop the less intact modality; 6) training must promote and develop the processes underlying learning - the patient must be started at a level in which he can succeed in completing a task and gradually increase the difficulty of the task; 7) training is dependent on the degree to which the deficit has been specified - rehabilitation according to this principle implies that it should be deficit - specific; 8) crucial to neurotraining is consistent and direct feedback - graphing training results which produce learning curves will provide progress information to the patient.

The three above models are somewhat different and interrelated in their approach. Luria makes use of existing intact functions whereas the Hawaii group take a dysfunction approach. In contrast the NYU group use a hierarchical approach to remediation which is very much along the Lurian approach of hierarchical brain organization. Their ideas and formulations are amalgamations stemming from neurology, neuropsychological assessment, developmental psychology, behavioral psychology, cognitive psychology, learning theory, and education. Rehabilitation efforts may be maximal by the complementary use of these three models. The design of the present rehabilitation study comprises elements of all three of the models. A hierarchical approach will be used both in the stimulation of the nervous system (lower to higher order functioning) and in the presentation of the stimuli (from simple to complex). Five functional modules will be included. Constant

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feedback will be provided to the patients. Tasks will be presented to the patients in a fixed order in order to respect minimal requirements of nomothetic science and methodological goals of replicability and objectivity.

C. Recovery from CHI

1. Neurological recovery from CHI

Many rehabilitation programs in traditional settings have focused on the recovery of physical abilities (Alan & Finlayson, 1983; Bond & Brooks, 1976). Admission to rehabilitation programs for cognitive rehabilitation was unheard of in those settings despite the fact that head injury patients were in dire need of cognitive rehabilitation (Bracy, 1983). Only when the head injured individual showed signs of aphasia, hemiplegia or a very obvious disorder was he likely to be admitted for treatment in a rehabilitation center. For many years an aura of pessimism has existed regarding the possibility of rehabilitating individuals that had sustained brain damage. The view was that once a neuron died there was nothing that could be done for the individual involved. This view, however, had to be revised in light of publications of various studies presenting more optimistic data. Brain injured individuals have a multiplicity of physical and cognitive deficits (Kreutzer & Morrison, 1986). Rehabilitation, therefore, should not be limited to the recovery of physical abilities but also viewed as an attempt to restore mental functions. Rehabilitation may vary from global to specific focus and from complete to minimal amount of recovery achieved (Crainek 1982). The type of rehabilitation program therefore

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that seeks to restore neuropsychological functions will likely vary depending on the patient's functional capacity.

Neuropathological changes following CHI have great implications for neuropsychological recovery (Levin, et al. 1982). There are many variables that may influence the outcome of neurological recovery (Miller, 1984). These include such variables as age, time elapsed since injury, coma (Lezak, 1983; Miller, 1984). With comparable lesions younger subjects show less behavioral disruption and better recovery. In CHI patients under forty years of age and who had been in a coma more than 24 hours (Gilchrist and Wilkinson (1979) demonstrated that age was not predictive of degree of recovery but that length of coma was.

Field (1976) further suggested that rehabilitation outcome may be influenced by emotional sequelae. That is, individuals with realistic self-appraisal fare better than those with diminished self insight. Ben-Yishay (1983) and Miller (1984) support Field's view that the individual's awareness of his or her problems may affect cognitive remediation. Groswasser, Mendelson, Stern, Schechter and Najenson (1977) found that behavioral disturbances as well as unawareness of disability are severe obstacles to a successful outcome in rehabilitation. Such disturbances were found to persist 30 months post injury. Other studies suggest that preinjury characteristics as well as severity of injury are primary determinants of outcome (see Levin et al., 1982 for a more detailed discussion). Moreover, the severity of the injury appears to vary with recovery in that the greater the severity the less optimistic is recovery. Severity has often been measured using as an index duration of coma or length of unconsciousness.

2. Neuropsychological recovery curves in CHI

There are various questions which a researcher is faced with when plotting recovery curves. Should the individual learning curves be averaged? In averaging the learning curves trial-to-trial variations due to individual differences would be smoothed out. In this case precision is gained at the expense of qualitative understanding of the individual's performance. That is, the averaged curve would not be characteristic of any individual subject. Although it may be possible not to average the curves with a few subjects ($N < 5$, as in Newcombe, Marshall, Carevick, & Hiorns, 1974) it may not be feasable when working with larger groups since this may simply confuse the picture. On the other hand, averaging the data makes it difficult to use these curves in clinical settings as a reference of recovery potential. Nonetheless, a learning curve may be a convenient way to summarize the results (i.e., make sense). In such instances where data have been averaged and standard errors of deviations plotted it is best to then look at individual subject's deviations from the averaged curve. It has been suggested that the shape and form of the learning curve may depend on different things such as past experience, the nature of the task, and so on (Hulse, Egeth & Deese, 1980).

Attempts have been made to describe the course and rate of recovery after head injury (Hiorns & Newcombe, 1979). Newcombe, et al., 1974) were concerned not only with the rate of recovery, but at which point in time post injury recovery reaches a plateau. To investigate this phenomenon they assessed word reading in three patients

with acquired aphasia. The plotted error curves as a function of time demonstrated that recovery in reading reached a plateau on the twentieth week post injury in two of the three patients observed. It is possible that since the third patient was tested after the point in time where improvement is at a minimum, no significant recovery was observed. It was suggested that this patient's potential for recovery was limited due to his premorbid poor reading skills in school. It has been suggested by, others (e.g., Miller, 1984) that reading tests may manifest appreciable practice effects. Consequently the degree and rate of recovery in such cases may be exaggerated.

Van Zomeren and Deelman (1978) investigated recovery over a long period post injury. The main aim of the study was to construct recovery curves for simple and choice reaction time over a period of two years post injury as a function of severity. Length of coma was used as an index of severity. Fifty seven CHI subjects subdivided into three groups (> 1 week unconsciousness = severe; >1<7 days = moderate; <60 minutes = mild) were given 10 practice trials followed by 40 experimental trials with interstimulus intervals of five seconds where each stimulus was preceded by a warning signal. The subjects were tested at 6, 12, 18, and 24 months intervals. They found that the slopes of the recovery curves of each group were different for simple and choice reaction time tasks. The mild group appeared to reach a plateau sooner post injury, whereas the severe group kept improving their choice reaction time two years post injury. It was concluded that choice reaction time is a more sensitive discriminator of severity.

In a subsequent study, Hiorns and Newcombe (1979) plotted recovery curves for writing, reading and spelling of patients where attempts were

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made to remediate these processes using paper and pencil techniques. A characteristic curve of recovery was demonstrated with most improvement taking place in the early phase of recovery. The pattern of the recovery curves for these three tasks however, showed variations in impairment. That is, reading, writing, and spelling are differentially affected by central nervous system dysfunction.

Roberts (1976) was concerned with physical recovery and plotted recovery curves for various motor functions after cerebral insult. Although the recovery curves were similar to those reported by Newcombe and colleagues (1974), unlike the latter, Roberts averaged the data of all the subjects.

3. Efficacy of perceptual-cognitive rehabilitation in CHI and some methodological considerations

Most previous studies looking at recovery have focussed upon cognitive functions in isolation such as information processing (Van Zomeren & Deelman, 1978), language (Kertesz & McCabe, 1977), memory (Lezak, 1979), or reading (Newcombe et al. 1974). Performance on any task may be impaired for more than one reason (Levere, Davis, & Gonder, 1979). For example inability to accomplish a serial addition task may be adversely affected by attention problems (Brouwer, Brettschneider & Deelman, 1984; Van Zomeren, 1981), memory problems, language problems, motivation and/or any combination of these. The degree to which a single behavior will be normal (or pathologic) may depend on its interactions between different cognitive functions (Ben-Yishay & Diller, 1981).

Since lesions rarely if ever have just one behavioral effect, it is

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important to keep this in mind in studies which investigate only one function. It seems therefore that one should attempt to investigate multiple functions in CHI since a given function under observation may often miss the real nature of the deficit. Ben-Yishay (1983) claims that "... remedial training will have to encompass the entire range of functions, ranging from basic attentional functions through the various psychomotor and perceptual motor integrative functions..." (p.6).

Other studies have considered recovery during the first year after injury, that is, in the acute phase (Brooks & Aughton, 1979; Kertesz & McCabe, 1977). Previous studies suggested (see Newcombe et al., 1974) that the rate of recovery is most rapid during the first three months post injury. During this phase spontaneous recovery is at a maximum (Brooks et al., 1984) and may have occurred in any case. If recovery declines as time elapses then it may be possible that treatment outcome is an artefact of spontaneous recovery. For example, when comparisons between 42 treated aphasics and 27 untreated aphasics were made, it was found that there were no statistical differences between these two groups (Vignolo, 1964). Kertesz and McCabe (1977) also found no significant differences between the treated and untreated groups for aphasia.

Studies that have investigated recovery past the spontaneous recovery period have found significant improvements in recovery two to three years post trauma (Sands, Sarno, & Shankweiler, 1969; Prigatano, Fordyce, Zeiker, Roueche, Pepping, & Case Wood, 1984). Although the acute phase approach addresses the issue of whether cognitive retraining implemented early in the recovery process enhances cognitive recovery, this approach does not usually control for spontaneous recovery (Malec,

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Jones, Rao, & Stubbs, 1984). The proposed study will address the issue of the effects of cognitive retraining (i.e., effects on learning) after spontaneous recovery.

A number of variables may affect outcome and therefore must be taken into consideration (Miller, 1984). These include such variables as age, handedness, time elapsed since injury, coma, and so on (Lezak, 1983; Miller, 1984). Given comparable lesions, younger subjects show less behavioral disruption and better recovery. Moreover, the severity of the injury appears to vary with recovery in that the greater the severity the less optimistic is recovery. Severity has often been measured using as an index duration of coma or length of unconsciousness. With respect to time elapsed since injury, as time increases recovery declines. This may be due to the artefact of spontaneous recovery.

D. Computers in Head Injured Populations

1. Advantages of computers in perceptual-cognitive rehabilitation

In less than a decade, with the increasing popularity and low cost efficiency of the micro-processor, cognitive rehabilitation of the brain injured patient has been carried out by many clinicians (Alan & Finlayson, 1983; Ben-Yishay, 1983; Ben-Yishay, Rattock, & Diller, 1979; Bracy, 1983; Gianutsos, 1982; Laatsch, 1983; Lynch, 1983, 1984a, 1984b; Malec, et al., 1984; Perez, Brown, Cooke & Grabois, 1980; Ticer, 1985) and rehabilitation centers (Bracy, Lynch, Sbordone & Berrol, 1985; Diller, Ben-Yishay, Gerstman, et. al., 1974; Ensley, McLean, & Lervark, 1984; Crain, 1982) with the aid of computers. There may be several

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reasons why computers are becoming increasingly popular in rehabilitation. For instance unlike humans, computers: are reliable in presenting repetitive given tasks (Alan & Finlayson, 1983) whereas it becomes monotonous for a person; are capable of presenting tasks hierarchically with fine difficulty increment; provide immediate feedback; are reliable in the collection of data; are easily available, are inexpensive and therefore easily available for use by the patient's family. The diversified software programs which may be purchased are easily available on the market (e.g., Bracy, Sbordone, Gianutsos, Smith, Katz, etc.) (for a review see Braun, 1987). The type of micro-processor mostly used in rehabilitation, at the present time, is the Apple II series. The most versatile of the Apple II series, which also uses the largest number of rehabilitation software, is the Apple II-e.

Contrary to popular belief about the 'triviality of most' software, several rehabilitation software programmes should not be undersold as trivial and only useful in passing time. They are sophisticated and deal with complex strategy and even abstract thinking. For example, they require that the user concentrate, formulate programs of action and evaluate the consequences of those actions. Additionally they are menu driven, provide detailed feedback, contain excellent graphics, and seem neuropsychologically sound.

2. Efficacy of computer rehabilitation in neuropsychology

Although there are many anecdotal and individual case studies (Lynch, 1984a) of the efficacy of cognitive rehabilitation with a computer, there are no controlled group studies (Bracy, et al., 1985;

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Gianutsos, 1982).

Lynch (1983) presented data of 4 patients (one right frontal cerebral vascular accident victim (CVA), one cerebellar tumor, two diffuse head injury) who received computer assisted remediation. The subjects were required to play "Caverns of Mars". In this game the player, with the help of a joystick, must manoeuver a spaceship downward through a twisting cavern and must try to avoid crashing into the walls or other obstacles. One of the diffuse head injured patients showed no ability to learn the task despite extensive training (100 games). In addition he failed the 600 millisecond barrier for the first five session but reached a consistent level of under 500 milliseconds after 15 sessions. It is obvious, from the plotted learning curves of the subjects, that there was an improvement in performance on game software (e.g Caverns of mars) but in software which involved speed (e.g., Simple Visual Reaction, see Appendix 2) there did not appear to have been any learning in the diffuse head injured patient.

Bracy (1983) presented two case histories of patients who received one year of computer assisted cognitive rehabilitation/therapy. Measurements taken at the end of each period were contrasted for (non)treatment effects. Both the traumatic head injured patient and the stroke patient were reported to have had IQ gains exceeding 20 points. Since these patients were three years post injury, it is unlikely that the gains in IQ could be attributed to spontaneous recovery. These selected cases represent, of course, unusually efficacious outcome.

Malec, et al. (1984) investigated what effects practice has on sustained attention in 10 patients with craniocerebral trauma. To evaluate the effectiveness of video games (e.g., Target Fun) on

sustained attention they used a randomized double crossover design. A treatment period was alternated with a non-treatment period twice in succession. Measurements taken at the end of each period were contrasted for (non)treatment effects. As a group the subjects showed some improvement in sustained attention with treatment, although there were no significant differences found between the "no games" and "games" conditions (i.e., no treatment vs. treatment). Since each subject acted as his/her own control any improvement could not be attributed to spontaneous recovery. In this study, contrary to previous findings, there was no relationship found between improvement and age, sex, length of coma, or extent of brain damage as indicated by CT scans. Sarno and Levita (1971) also found age, education and initial performance not to correlate with change.

More recently the effectiveness of an attention training program, which was a hierarchical multilevel treatment program, assisted by the microprocessor was evaluated by Sohlberg and Mateer (1987). Four subjects (1 CVA, 1 gunshot, 2 CHI) received between seven and nine remediational sessions per week using various computer tasks such as tasks of visual stimulus discrimination. Tasks were arranged in hierarchies of difficulty based on complexity and speed requirements. It is not clear, however, how long each session lasted nor which tasks were used in each, nor how many times each task was performed. These authors concluded that all four subjects demonstrated significant gains in attention. It is not possible, however, to evaluate this contention since it is not reported how statistical significance of dependent measures was established (i.e., which tests). Unfortunately this study

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does not present data on the performance measures of the computer tasks used during remediation.

An attempt was made to illustrate a neuropsychological approach to the principles and practice of cognitive remediation and the efficacy of microcomputer-assisted remediation using one single case study (Finlayson, Alfano & Sullivan, 1987).

The patient was a righthanded single female with a B.A. degree who had sustained a severe head injury in a motor vehicle accident. She was unconscious for 19 days. The age of the patient and the type of head injury were not reported. The rehabilitation of this patient was carried out 11 months post injury (i.e., during spontaneous recovery) and covered a period of only 12 weeks/twice weekly. The duration of each session was not reported nor was it clear how many computer exercises were used in total, although four were described, nor how often these exercises were repeated per session. The patient was reported to have had significant improvements in rehabilitation. There were, however, no results reported on which to base this claim. Furthermore, these authors claim that the performance of a single task may be used as a baseline. It would be preferable to use multiple baselines with which to evaluate performance in other aspects of rehabilitation. The gains made on one computer exercise is hardly adequate in making generalizations to independent test performance. Moreover, it is difficult to determine whether these results support the potential efficacy of microcomputer-assisted cognitive remediation since remediation was given during the period of spontaneous recovery.

Methodological difficulties plaguing the above studies, are such that scientific research is still required to demonstrate efficacy of

cognitive-perceptual rehabilitation assisted by a microprocessor.

E. Learning

1. Human learning: spaced versus massed schedules

According to learning theory (Hull, 1937) there are two crucial conditions if an organism is to learn. These conditions are temporal contiguity of events and contingent reinforcement. Temporal contiguity refers to events which occur close together in time, these events tend to be associated or learned. Reinforcement refers to a form of reward or feedback given to the organism following some behavior. Temporal contiguity may also be interpreted as a form of continuous repetition of a task in a short period of time or what is most commonly referred to by conditioning paradigms as massing of practice. The effects of massed practice may help to increase the strength of the memory trace since sporadic (i.e., not repeatedly reinforced) learning (spaced practice) may result in the integration of the learned material with other traces.

The empirical law stating that "spaced practice" is superior to "massed practice" has been found to hold under nearly all conditions in normal populations (Osgood, 1953). Essentially a massed practice schedule requires that a given task be performed repeatedly, with a predetermined number of trials, without rest periods between successive trials. In contrast a "spaced practice schedule" is one where a given task is performed at predetermined time intervals.

Although spaced practice has been espoused as a better learning condition, some studies seem to contradict this methodology. For example, Lorge (1930) compared various tasks using a spaced or a massed

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practice condition. Subjects performed tasks of mirror drawing, mirror reading and code substitution with one minute and one day practice intervals. Their results indicated that massed practice was as beneficial as spaced intervals. One criticism of this experiment was that there were only two extreme time intervals investigated and that perhaps the most beneficial schedule may have been between one minute and a day.

Kientzle(1946), however, did not find any significant differences when varying the time between tasks beyond 45 seconds. Subjects were required to print upside down as many letters of the alphabet possible in time intervals of 15, 30, 45, 60, 75, 90 seconds, or seven days. There were no significant gains between the first and tenth practice trials when the time distribution interval went beyond 45 seconds. That is, subjects reached a plateau at 45 seconds without subsequent gains in performance. Interpolated rest periods may have beneficial effects (i.e., maximal) only within short time intervals. That is, gains in performance are maximal when the repetition of a task occurs in less than 45 seconds.

In a subsequent study Hovland (1940) investigated the superiority of retention under massed and spaced practice. It was expected that when the same criterion of mastery (e.g., one perfect repetition) of a task is used in both conditions then massed practice would be superior. The results demonstrated that in the spaced condition the slope of the learning curve was flatter than in the massed condition in the first few minutes. This implies that learning improved to a greater extent when in a massed condition in the first few minutes. What is also apparent from

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these learning curves is that beyond a few minutes there is a deterioration in learning rate in both conditions. In point of fact, the learning curve in a spaced condition demonstrated a constant deterioration of learning rate across trials over time. Contrary to previous findings, the above studies therefore, do not support the idea that spacing of practice both facilitates learning and leads to superior retention in normal subjects.

2. Practice schedules in the clinical setting

Clinical reports indicate that it is possible to enable a significant portion of brain damaged individuals to live autonomously and in some cases to return to gainful employment (Ben-Yishay et al., 1979, Scherzer, 1986). Such projects, however, involve a multidisciplinary team and can be very costly. With the advent of the microprocessor there may be some promise in permitting a more economical means of remediating cognitive dysfunction. There are two important considerations to be made in rehabilitation of CHI, repetitive stimulation and feedback.

A massed practice may be a very useful method in providing reinforcement contingencies and repetitive stimulation. When the patient has severe neuropsychological impairement a massed practice schedule combined withreinforcement would be appropriate to help form associations between behavior and the response to that behavior (Wood, 1984). Further, Golden (1978) stresses that maximum effects may be achieved by providing immediate clear, accurate feedback to the brain injured patient, and this could be made possible through the use of computers.

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Moreover, neuropsychological sequelae after CHI such as impaired attention and memory deficits mean that particular attention is required in the style or way reinforcement is given to the patient. Optimal conditions must be provided if the patient is to make the association between behavior and reinforcement. Reinforcement may be in the form of performance feedback, praise, encouragement, or simply giving the individual attention. Preferably, reinforcement should be given as immediately as possible and in a highly salient manner to ensure that appropriate associations are made (Wilson, 1983).

Johnston and Diller (1983) investigated error evaluation ability of right hemisphere brain lesioned patients who had received perceptual-cognitive retraining. The results emphasize the importance of making patients aware of their errors when performing a task. Their subjects tended to underestimate the errors made. As well, the patients were not able to predict when or where mistakes occurred. Similar results were obtained by Wolfe, Dennis and Short (1984) where CHI subjects also could not accurately evaluate their own performance. Furthermore, contrary to Dolon and Norton (1977) these results indicated that the subjects with impaired performance failed to profit from feedback. That is, in spite of the feedback they did not change their strategy in order to successfully accomplish the task. Feedback in this case involved cues (i.e., "yes", "no") given by the experimenter regarding categorization of cards on the Wisconsin Card Sorting Test. This type of feedback may be too sutle for a CHI individual. According to Crain's (1982) eight principles of neurotraining, without consistent feedback and reinforcement the brain damaged patient may become overwhelmed by the

environment and by his or her limitations. Any and all means of reporting back to the patient his results should be used (Luria, 1973). It is also preferable that reinforcement be given as often as possible over an extended period in order to help consolidate the behavioral response (Wood, 1984).

Dolan and Norton (1977) investigated the effects of reinforcement on acquisition and retention in brain injured patients. They had three groups (Contingent material & verbal reinforcement; contingent reinforcement; no training) perform in a picture and question condition. The pre/post test results demonstrated that the material and praise groups performed significantly better than the control group on post-test measures in spite of the fact that all groups were equivalent on pre-test. The authors stressed the point that when working with such a population, psychologically and economically speaking it may be more effective to use verbal praise (reinforcement) alone since group one and two did not differ in post-test performance.

The method which espouses the process of repetitive stimulation may help the behavioral response. The literature stresses that CHI individuals manifest severe short term memory (Squire, 1986) and short attention span (Malec et al., 1984). Repetitive practice may lead to a deeper level of processing that may improve the original behavioral response. This procedure is also less likely to result in a loss in the strength of association between the stimulus and response. This form of learning may also diminish the possibility of forgetting or extinction of such responses. It is also possible that repetitive stimulation may help the behavioral response to generalize to other situations which are less controlled. The scope of the present study, however, will be

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limited to "intra-task" and will not deal with generalization to other measures. That is, generalization measures are relevant to consider and will be dealt with in a subsequent project. The relative efficacy of massed practice versus spaced practice in remediative training has not been assessed. Such a methodology has not been attempted with closed head injured individuals, be it with or without computer assisted remediation. It is only superficially, by looking at studies that had patients perform a task repeatedly, that perhaps some knowledge may be gained about the efficacy of massing of practice in head injured populations.

Glasgow, Zeiss, Barrera and Lewinsohn (1977) presented two case studies in which they attempted to improve memory retention. Of most relevance here was the case where a repetitive strategy and the PQRST (Preview, Question, Read, State & Test) strategy were used to improve academic skills of a 22 year old female who had sustained left hemisphere brain damage in an automobile accident 3 1/2 years prior to rehabilitation. The PQRST method produced retention of the majority of the material (85%) half a week later. One week later memory retention had dropped to 83%. The first method of retention (i.e., repetition strategy), although clearly inferior to the second method, helped improve recall after a one week interval by an average of 13%. The second case that was presented is not reviewed here since it has no relevance to this study.

Glisky, Schacter and Tulving (1986) attempted to ameliorate memory in CHI patients with the help of a microprocessor. Similar to Glasgow et al. (1979), the results demonstrated that a good deal of new knowledge

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may be acquired through extensive repetition. The study conducted by Van Zomeren and Deelman (1978) discussed above also used repetitive stimulation. Learning kept improving in the severe group even beyond spontaneous recovery.

The use of repetition (massing of trials), therefore, appears to be a useful strategy to facilitate retention. Maximal effects may be observed by intensive and coordinated presentation of tasks since CHI individuals demonstrate a multitude of residual difficulties especially in learning and remembering (Prigatano et al., 1984).

It is reasonable to believe from the above literature review that to obtain the best cumulative effects of cognitive remedial training, the presentation of stimuli should be organized such that the relatively simpler tasks (e.g., tasks of reaction time) be presented first and more complex tasks (e.g., problem solving tasks) be presented toward the end of the program (Ben-Yishay, 1983; Ben-Yishay & Diller, 1981; Luria, 1963; Lynch, 1984a). Such a remediational model which requires that easier and less complex tasks be presented and mastered first is more likely to be accepted by the head-injured individual, since greater task demands would probably be discouraging, leading possibly to low self-esteem, feelings of inadequacy, discouragement and so on with ultimate consequences of attrition. More important however, is the fact that if the integrity of the nervous system has been disrupted or compromised by head trauma, such that the most fundamental functions of attention/concentration are affected, then it would not be reasonable to expect improvement of residual higher order functions. It is important to keep in mind that such a remediation model precludes randomization of the presentation order of the tasks.

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The most appropriate software package available which is also hierarchical in nature, and explicitly derives its inspiration from Luria's model, is the Psychological Software Services Cognitive Rehabilitation Package (PSSCRP). This package contains software diskettes which comprise tasks of attention, visual-motor coordination, audition, memory, and problem solving. These software vary in complexity and/or speed of presentation.

The primary goal of the present study was to investigate whether learning occurs in computerized cognitive-perceptual rehabilitation of CHI individuals, and if yes, whether learning improves as a function of practice condition (i.e., massing of practice versus spacing of practice). It was hypothesized that learning would be facilitated by massing of practice compared to spacing of practice. Other goals included the investigation of: which function best describes the learning curves; whether variability is stable between trials as a function of condition; of which type of exercises (attention, visuospatial, auditory, memory, problem solving) promotes learning the most.

These goals are formulated in the following null hypothesis form:

1. The slopes of the exercises will be flat.

2. There will be no difference between the slope steepness of the massed versus spaced practice conditions.

3. There will be no interaction between the practice condition factor (i.e., spaced vs massed condition) and the repeated factor (i.e., trials 2 versus 10) of the ANOVA.

4. The type of function (e.g., linear, quadratic, cubic, etc.)

which best describes the learning curves in the massed versus spaced conditions will not differ.

Subjects

The study comprised 22 individuals who had sustained severe closed head injury (19 males and three females). This disproportion of the sexes was due to the fact that the majority of victims, due to car accidents, are males between the age of 15 and 25. This sample therefore, was representative of the population of traumatic closed head injury patients with confirmed brain damage of severe magnitude. Six subjects were outpatients from the Lethbridge Rehabilitation Center, 11 subjects were referred by Maison Lucie Bruneau, and 5 subjects were recruited with combined efforts (i.e., advisors and graduate students) from the Montreal General Hospital (n=1), Regie d'accident automobile du Quebec (n=2), and word of mouth (n=2). Of the 22 subjects, 2 did not complete the entire rehabilitation protocol. One suffered medical complications and the other lacked motivation.

Since the literature seems to suggest (see above) that variables such as age, education, coma, and so forth may have an effect on rehabilitation outcome it was decided to obtain measures on these variables for statistical analysis. Moreover, in order to further demonstrate neuropsychological cerebral lesioning, standardized neuropsychological tests were administered (see below). The following information was therefore, collected from the subjects:

-Demographic information included age, education, employment status, interval since trauma and pre-testing in the present project, drink (i.e., alcoholic) consumption during the study, and illicit drug consumption during the study (see Table 1).

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Table 1

Descriptive variables for all subjects combined (Means=M, standard deviation=SD, Range=R)

DEMOGRAPHIC		All subjects		MEDICAL		All subjects
Age(year)	M	30.27		Skull Fracture	YES	13
	SD	8.55			NO	9
	R	19-50				
				Brain surgery	YES	9
Education	M	11.14			NO	13
(years)	SD	2.74				
	R	5-19		Symptoms reported		
				by subject	M	18.5
Interval since	M	79.14			SD	6.1
trauma (months)	SD	58.43			R	9-30
	R	12-204				
				Medication	YES	11
Employment	YES	0		(Dilantin)	NO	11
	NO	22		during study		
Alcohol used	NONE	6		NEUROPSYCHOLOGICAL		
during study	FEW	14				
	<2/day	2		Vocabulary	M	19.18
	>2/day	0		(raw score)	SD	6.24
Other illegal	YES	5		Percentage	M	33.29
drugs	NO	17		deficits	SD	15.39
MEDICAL				Most Functional		
				Hand	Right	12
Coma(days)	M	106.82			Left	10
	SD	196.48				
	R	7-960				

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-Medical information included coma duration, presence or absence of skull fracture, brain surgery, type of medication consumed during study, and number of symptoms (off the neuropsychological questionnaire, see Appendix 1) reported by the subject (see Table 1).

-Neuropsychological assessment included determination of the subject's most functional hand, from the test scores on the Finger Tapping Test, Dynamometer Test, and Tremometer Test, WAIS (Wechsler, 1981) vocabulary score, and percentage of deficiencies on 34 neuropsychological test scores (see Table 2). The dependent measures obtained from the most functional hand was used so as to permit making interpretation of dependent measures between and within subjects in terms of the "best hand performance" rather than "dominant hand performance". Of course, there were cases in which these coincided.

Inclusion / Exclusion Criteria

The subjects were selected according to the following criteria: 1) Having passed a minimum of three days in a coma; 2) Were between 18 and 50 years of age; 3) Were able to understand verbal instructions and were able to verbalize; 4) Had the ability to mobilize self, with the help of a cane, crutches or wheelchair; 5) Did not have premorbid psychotic symptoms or severe behavioral problems; 6) Were not epileptic or were seizure-free during the study; 7) Were autonomous with respect to elimination; 8) Were available for a period of six months twice weekly, two hours per session; 9) Gave their consent to participate in this research project and agreed to the other standard ethical concerns (e.g., confidentiality, right to withdraw at any time, etc.); 10) Had neuropsychologically and neurologically confirmed cerebral lesions.

These criteria were determined from an initial one hour interview with the subject using rating scales as well as from the neuropsychological questionnaire. One was completed by the experimenter/subject and one by a family member or custodian (see Appendix 1) at pre-test and at post-test. Further information about the subjects was obtained when required through the institutions and hospital medical reports obtained with the subject's consent.

Materials

Six micro-processors were used to present the software to the subjects. These included two Apple IIe; two Apple IIc; one Apple II+, and one Apple II clone. Each computer was equipped with a cathodic color monitor. There were six Atari joysticks as well as four sets of Apple II+ game paddles which were available to facilitate manual control in the execution of a task. Four joystick / paddle - computer connections were made possible through Sirius joyport connections while two had direct computer connections.

A diversified selection of software programs were selected from the Psychological Software Services Cognitive-perceptual remediation package (for a description and norms, see Braun, Baribeau, & Ethier, 1987). These were contained on 5 Apple II diskettes named Foundations, Visual-Spatial, Memory, Auditory, Problem Solving. The Foundation software package comprised 12 exercises focusing on attention, shifting, discrimination, initiation, inhibition and making differential responses (see Appendix 2). Visual-Spatial included nine exercises designed to improve skills in visuomotor integration and visual perception (see Appendix 3). The Memory package included 9 exercises focusing on verbal memory (sequenced, nonsequenced, and reversed) and spatial memory (see·

Appendix 4). In the Auditory package two exercises designed to strengthen auditory tone discrimination were used (see Appendix 5). Finally the Problem Solving software comprised five exercises. These were exercises focusing on executive functions (e.g., planning) (see Appendix 6).

Coding sheets were used to record the following: dates and duration of rehabilitation per session (see Appendix 7); which and how many times each exercise was performed (see Appendix 8); performance on each exercise. The subject's individual cumulative performance record on each exercise was recorded on a separate sheet which also provided visual feedback to the subject (see Appendix 9).

A battery of standardized neuropsychological tests was used to assess central nervous system dysfunction (see Table 2). The rationale in the choice of these tests was as follows: the objective of the testing should serve two goals. First, performance on a large range of problematic behavioral dimensions in CHI was to be measured including attention, sensation, perception, motor control, memory, cognition, and language. Second, the integrity of cerebral zones clearly circumscribed was to be determined in the brain in such a way as to allow subsequent neuroanatomical interpretation of obtained results. In both cases it is obvious that standardized tests were required, and their ability to localize had to have been already established in the neuropsychological literature. The target zones of the brain in the present project are the left and right frontal, temporal and parietal lobes. The occipital lobes were to be superficially evaluated since their role is primarily sensory, therefore, less pertinent in the type of practical intervention

Table 2

Neuropsychological Tests Included in the Battery

_____

Related to Integrity of the Frontal Systems
        Design Fluency
        Benton C.O.W.A.T. (Word Fluency)
        Finger Tapping
        Dynamometer
        Kolb Sequential Praxia
        Wisconsin Card Sorting

Related to Integrity of the Temporal Lobes
        Russell Delayed Recall.
        Dichotic Listening
        Ekman Facial Affect
        Verbal-contextual
        Audiometer

Related to Integrity of the Parietal Lobes
        Benton Right-Left Discrimination
        Tactual Performance
        Aesthesiometer
        Single and Double Simultaneous Stimulation
        Semmes Body Placement

Related to the Integrity of the Occipital Lobes
        Perimetry
        Visual Acuity

Auxiliary tests
        D^2
        Vocabulary
        Token
        Tremometer
        Humour
        Corpus Callosum
        Harris Lateral Dominance
        Reaction Time

_____

Note. For detailed description of this battery, see Braun & Baribeau,

1987.

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in this project.

Procedure

Interview-Initially each subject was seen in private interview,
lasting approximately one hour, by a graduate student in which the
neuropsychological questionnaire was completed by the interviewer with
the help of the subject. In addition the subject was informed about the
objectives and procedures of the study, exactly what their participation
involved (e.g., days per week) and the type of rehabilitation therapy
they were to receive given that they met all the inclusion criteria.
(S)He was informed that participation in this study was voluntary, (s)he
had the right to discontinue or withdraw from this project at any time
(s)he wished to do so. It was explained that there were no risks of
psychological or physical harm involved in this project. The subject was
told that (s)he was guaranteed full confidentiality of his/her files
with the exception of professionals and graduate students involved in
the project. Since performance feedback was provided throughout the
project there were no debriefing instructions necessary. The subject was
then asked to sign a consent form (see Appendix 22). Following this
interview the subject was scheduled according to availability for
neuropsychological assessment. The same questionnaire was completed by a
parent or custodian of the subject independently.

Neuropsychological assessment-The neuropsychological assessement
lasted between two to three days (in most cases consecutive days)
depending on the subject's speed and capacity to perform. Testing began
at 9:30 A.M. until 4 P.M. with intermittent rest periods as well as an
hour lunch break. If the subject was unable to endure testing all day

due to fatigue he or she was allowed to leave and return the following day. The subject was assessed for perceptual, cognitive, sensory, and motor functions. The order of testing (i.e., neuropsychological tests) was such that there was a variability of difficulty and duration of the tests in order to prevent overtaxing the subject (see Appendix 11). Test administration and instructions provided to the subjects were in accordance with standard recommended test instructions as specified in the test manuals.

Rehabilitation procedure- The subject received two hours of rehabilitation (which constituted one session) twice weekly, for a period of six months. The time of day of rehabilitation was counterbalanced to control any possible time of day influence. That is, half the subjects were required to present themselves for rehabilitation, the first session in the week in the morning and the second session in the week in the afternoon, and vice versa for the following week.

The subject was randomly assigned to a 'massed' (i.e., 10 consecutive repetitions of a given exercise) or a 'spaced' (i.e., one presentation of a given exercise per session) schedule for the first exercise. Subsequent exercise schedules alternated with the first. For example, suppose subject one performed exercise one in a massed schedule (randomly determined) then exercise two was performed in a spaced schedule and exercise three in a massed, and so on. Subject two's schedule depended on subject one's first exercise schedule, so that if it was massed for the first subject then subject two performed exercise one in a spaced schedule and exercise two in a massed schedule and so forth. An exercise was defined as one specific computer program from a given package (e.g., Simple Visual Reaction 1). A trial constituted of

completion of a given exercise.

The subject was seated comfortably, together with the experimenter, in a well lit and ventilated room which contained the computer. The subject was instructed on how to perform the first exercise which was presented by the microprocessor (i.e., Simple Visual Reaction 1) and if there were no questions proceeded in completing the given exercise. Performance measures, mean errors, variance, and speed of execution were recorded by the experimenter on specific recording sheets (see Appendix 12). Besides the immediate performance feedback that was provided by the microprocessor the subject was shown a graphed performance chart after completion of a trial. Following completion of exercise one (trial one) the subject was either instructed on how to accomplish completion of exercise two or repeated exercise one (i.e., if the condition was massed) and the same procedure was followed for each trial. The date and duration of rehabilitation were recorded at the end of each session (see Appendix 7.) as well as the completion of each exercise (see Appendix 12).

All subjects began with simple to complex exercises in the Foundation software pakage. Upon completion of a packge the subject proceeded to complete the next package (i.e., Visual Spatial package then the Memory package followed by the Auditory package and finally the Problem Solving package). Each package had to be completed before going on to the next. The number of sessions required to complete a package varied with the subject's ability and continuity of sessions.

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Results

A: <u>Descriptive analyses for all subjects in all conditions</u>
<u>(Means, Z scores, and slopes)</u>

The exercises used in this rehabilitation program did not all yield the same dependent measures. Table three (see Table 3) presents the means and standard deviation for all the dependent measures on all exercises for the two practice conditions. The N does not always add up to 22 or is not equal for both conditions for various reasons. 1) Sometimes a subject did not want to repeat an exercise more than once per session due to fatigue, boredom, or motivation, consequently for that exercise the condition would be spaced instead of massed. 2) If more than one dependent measure was missing for an exercise it was not entered in the analyses. 3) Cases were deleted from the analyses if the dependent measure was beyond limits ($\pm$ 3 SDs). 4) There were subjects who were apraxic of an upper limb and these subjects could not perform an exercise that required the use of both hands (N=2). 5) There were exercises that were too complex for some subjects and this affected the N (e.g., PS3 level 2). The SD for some exercises was sometimes in excess of the $\bar{X}$ or close to it (see for example VS6, PS2). In order to permit descriptive comparisons between disks as well as exercises all the dependent measures were converted to standard scores (i.e., Z scores). To determine whether performance improved across 10 trials (T1 to T10) as a result of repetitive stimulation, performance slopes for all exercises were calculated always using trials as the X variable and the dependent measure as the Y variable. The equation for the calculation of the slope was as follows:

$$b = \frac{\Sigma XY - (\Sigma X \Sigma Y / N)}{\Sigma X^2 - (\Sigma X)^2 / N}$$

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Table 3. Means (X), Standard Deviations (SD) of performance measures and number of subjects(N) per condition for each exercise.

| Exercise | Massed | | | | Distributed | |
	N	X	SD	N	X	SD
F1(time)	11	.40	.14	11	.42	.11
F2(time)	10	.46	.10	12	.39	.12
F3(time)	10	.53	.16	12	.57	.16
F4(time)	9	.65	.25	13	.52	.12
F5(time)	10	.71	.24	11	.83	.38
F6(time)	9	.41	.16	13	.32	.11
F7(time)	10	.66	.18	10	.78	.29
F8(%)	11	81.29	13.07	10	92.30	4.14
F9(%)	10	73.98	28.07	12	70.55	28.25
F10(time)	8	.44	.21	14	.34	.09
F11(time)	10	.61	.39	11	.67	.23
F12(time)	10	.46	.15	12	.34	.08
VS1(time)	12	47.22	27.83	10	65.11	23.87
VS2(time)	8	126.68	71.60	14	74.44	27.61
VS3(errors)	12	77.09	46.55	10	155.70	105.28
VS4(errors)	8	390.95	128.33	13	263.24	84.90
VS5(errors)	14	161.96	79.83	6	251.47	113.65
VS6(hits)	10	19.62	23.21	12	63.83	70.52
VS7(%)	11	77.93	13.72	10	69.61	7.95
VS8(%)	10	68.64	10.64	12	73.27	11.37
VS9(time)	12	419.68	169.21	8	661.13	331.60
M1(moves)	14	57.37	25.35	8	74.39	16.64
(steps)	14	5.70	.90	8	5.9	.82
(time)	11	123.55	110.38	8	230.19	133.47
M2(words)	9	12.49	5.04	12	13.40	6.18
M3(tones)	11	14.91	9.48	9	15.38	7.91
M4(score)	10	5.27	4.81	10	4.82	5.34
(time)	8	219.89	56.31	6	181.72	39.95
M5(level)	10	3.12	.48	12	3.22	.67
M6(level)	10	4.11	1.28	12	4.77	.79
M7(errors)	11	3.63	.34	10	3.49	.82
(level)	11	2.95	1.11	10	2.22	.81
M8(level)	9	2.16	.62	12	2.38	.50
M9(level)	12	3.85	1.15	9	4.00	1.09
AD1(error)	10	14.15	9.15	11	6.47	3.40
AD2(error)	11	8.79	5.10	8	11.65	6.78
PS1(errors)	10	8.89	4.98	10	5.31	3.06
(time)	10	256.91	176.74	10	158.50	32.08
PS2(moves)	9	57.61	31.82	10	52.86	15.19
(time)	10	355.62	280.15	9	595.59	478.14

Table 3 continued

PS3(level 1)	10	2.02	2.06	9	.90	.80
(level 2)	4	14.10	7.01	5	14.26	13.48
PS4						
(wrong moves)	12	4.46	3.88	7	10.76	9.75
PS5						
(wrong moves)	9	10.81	5.40	12	9.03	4.93
(delay)	8	10.37	26.86	11	15.15	44.05
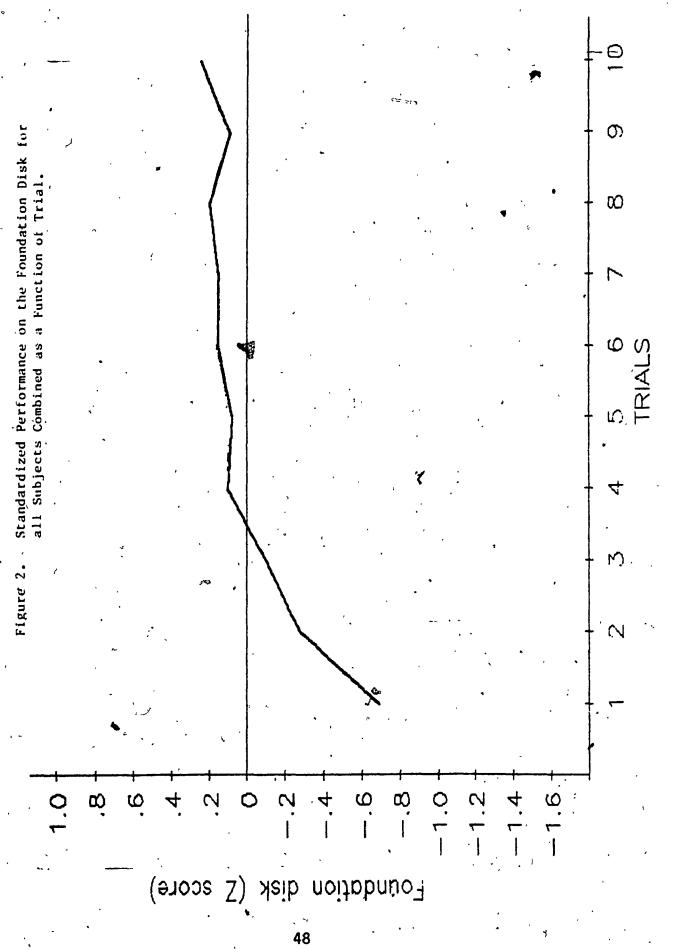
(Minium & Clark, 1982). The larger the slope (b) coefficient-the steeper the slope-the better the performance. All dependent measures were converted into standardized scores (for each exercise) and then a mean was calculated for each trial. Graphed performance curves were ascending if there were improvements in performance. To maintain consistency reaction time curves were inverted. The analyses of standardized scores illustrated that the subjects' performance improved from trial to trial when all dependent measures across all exercises were combined (see Figure 1). Whereas on T1 performance was at $Z = -.9$ from the mean, by T10 performance improved to $Z = +.4$. Improvement in performance, however, was not similar on all the disks. The most improvement across trials, determined by the slope coefficient, in descending order occurred on the Auditory disk, Visuospatial disk, Problem Solving disk, Memory disk, and Foundation disk (b = .259, .158, .15, .125, .076 respectively).

1: <u>Descriptive</u> <u>statistics</u> <u>for</u> <u>all</u> <u>subjects</u> <u>on</u> <u>the</u> <u>Foundation</u> <u>exercises</u>

On the Foundation disk the subjects reduced RTs from T1 to T10 (see Figure 2). Decrements in RTs, determined from the slope steepness from standardized scores, were greatest in descending order for F12, F6, F3, F5, F1, F10, F4, and F7 (b = .262, .145, .121, .098, .069, .065, .052, .016 respectively). For exercises F2 and F11 the slope was in the opposite direction, consequently RT increased instead of decreasing across trials (b = -.01 and -.1 respectively). The mean RT fluctuated considerably from trial to trial from the best fitting line for these two exercises.

Exercises F8 and F9 were not speeded exercises but rather looked at
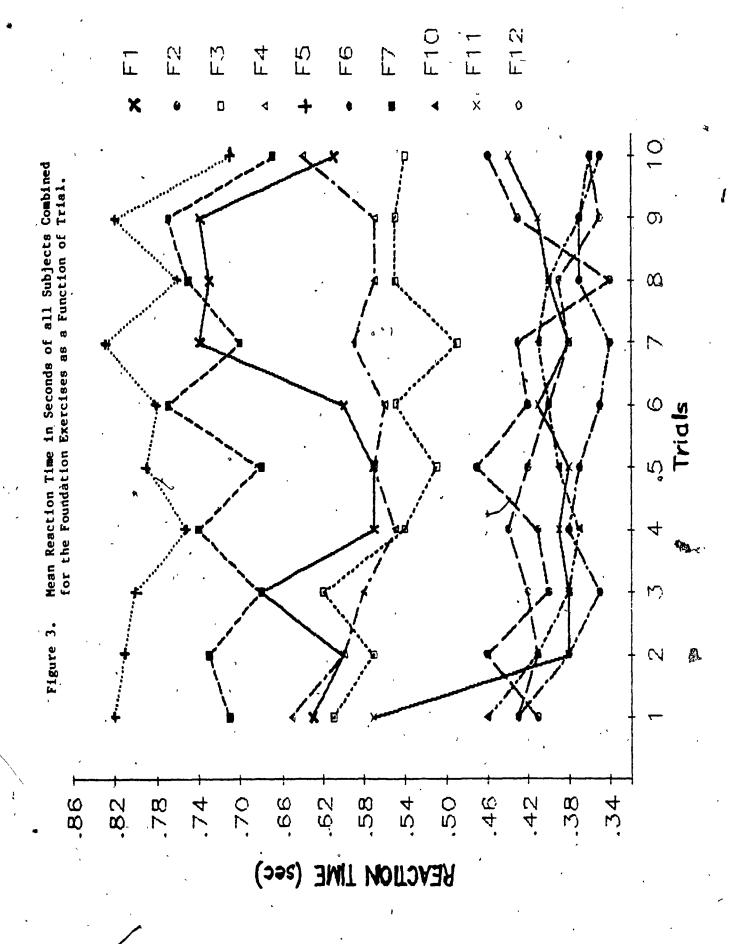
Figure 1. Standardized Performance Measures on Combined Exercises for all Subjects as a Function of Trial.

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Figure 2. Standardized Performance on the Foundation Disk for all Subjects Combined as a Function of Trial.

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the hit rate. The slope was steeper for F8 than for F9 (b = .216 and .192 respectively).

Foundation exercises that were speeded also provided dependent measures of the variability between stimulus presentation and response. These variances were also converted to standard scores for all subjects combined and performance slopes were calculated. The steepness of the slopes illustrated that variability of response improved most from trial to trial in descending order on F5, F10, F1, F12, F6, F3, F2, and F7. For exercise F4 the subjects were unable to stabilize their response from trial to trial, the single best predictor for this exercise was the Y mean (i.e., $Z \doteq 0$). For exercise F11 variability increased instead of decreasing, the slope was, therefore, in the opposite direction.

The mean score for each trial of a given exercise was calculated for all subjects combined for descriptive purposes. The mean RT on T1 varied across Foundation exercises from a mean of .41 s to .81 s. After having completed 10 trials of these exercises RTs decreased, depending on the exercise, from between .36 s to .63 s (see Figure 3). The exercises that produced similar RTs were F1, F2, F6, F10 and F12. The exercise that required the most processing time was F5 (range = .50 s).

There was great variation in response from trial to trial for exercises involving RT (see Appendix 13). This variation is not obvious from Figure 2. The greatest decrement in RT (T1 minus T10) was observed for F1 which was a reduction of 120 ms. This exercise also resulted in the least variation of responses across trials, ranging between 380 ms on T2 to 430 ms on T10. The mean response on T1, however, was 560 ms. The exercise that resulted in most erratic responses from trial to trial was F7. For this exercise the subjects' RT fluctuated between 770 ms on

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Figure 3. Mean Reaction Time in Seconds of all Subjects Combined for the Foundation Exercises as a Function of Trial.

T6 to 670 ms by T10.
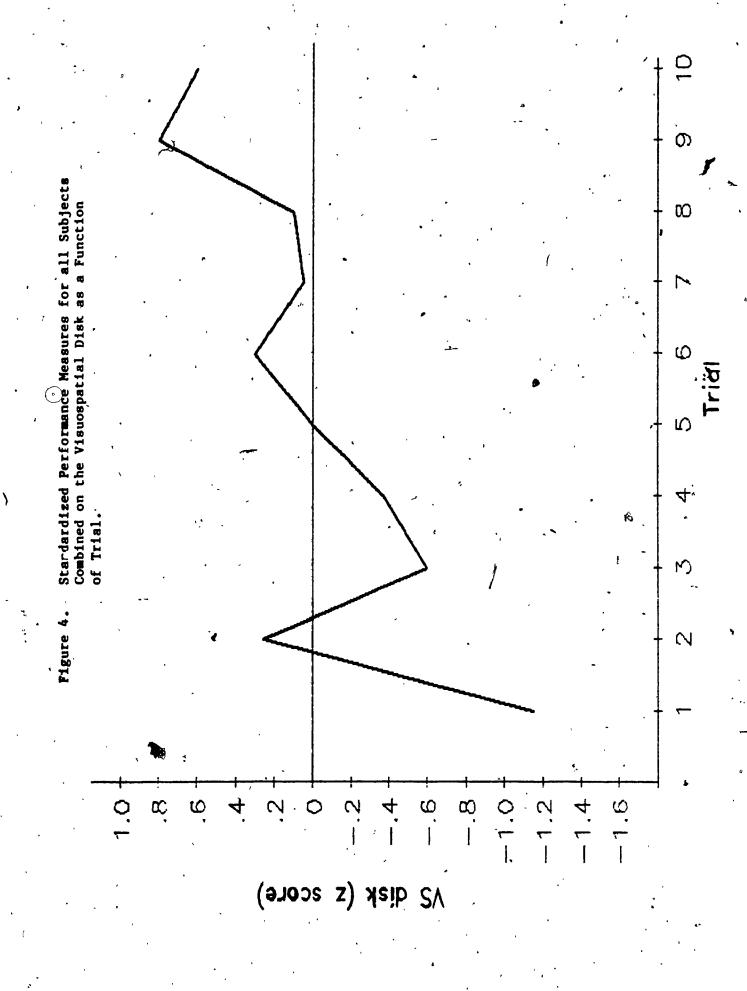
For non-speeded exercises (i.e., F8 and F9) there was a steady improvement across trials. The hit rate for F8 ranged from 78% on T1 to 91% on T10. For F9 the hit rate ranged from 60% on T1 to 76% by T4 and down to 74% by T10.

2: <u>Descriptive statistics for all subjects on the Visuospatial exercises</u>

Performance on all exercises combined improved from T1 (Z = -1.1) to T10 (Z = +.6) (see Figure 4). The slopes calculated on standardized scores for the Visuospatial exercises illustrated that the greatest improvement in performance occurred on VS1 (exercise completion time) and VS6. These two exercises had the same slope coefficient (b = .264). The exercises that resulted in less improvements in performance compared to VS6 and VS1 in descending order were: VS9, VS5, VS2(time), VS8, VS4, VS7, and VS3 (b = .212, .193, .113, .105, .099, .096, and .075 respectively).

The mean time required to complete VS1 decreased from T1 ($\bar{X}$ = 70 s) to T10 by 22 s. In a maze of higher complexity (VS2) the mean time required to complete the exercise improved from 112 s on T1 to 98 s by T10. For VS3 the subjects reduced the mean error rate from 136 on T1 to 104 by T10. On a more complex tracking exercise (VS4) the subjects' mean error rate declined from T1 ($\bar{X}$ = 329) to T10 by 26 errors. In a subsequent tracking exercise that required the use of both hands (VS5) the subjects reduced errors from T1 ($\bar{X}$ = 231) to T10 by 53 errors.

The mean percentage accuracy for VS7 improved from T1 ($\bar{X}$ = 72%) to T10 by 3%. On VS8 subjects improved their mean percentage accuracy from 65% on T1 to 74% by T10. The final exercise on this disk (VS9) resulted

Figure 4. Stardardized Performance Measures for all Subjects
Combined on the Visuospatial Disk as a Function
of Trial.

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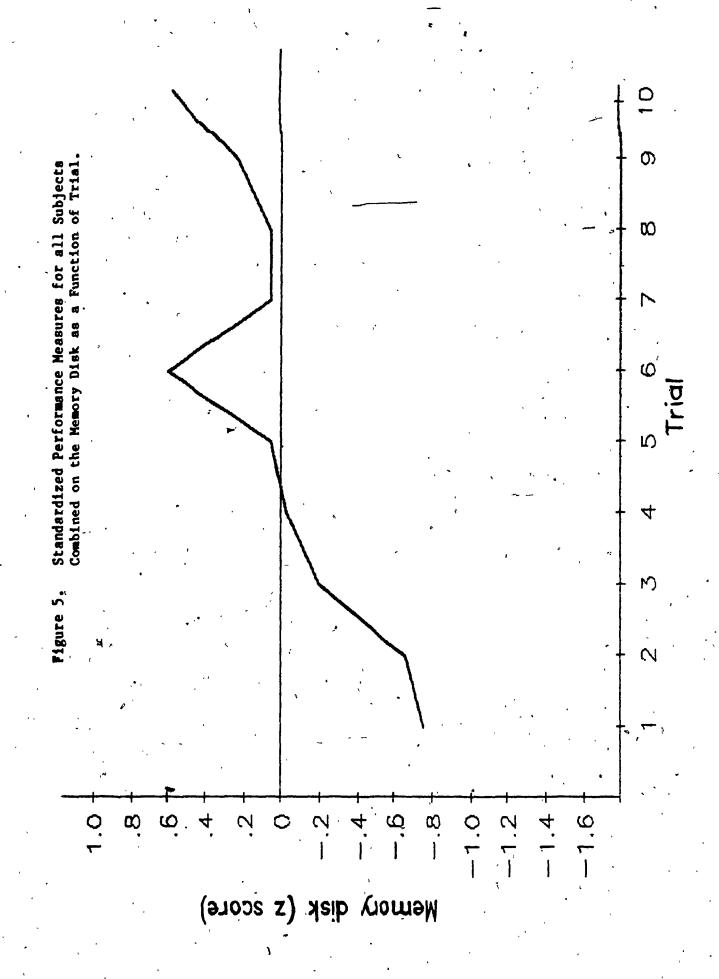
in reduced time (measured in computer cycles as time units) from 831 on T1 to 502 by T10 (see Appendix 14 for VS exercises).

On the Visuospatial exercises, mean performance measures between trials varied tremendously and not always in the expected direction. That is, performance did not always improve as a function of practice. The most erratic performance between trials occurred for VS4. Most errors committed were on T8 ($\bar{X}$ = 338, range = 35) for this exercise. Performance measures that increased in a consistent way (i.e., in the expected direction) between trials were observed primarily on VS6, with the exception of T8 where performance declined. Absolute performance improvements (T1 minus T10) were greatest on VS9.

3: Descriptive statistics for all subjects on Memory exercises

Standardized performance measures of all the Memory exercises combined (all subjects combined) increased from T1 to T10. Whereby on T1 recall was at Z = -.8 by T10 the subjects improved their recall to Z = +.6 (see Figure 5). From the 9 memory exercises the time required to complete the task was collected for M1 and M4. For both these exercises the slope was in the opposite direction.

The performance slope, from standardized mean total scores, was steeper for M4 than it was for M2 and M3. The slopes were in the expected direction (b = .272, .271, and .184 respectively). Slope calculated for errors on M5 was in the wrong direction (b = -.188). This was not the case on M7, errors decreased with practice (b = .124). The number of items retained (i.e., level) per trial improved for memory exercises. In a descending order the steepness of the slopes for M5, M9, M2, M3, M6, M7, M8 and M4 were respectively, b = .305, .239, .238,

Figure 5. Standardized Performance Measures for all Subjects
Combined on the Memory Disk as a Function of Trial.

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.185, .177, .139, .137, and .125.

According to unstandardized measures on M1 the subjects started with 4.8 steps on T1, increasing to 6.6 by T10. However, as steps increased so did the number of moves (43 vs 77) required to complete the exercise. In terms of time required, in spite of increased demands, speed varied by only 3 s (190 s to 187 s). Where subjects required on the average 190 s to complete the exercise at 4.8 steps, they only required 187 s at 6.6 steps (see Appendix 15 for Memory exercises).

Mean cumulative word recall for M2 improved from T1 to T10 (10.7 words to 16.7 words). The number of words the subjects were able to recall, however, increased by only .6 (3.32 to 3.82).

With respect to tone recall on M3 the subjects' mean cumulative retention per trial increased from 10.8 on T1 to 17.8 by T10. The number of tones recalled at any one time ranged from 1.9 to 3.4 tones.

On M4, which trained visuospatial memory, the overall mean retention increased from 3.82 to 5.91 objects. The number of objects and their locations recalled at any one time, however, was only increased from 2.09 to 2.27. The amount of time required to complete the exercise varied from T1 to T10 by 7 s (218 to 225).

In recall of nonsequenced letters (M5) the retention level increased from 2.16 on T1 to 3.59 letters by T10. There were more errors as retention level increased (2.99 to 3.84). In recall of sequenced letters (M6) the level increased from 4.35 to 4.71 on the final trial. In recall of letters in a reverse order (M9), the number of letters recalled increased from 3.68 to 4.40.

On M7 errors declined from 3.82 to 3.42 as recall level increased from 2.40 to 2.90 for nonsense visuospatial nonsequenced designs. For

M8, where designs must be recalled in a sequence, the mean number of designs recalled increased from 2.06 to 2.71 by the final trial.
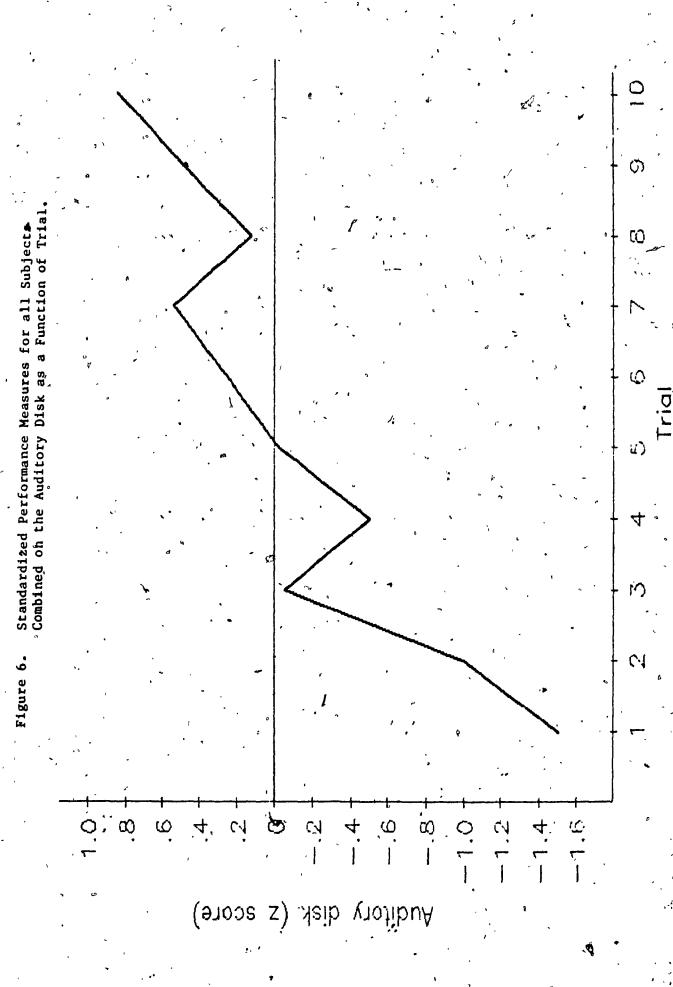
4: Descriptive statistics for all subjects on Auditory exercises
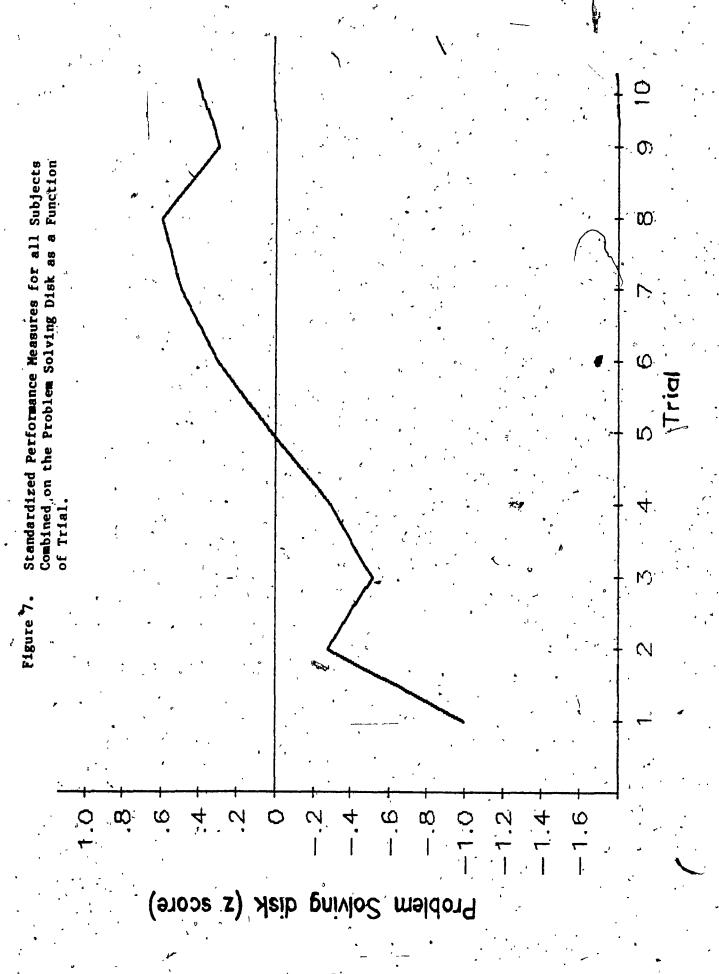
Analyses of standardized scores illustrated that the mean errors decreased linearly as trials increased for both AD1 and AD2 (see Figure 6). The steepness of these two slopes differed by .02 (b = .25 and .27 respectively). Mean errors on T1 (Z = -1.5) decreased by T10 (Z = + .9) for both exercises.

Unstandardized scores on AD1 indicated that mean errors (the difference between the choice and the actual correct response) decreased from 13.2 on T1 to 7.9 by T10. On AD2 (which is similar to AD1 except that the subject can only hear one tone at a time), the mean errors were 18.2 on T1 and decreased to 6.8 by the final trial. The mean % errors reached a plateau from T6 to T9 (see Appendix 16).

5: Descriptive statistics for all subjects on Problem Solving exercises

Subjects' performance improved from T1 (Z = -1.0) to T10 (Z = +.5) for combined exercises (see Figure 7). There were three exercises for which exercise completion time was recorded (PS1, PS2, PS5). Unlike F2, F11, M1, and M4, the slope was in the expected direction. The steepest slope was on PS1 (b = .281) followed by PS2 (b = .277) and PS5 (wrong moves) (b = .156). On PS1, Z ranged from -1.5 to +1.2 from T1 to T10. In contrast the range for PS2 was between -1.5 and +1.0, and for PS5 from -.8 to +.8. The steepest slope for errors occurred for PS5 (delays) (b = .202) compared to PS1, PS3, and PS4. Least reduction of

Figure 6. Standardized Performance Measures for all Subjects Combined on the Auditory Disk as a Function of Trial.

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Figure 7. Standardized Performance Measures for all Subjects Combined on the Problem Solving Disk as a Function of Trial.

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errors on all PS exercises was observed on PS4 for which the Y mean (i.e., Z = 0) became the single best predictor of performance.

Analyses of raw scores demonstrated that on PS1, error rate increased from 7.39 on T1 to 7.55 by T10 whereas exercise completion time was reduced from 272 s to 169 s.

On PS2 the number of moves required to solve the numeric puzzle were reduced from 100 to 49 by T10. The subjects also shortened the exercise completion time from a mean total of 997 s on T1 to 306 s by T10.

On PS3 mean total errors made were not reduced for level one with practice (1.550 to 1.535). On level two, however, errors decreased from 20.86 to 15.57 by the last trial.

Wrong moves in a maze of moderate complexity (PS4) declined from 13.4 on T1 to 6.9 by T10. In contrast, mean delays increased from 28 on T1 to 48 on T10. On a similar but more complex task (PS5) subjects reduced wrong moves (11.5 to 6.9) as well as delays (139 to 73.9). In addition, mean completion time for PS5 improved from 22 s to 5 s (see Appendix 17 for PS exercises).

On the problem solving exercises there was a plateau reached on PS2 from T3 to T10 with very slight variation across trials (range = 4 wrong moves). PS3 (level one) demonstrated floor effects across trials on mean errors. Subjects made on the average 2 errors on each trial. Dependent measures across trials were most erratic for PS4 with respect to the mean delay. There was a trade-off between delays and wrong moves for PS4 observed. The subjects made less wrong moves but did not improve delay.

B: Analyses of the Practice Conditions (Descriptive statistics, Slopes, Trends)

1: Descriptive analyses of the massed and spaced conditions (Standard scores (Z), Means (X), and Standard Deviations (SD))

Standard scores, of all exercises combined, indicated that the spaced condition resulted in more improvements in performance than the massed condition.   Subjects' performance in the spaced condition ranged from T1 to T10 from Z = -1.0 to +.6.   In contrast subjects' performance in the massed condition ranged from Z = -.9 on T1 to +.5 by T10 (see Figure 8).

Standardized performance scores of all exercises per disk and per condition indicated that on the Foundation disk performance in the massed condition ranged between Z = -.8 on T1 to +.2 by T10.   In contrast performance measures in the spaced condition on T1 was Z = -.9 and by T10 improved to Z = +.3.   On the Visuospatial disk the subjects in the spaced condition improved their performance from T1 (Z = -1.5) to T10 (Z = + .8).   In contrast the subjects in the massed condition improved their performance from T1 (Z = -.9) to T10 by 1.6 Z scores. On the Memory disk the spaced condition resulted in similar improvements, from T1 to T10 (Z = -.8 to +.6), as that of the massed condition (Z = -.6 to +.6). On the Auditory disk, however, the subjects in the spaced condition did better than the subjects in the massed condition (Z = -2.0 to +1.0, -1.3 to +.8 respectively).   Finally on the Problem Solving disk the subjects in the spaced condition improved more from T1 to T10 (Z = -1.0 to +.6) than the subjects in the massed condition (Z = -1 to +.3).

Standard score distributions illustrated that on Foundation

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Figure 8. Standardized Performance Measures of Combined Exercises for each of the Practice Condition as Function of Trial.

SPACED

MASSED

exercises subjects in both conditions improved their performance most on F12. Performance varied from $Z = -1.5$ on T1 to $Z = +2.0$ by T10. Performance on F11, for both conditions, declined from T1 to T10. The massed condition for F10 also showed decrements in performance while decrements in the spaced condition were observed (besides F11) on F7.

The variability between stimulus onset and response on the speeded Foundation exercises indicated that, in a massed condition, stability in response was hampered on F1, F4, F11, and F12. The spaced condition in contrast manifested this effect on exercises F2, F3, F7, and F11. In the spaced condition variability between stimulus onset and response was improved most across trials on F1. In the massed condition the least variability in responses across trials was observed on F6.

On the Visuospatial disk subjects' performance, in the massed condition, deteriorated with practice on VS2, VS3, and VS7. The most improvements in this condition were observed on VS6 in which on T1 $Z = -1.5$ and by T10 $Z = +2.0$. Subjects in the spaced condition in contrast improved their performance with practice on all the VS exercises. Performance improved most in this condition on VS1(time) where Z ranged from -1.5 on T1 to $+2.0$ by T10.

On the Memory disk subjects in the massed condition improved their performance most on M5 (level) ($Z = -1.5$ to $+2.5$ by T10). The errors, however, increased from T1 to T10 ($Z = +.5$ to -2.3). The spaced condition also illustrated superior performance increments on M5 (level) ($Z = -1.5$ to $+2.0$ by T10) compared to the other exercises. Performance decreased in the spaced condition on M5 (errors-increased as trials increased), M4 (time), and M1 (time).

For both Auditory exercises performance in the spaced condition

improved more than in the massed condition. In the spaced condition performance increased more on AD1 whereas in the massed condition there were greater improvements on AD2.

On the Problem Solving exercises subjects in the spaced condition decreased the exercise completion time on PS1 and PS2 more than subjects in the other condition. Standard scores in the former condition ranged from $Z = -2.1$ on T1 to $Z = +1.5$ by T10 for PS1. In the latter condition scores ranged from $Z = -2.5$ on T1 to $+.5$ by the final trial. Performance improved least in the massed condition of PS3 (level 2 errors) whereas this was the exercise in the spaced condition which improved most on ($Z = -2.0$ on T1 to $+1.0$ by T10).

2: Analyses of slopes per exercise and condition

Slope coefficients that differed between conditions by less than or equal to .005 were not considered as large enough differences to conclude that one condition resulted in a steeper learning slope than the other condition since a .005 coefficient manifests a very negligable difference. On Foundation exercises slope coefficients of reaction time were in favour of the spaced practice condition (see Table 4).

On visuospatial exercises the slope was steeper for the spaced condition 6 out of 9 times than the massed condition (3 out of 9) (see Table 4). This difference resulted from exercises where performance level was superior in the spaced condition (VS7, VS8, and VS9). With regard to error scores, the two conditions were similar (3 and 3), that is, the massed condition had a steeper slope on 3 exercises (VS1, VS4,

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Table 4

Performance slopes for each exercise in the Massed (M) and
Spaced (S) Conditions (Condn).

Exercise	Condn	Slope	Exercise	Condn	Slope
F1	M	− .01	VS3	M	.508*
	S	.001*		S	− 4.662
F2	M	.002*	VS4	M	− 1.834
	S	− .004		S	− 1.182
F3	M	− .014	VS5	M	− 8.086
	S	− .002		S	− 3.103
F4	M	.005*	VS6	M	1.933
	S	− .009		S	8.320
F5	M	− .003	VS7	M	− .069*
	S	− .008		S	1.02
F6	M	− .002	VS8	M	.378
	S	− .007		S	.447
F7	M	− .002	VS9	M	−13.073
	S	.006*		S	−40.978
F8	M	.011	M1(moves)	M	5.521
	S	.013		S	4.677
F9	M	.325	(level)	M	.212
	S	2.129		S	.217
F10	M	.003*	(time)	M	7.561*
	S	− .014		S	.355*
F11	M	.019*	M2(score)	M	.598
	S	− .00012		S	.698
F12	M	− .006	(level)	M	.074
	S	− .01		S	.061
VS1(time)	M	−2.649	M3(score)	M	.18
	S	−2.022		S	.877
VS2(time)	M	.247*	(level)	M	.041
	S	−2.956		S	.213

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Table 4 continued

M4(score)	M	.302	PS1(error)	M	−	.113
	S	.196		S	−	.105
(level)	M	.053	(time)	M	−	9.95
	S	.001		S	−	8.752
(time)	M	− .799	PS2(time)	M		−62.724
	S	2.29 ✳		S		−57.707
M5(error)	M	.086 ✳	(moves)	M	−	5.0
	S	.046 ✳		S	−	1.898
(level)	M	.135	PS3(level 1)	M		.023 ✳
	S	.123		S	−	.084
M6	M	.043	(level 2)	M	−	.061
	S	.06		S	−	.728
M7(error)	M	− .053	PS4(wrong moves)			
	S	− .087		M	−	.18
				S	−	.409
(level)	M	.071	(delay)	M	−	.495
	S	.023		S		1.231 ✳
			PS5(wrong moves)			
				M	−	.664
M8	M	.001		S	−	.822
	S	.092	(delay)	M	−	1.973
				S	−	7.416
M9	M	.085	(time)	M	−	1.816
	S	.054		S	−	1.498
AD1	M	− .521				
	S	− .974				
AD2	M	− .598				
	S	− 1.243				

✳ Indicates that the slope was in the wrong direction consequently this
condition did not result in improvement of performance. The greater
the slope coefficient the better the performance.

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VS5) and the spaced condition had a steeper slope on 3 other exercises (VS2, VS3, VS6).

For Memory exercises the slope was found to be steeper for the massed condition on 5 out of 8 exercises where level was analysed (M2, M4, M5, M7, M9) (see Table 4). On M5 and M7 for which both level reached and errors were analysed there was a strong condition effect as indicated by the steepness of the performance slopes across trials. The massed condition slope was steeper for errors (i.e., more errors across trials) but also steeper for level reached (i.e., greater retention).

The slope of both auditory exercises was steeper in the spaced condition compared to the massed condition. The greater steepness on AD2 resulted from the initial greater percentage error decrease from T1 to T2 in the spaced group (23 to 13).

On PS exercises on which time to complete the task was recorded (PS1, PS2, and PS5), the massed condition had steeper slopes. The massed condition also had steeper slopes (i.e., less errors across trials) on 2 of the 5 exercises performed (PS1 and PS2) whereas the spaced condition had steeper error slopes on PS3, PS4 and PS5. It is of interest to note that the spaced condition reached a plateau on trial 5 of PS1 (time) with very little variation between T5 and T10, ranging between 132 to 145 s.

On PS2 (time) the massed condition manifested a plateau on T6 ranging between 233 to 210 s while the spaced condition reached a plateau on T8 ranging between 101 and 337 s. With respect to errors neither condition demonstrated much of an improvement on PS1. For PS2 the massed condition improved their mean total rate from 127 on T1 to 48 by T3 and scores remained stable from T3 onwards, with mean total errors

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.ranging between 51 and 45. On PS4 the spaced condition issustrated, a trade-off between the steepness of the wrong moves slope and the delays slope. That is, while the mean wrong moves slope was negative (-.409) the delay slope was positive (1.231). On PS5 although the massed condition did not improve wrong moves as much as in the spaced condition (slope = -.644 vs -.822 respectively) the time to complete the exercise improved more in the massed condition (slope = -1.816 vs -1.498 respectively). On both PS4 and PS5 the stability of response across trials was extreme.

3: Analyses of Trend for the Massed and Spaced Condition

Subjects were required to complete 10 trials of each exercise, consequently the number of functions that may have contributed to the trials main effect were nine. These analyses were motivated by the interest in finding the simplest function that would adequately describe the results. Interpretation of these results were in consultation with Keppel (1973). The number of peaks and troughs in the curves of the different figures and the changes in/the direction of these curves provide an intuitive indication of the complexity of the function underlying the data. Appendix 18 presents the functions that account for the greatest percentage of the trial main effect. The more complex or higher order the function, the more reversals in the curve. For example, function one refers to the "first order" function or what is called "linear component" in the data. The second function refers to a "second order" function or quadratic component in the data, and so on.

Trend analyses calculated by condition indicated that simpler

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functions (of the first, second and third order) explained a greater percentage of the trial main effect in the spaced condition compared to the massed condition. Of the 37 exercises analysed 21 exercises resulted in less reversals in the trial to trial mean in the spaced condition while only 9 exercises in the massed condition. The balance were equal in terms of complex functions in either condition (see Appendix 18).

On the 12 Foundation exercises there were 7 that resulted in less reversals in the mean between trials in the spaced condition and 2 in the massed condition. In the spaced condition for F1 the variation among the means was accounted for mostly by the linear component. This was not the case in the massed condition. In terms of percentage, the linear component represented 73% of the trial main effect in the former condition and only 21% in the latter condition. In the massed condition it was the cubic component that explained most of the trial main effect (31%). In the spaced condition the only other exercises for which the linear component accounted for the greatest percentage of the trial main effect were F9 and F12. In contrast for the massed condition the linear component explained most of the trial main effect on F12, F8, and F11. This was not, however, always superior to that of the spaced condition (see Appendix 18). Highly complex functions (i.e., beyond cubic) described the changes in the direction of the performance curve on most of the Foundation exercises for both conditions, however.

From the Visuospatial exercises only subjects in the spaced condition manifested stability of response with respect to variation among the means between trials on 5 of the 9 exercises. In this condition the linear component accounted for 88% of the trial main

effect on VS6 while in the massed condition, the linear component represented 65%. The linear trend explained less of the trial main effect on other exercises (i.e., beside VS6) in either condition. In fact in the massed condition changes in the direction of the curve were best accounted for by complex functions for most of the exercises on this disk. This was not always the case in the spaced condition.

On Memory exercises the conditions were similar on all exercises except M5 and M6. That is, exercises M1, M2, M4, and M9 illustrated the least variation among the means. M5 showed more reversals in the means between trials in the spaced condition. M6 manifested less changes in the direction of the curve in the massed condition.

Both Auditory exercises in the spaced condition manifested least variations among the trial means since the linear component explained most of the trial main effect. In the massed condition there were more changes in the direction of the performance curves than that observed for the spaced condition. For AD1 the linear component accounted for 83% of the trial main effect in the spaced condition and only 35% in the massed condition. In the latter condition for this exercise the fifth function represented the greatest percentage (53%) of the trial main effect.

The only exercises on Problem Solving which illustrated a linear or at worst a quadratic trend in both conditions were PS1 and PS2. On the rest of these exercises for both conditions there were more reversals in the direction of the curve than that observed on PS1 and PS2.

C: Analyses of Variance

  Despite the risk of reducing the power of the ANOVA tests, dependent measures that were beyond ±3 standard scores from the mean, from the expected direction, were excluded because it was observed that such extreme scores only arose from subjects who were not performing the exercise. If these data had been included in the analyses it would have been more likely to conclude that a treatment was effective. Thus this precaution reduces the risk of inflation of errors.

  Trial 1 was used as a habituation and practice trial. Performance was, therefore, calculated using T2 versus T10 for all ANOVAs. The ANOVA design comprised factor A (treatment condition) which had two levels (massed, spaced) and factor B (trials) which also had 2 levels (T2, T10). The a priori probability level was set at .05. Table 5 summarizes p values and degrees of freedom for all ANOVAS (see Table 5).

1: Practice condition main effects

  Of the 37 exercises used in these analyses, 6 dependent measures significantly differentiated the two treatment conditions in exercises F11, F12, VS4, VS8, M4 and PS4 (see Table 5). Fully detailed ANOVA summary tables for each exercise are found in Appendix 19.

Foundation exercises

  From the 12 exercises on the Foundations disk two significantly differentiated the two conditions. A significant condition main effect for F11 was in favor of the massed condition ($F(1,17) = 5.14$, $p<.03$) with a shorter RT compared to the spaced condition (.40 vs .57 s). The

Table 5. Summary of the probability and degrees of freedom(df) from ANOVA tables for the practice condition(C), trial(T), and practice by trial (CxT) effects for each exercise.

Exercise	df	Probability C	T	CxT	Exercise	df	Probability C	T	CxT
F1	19	.43	.70	.44	M4(score)	12	.04	.08	.78
F2	20	.72	.95	.88	(level)	12	.14	.36	.36
F3	19	.57	.17	.85	(time)	12	.44	.90	.97
F4	19	.11	.43	.42	M5(errors)	18	.36	.82	.84
F5	20	.07	.02	.03	(level)	18	.23	.00001	.84
F6	20	.22	.20	.50	M6(level)	19	.65	.04	.99
F7	16	.23	.38	.92	M7(errors)	16	.81	.14	.47
F8	19	.055	.02	.08	(level)	16	.34	.17	.43
F9	20	.62	.21	.05	M8(level)	18	.14	.02	.61
F10	20	.06	.10	.66	M9(level)	19	.70	.02	.82
F11	17	.04	.49	.43					
F12	20	.02	.03	.33	AD1	19	.06	.001	.55
					AD2	17	.36	.02	.37
VS1	19	.08	.001	.70					
VS2	19	.11	.07	.57	PS1(error)	17	.27	.43	.43
VS3	19	.055	.99	.56	(time)	17	.12	.002	.45
VS4	19	.02	.34	.31	PS2(moves)	16	.90	.17	.78
VS5	18	.14	.038	.76	(time)	16	.07	.02	.32
VS6	18	.27	.09	.28	PS3L1				
VS7	19	.49	.74	.56	(error)	8	.96	.87	.87
VS8	19	.008	.89	.90	PS3L2				
VS9	17	.35	.001	.049	(error)	8	.96	.85	.85
					PS4 (wrong moves)				
M1(moves)	15	.16	.003	.40		17	.05	.94	.81
(steps)	15	.58	.0001	.95	(delay errors)				
(time)	15	.07	.15	.91		17	.04	.05	.08
M2(score)	18	.94	.0004	.44	PS5 (wrong moves)				
(level)	18	.49	.03	.74		17	.33	.06	.33
M3(score)	18	.91	.058	.59	(delay errors)				
(level)	18	.66	.18	.93		17	.16	.63	.26
					(time)	17	.23	.41	.28

significant condition main effect for F12 was in favor of the spaced condition ($\underline{F}(1,20)$ = 6.64, $\underline{p}<.01$) in which subjects reacted faster than the subjects in the massed condition (.31 vs .45s respectively). F8 approached ($\underline{p}>.055$) but did not reach significance (see Table 5).

In the Foundation exercises, after having graphed each exercise by condition there seemed to be a systematic shift in the performance of one group of subjects relative to the other, irrespective of practice condition. In other words, the subjects in one group, irrespective of practice condition, were outperforming the subjects in the other group (although not always significantly) (see graphs 1 to 12 in Appendix 23). This shift is possibly due to accidental sampling bias which sometimes occurs in small n studies. This possible small N sampling bias will be verified and tested in section E of the Results chapter.

Visuospatial exercises

Of the 9 VS exercises analysed from this disk two attained significant condition main effects. For VS ($\underline{F}(1,19)$ = 7.09, $\underline{p}<.01$) the subjects in the spaced condition outperformed the subjects in the massed condition ($\overline{X}$ = 246 vs 376 errors).

For VS8 ($\underline{F}(1,19)$ = 8.96, $\underline{p}<.007$), the percentage accuracy score of the spaced condition ($\overline{X}$ = 81) was greater than that of the massed condition ($\overline{X}$ = 69). VS3 approached ($\underline{p}>.055$) but failed to reach significance (see Table 5).

Memory exercises

Only one of the 9 exercises significantly differentiated the two treatment conditions. On M4 ($\underline{F}(1,12)$ = 5.18, $\underline{p}<.04$) for the correct

total number of objects recalled, subjects in the massed condition demonstrated better recall than in the spaced condition ($\bar{X}$ =6.75 vs 2.83 respectively). The reason for the 13 degrees of freedom for this exercise was because BMDP2V rejected all cases where recall was less than one.

Neither of the two dependent variables used from the Auditory disk (AD1 & AD2) demonstrated significant condition main effects.

Problem Solving exercises

Of the five exercises only PS4 differentiated the two conditions. There were significant main effects on the number of wrong moves ($F(1,17) = 4.33$, $p<.05$) as well as on delays ($F(1,17) = 5.06$, $p<.03$). Subjects in the spaced condition made significantly more wrong moves and more delays respectively than in the massed condition ((1) $\bar{X} = 9.9$ vs 4.2, (2) $\bar{X} = 13.7$ vs 49.6 respectively).

2: Trial main effects

Of the 37 exercises, 17 reached significant trial main effects (see summary of ANOVAs in Table 5 and full list in Appendix 19).

Foundations exercises

On this disk exercises F5, F8, and F12 were found to be significant. For F5 the significant trial main effect ($F(1,20) = 6.43$, $p<.01$) resulted from the reduced reaction time on T10 ($\bar{X} = .82$ vs .71 s). In F8 ($F(1,19) = 6.24$, $p<.02$) the significant effect again resulted from the performance ratio increase in correct response on T10 (.81 vs .91). Subjects also improved the speed of response from T2 to T10 on

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F12 by 53 ms. Reaction time decreased from 406 ms to 353 ms ($F(1,10)$ = 5.73, $p<.02$).

Visuospatial exercises

The exercises which resulted in significant trial main effects on this disk were not the same exercises that differentiated the two conditions. Significant trial main effects ($F(1,19)$ = 13.09, $p<.001$) were observed for time on VS1 where time declined from a mean of 57 s on T2 to 43 s. by T10. For VS5 ($F(1,18)$ = 5.02, $p<.03$) the subjects reduced their error rate from 215 on T2 to 162 on T10. For VS9 ($F(1,17)$ = 15.87, $p<.001$), the mean computer cycles dropped from 461 on T2 to 351 on T10.

Memory exercises

Of the nine exercises analysed, six yielded significant trial main effects. For M1 ($F(1,15)$ = 12.95, $p<.002$), the subjects made more moves on T10 compared to T2 (62 vs 34 respectively). This increase, however, was because the number of steps (i.e., recall) from T2 to T10 was increased significantly from 4 to 7. This 3 point increase resulted in a significant trial main effect ($F(1,15)$ = 33.85, $p<.00001$).

On M2 both the cummulative word recall ($F(1,18)$ = 19.27, $p<.0004$) and the level reached ($F(1,18)$ = 5.69, $p<.02$) demonstrated a significant trial main effect. The mean for cumulative word recall increased from T2 (9.8) to T10 by 6.65 words. The number of words (i.e., level) retained increased by .6 words.

The number of nonsequenced letters recalled for M5 by T10 was significantly larger ($F(1,18)$ = 32, $p<.00001$), ranging from 2.5 words on T2 to 3.85 words by T10.

Where the subjects were required to recall letters in a reversed order of presentation (M9) the trial main effect was significant at $p < .01$ level. Subjects increased their recall from 3.57 letters to 4.38 letters. For M6 the sequenced letters recalled were significantly different from T2 to T10 ($F(1,19) = 5.01$, $p < .03$). Sequenced letter recall on T2 was equal to a mean total of 4 letters and increased to 4.8 letters by T10. On M8 for sequenced visuospatial recall the total number of designs recalled from T2 (2.2) to T10 (2.85) was significantly different ($F(1,18) = 6.67$, $p < .01$).

Auditory exercises

Both auditory exercises resulted in significant trial main effects. On AD1 ($F(1,19) = 14.02$, $p < .001$) subjects decreased the total number of errors from a mean of 15.2 on T2 to 7.7 by T10. On AD2 ($F(1,17) = 6.24$, $p < .02$) number of errors decreased from 11.1 on T2 to 6.7 by T10.

Problem Solving exercises

Of the five exercises three yielded significant trial main effects. On PS1, a serial addition task, although the number of errors did not significantly decrease from T2 to T10 the exercise completion time was significantly different from T2 to T10 ($F(1,17) = 12.91$, $p < .002$). On T2 the subjects required an average of 224 s to complete the exercises, this processing time improved to 145 s by T10. On PS2 there was also a significant trial main effect for the exercise completion time but not for the number of moves ($F(1,16) = 7.34$, $p < .01$). Time improved from 537 s on T2 to 295 s by T10.

On PS4 the delay in decision making was significantly different

($\underline{F}(1,17) = 4.53$, $\underline{p}<.04$). The mean total of 14.5 delays on T2 increased to 39.4 by T10.

3: Practice Condition by Trial Interaction (CxT)

Of the 37 exercises there were 3 significant interactions found. Two were from the Foundation disk and the other from the Visuospatial disk. Figures (9 & 10) will not be presented in this section to illustrate the significant interaction. They will be presented in the ANCOVA section below since the interactions did not always remain significant as a result of ANCOVA.

On Foundations, the two exercises that resulted in significant practice by trial interaction were F5 and F9. F8 approached significance. For F5, ($\underline{F}(1,20) = 5.12$, $\underline{p} <.03$), this interaction resulted from the subjects in the spaced condition having a longer RT on T2 compared to the subjects in the massed condition (.97 vs .65 s), and then reducing their RT on T10 by .20 s, whereas RTs in the massed condition remained stable. For F9 the significant interaction ($\underline{F}(1,20) = 4.48$, $\underline{p} <.04$) means that the percentage of hits of the subjects in the massed condition remained somewhat stable from T2 to T10 (76 vs 73) whereas in the spaced condition performance improved from T2 to T10 (62 vs 75).

Of the 9 Visuospatial exercises only VS9 resulted in a significant interaction ($\underline{F}(1,17) = 4.50$, $\underline{p} <.04$). Performance in the spaced condition on T2 was superior to that of the massed condition ($\overline{X} = 544$ vs 349), on T10 the massed condition surpassed the performance of the spaced condition ($\overline{X} = 353$ vs 349).

Of all the exercises on the Memory, Auditory, and Problem
Solving disks there were no significant interactions. The closest to
approaching significance was PS4 (delays) for which in the spaced
condition there was a deterioration in performance on T10. Where the
delays on T2 were 19 this increased to 79.6 by T10. The massed
condition also increased the delays on T10 but not so drastically (11 vs
16).

D: Other Variables

Previous literature has indicated the possible influence of age,
interval since trauma, education, duration of coma on the outcome of
rehabilitation. It was, therefore, decided to calculate analyses of
covariance for these variables. All four covariates were entered into
the analyses for each of the 37 exercises on the first run. Since most
analyses showed that only one covariate was significant, and since the
power of the test is lowered by using four covariates, ANCOVAs were
rerun only for the exercises where there was a significant covariate
and only with the significant covariate. To avoid redundancy the
results from the first analysis will not be reported in the text for
exercises in which the more parsimonious second analysis was run, but
rather the results from the second run will be reported. A summary of
the covariates and the probability are found in Appendix 20.

1: Analyses of Covariance

Foundation exercises

Analyses of covariance demonstrated that on exercises F4, F5, and

F10 respectively, the covariate coma was significant or approached significance (.004 < $\underline{p}$ < .07). On F4 coma was significant at $\underline{p}$ < .004. The length of coma was shorter in the spaced condition than the massed condition (79.8 vs 145.8 days). The overall mean RT in the massed condition was originally .734 s and was adjusted to .704 s. For the spaced condition the mean was adjusted from .487 to 508 s.

For F10, coma demonstrated to be significantly related to the dependent measure at $\underline{p}$ <.004. For this exercise subjects in the massed condition had a longer coma duration than subjects in the spaced condition (153 vs 81 days). The standard error (SE) of the mean was much greater in the massed condition than the spaced condition (115.9 vs 19.7). Means were adjusted from .44 s to .42 s in the massed condition and from .32 s to .33 s in the spaced condition.

The only other exercise that had a significant covariate was F12. For this exercise, however, it was not coma but age which was the significant covariate ($\underline{p}$ <.01). Age as the only covariate demonstrated that subjects in the massed condition were older ($\overline{X}$ = 32 years) than subjects in the spaced condition ($\overline{X}$ = 28.8). Means were adjusted in the massed condition from .45 s to .44 s. In the spaced condition they were adjusted from .31 s to .33 s.

Visuospatial exercises

On VS exercises age was the only significant covariate (VS7 and VS8) except for VS9 in which coma was the only significant covariate. On VS7 when all covariates were used only age covaried with performance ($\underline{p}$ < .04). When age was covaried alone it was no longer significant. For VS8, which is similar to VS7, age covaried significantly with

percentage accuracy ($p < .02$). Subjects in the massed condition were older than subjects in the spaced condition (32 vs 28 year). Percentage accuracy means were adjusted in the massed condition from 69% to 70.6%. In the spaced condition it was adjusted from 77.6% to 76.6%. For VS9 all covariates in combination were significant ($p < .0001$) but this significance was attributable to coma which covaried most with performance ($p < .00001$). The mean duration of coma for subjects in the massed condition was 76 days whereas in the other condition it was 316 days. Means were adjusted from 382 computer cycles to 447 in the massed condition and from 609 computer cycles to 511 in the spaced condition.

Memory exercises

Of the 9 memory exercises, M2, M8 and M9 had significant covariates. For M2, coma was a significant covariate ($p < .009$) for the total number of words recalled. Duration of coma for subjects in the spaced condition was shorter than those in the massed condition (81 days vs 167 days). While the SE was 114 days in the massed condition it was only 23 days in the spaced condition. Means were adjusted from 13.2 words in the massed condition to 13.8 words and from 13.04 words to 12.6 words in the spaced condition. When subjects were required to recall nonsense diagrams in order (M8) both age and interval since trauma were significant covariates ($p < .01$) with age contributing most to this significance ($p < .008$ vs $p < .04$). Subjects in the massed condition were younger in age than the spaced condition (28.9 vs 31.2 years) but the interval since trauma was shorter in the latter (65.8 vs 86.1 months). Means were adjusted by a difference score of .12 in the massed condition (2.25 to 2.13) and by .08 in the spaced condition (2.71

to 2.79).

Recall of letters in a reversed order (M9) covaried both with age and coma ($p < .002$). Age, however, contributed most to this significance compared to coma ($p < .004$ vs $p < .04$). Subjects in the massed condition were older (31 years vs 30 years) but had a shorter coma duration (83 days vs 148 days) than subjects in the spaced condition. Means were lowered by .1 in the massed condition (3.9 to 3.8) but raised in the spaced condition (4.1 to 4.2).

Auditory exercises

For AD2 when all covariates were included in the ANCOVA, coma was a significant covariate ($p < .04$). Coma duration of subjects in the massed condition was shorter than that of subjects in the spaced condition (58 vs 195 days). Education approached but did not reach significance ($p < .06$) and the four covariates in combination were not significant nor was the covariate coma when looked at in isolation. Adjusted means taking into consideration the combination of covariates were 9.5 errors for the massed condition and 8.1 for the spaced condition.

Problem Solving exercises

On PS exercises coma was a significant covariate for PS1, PS4 and PS5. On the serial addition task (PS1) coma was a significant covariate for both errors ($p < .001$) and time required to complete the task ($p < .00001$). Coma contributed most to the significance of all the covariates (errors = $p < .01$, time = $p < .00001$). The subjects in the spaced condition had a shorter coma duration ($\bar{X} = 63$

days) than those in the massed condition ($\bar{X}$ = 159 days). Education had a slight contribution on time required to complete the exercises (p <.01). Both unadjusted errors and time were less in the spaced condition ($\bar{X}$ errors = 9.3, $\bar{X}$ time = 252 s). Mean adjustments for errors and time in the spaced condition were 7.07 errors and 200.5 s respectively and in the massed condition they were 8.27 errors and 216 s respectively.

For PS4 coma was the only covariate that covaried with the number of wrong moves made (p < .03) but there were no significant covariates with respect to delays on this exercise. Duration of coma was shorter in the massed condition than in the spaced condition (59 vs 211 days). Means were adjusted from 4.2 to 5 days in the massed condition and from 9.9 to 8.5 in the spaced condition.

Coma was not a significant covariate for wrong moves or delays when the exercise was more complex (PS5) but rather education (p < .01) contributed to the delays in decision making. The subjects in the spaced condition had a lower educational level (10.6 vs 12.5 years). Means in the massed condition were adjusted from 117 delays to 96 delays and from 57 delays to 71 delays in the spaced condition. The massed condition was also at a disadvantage with respect to time required to complete the exercise and coma covaried significantly (p < .00001) with this time. The massed condition had a shorter mean coma duration than the spaced condition (76 vs 135 days). Means were adjusted for time in the massed condition from 3.2 s to 5. 6 s whereas in the spaced condition the time was reduced from 8.5 to 7 s.

2: <u>Changes in ANOVA Practice Condition Main Effect as a Result of ANCOVA</u>

Originally, F4 was not significant in terms of condition main effect but after having covaried coma the practice condition effect approached significance ($p < .056$). The mean RT in the spaced condition was adjusted from .49 s to .51 s and in the massed condition it was adjusted from .73 s to .70 s.

For F8 the use of covariance removed 4 df, therefore, resulting in a higher probability level (.09 vs .055). This effect was also observed for F10 (.09 vs .06). Moreover, where F11 condition main effect was significant originally ($p < .03$) this was no longer the case after having used covariance. The condition main effect for F12 was originally $p < .018$ and after having covaried age this condition effect was reduced to $p < .026$ (see Appendix 20).

Analyses of covariance obliterated the significance levels for VS4 and VS8. For VS4 the probability level changed from $p < .02$ to $p > .14$; for VS8 it was altered from .008 to .27.

For M8 (level) the practice condition main effect resulted in significance once age 'and interval since trauma were covaried ($p < .02$). Once adjusted, means differed in the massed condition negatively (2.25 vs 2.13) and positively in the spaced condition (2.71 to 2.79).
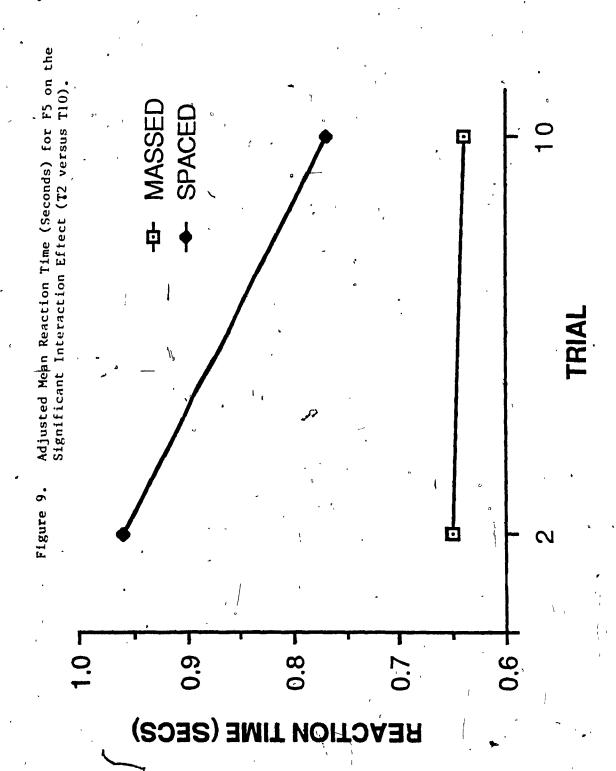
The original significant condition main effect for both wrong moves ($p < .05$) and delays ($p < .04$) on PS4 resulted in nonsignificance once coma was covaried (condition main effect $p > .19$, $p > .09$ respectively).

3: Changes in ANOVA trial main effect as a result of ANCOVA
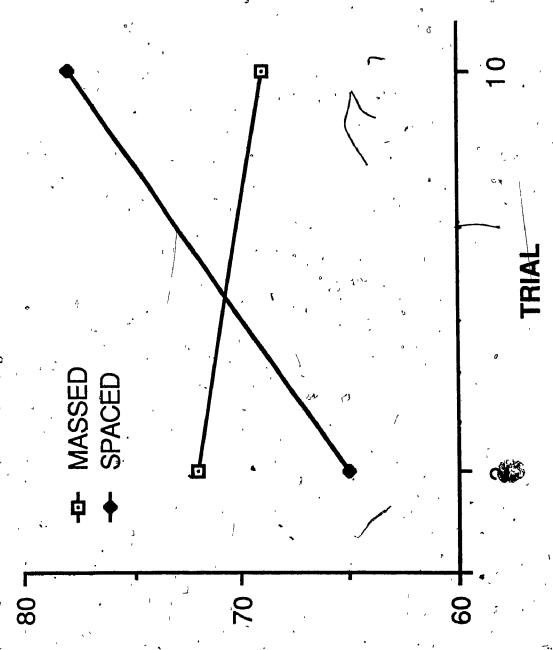
On VS1, VS9, M1 (moves and steps), PS2 (moves and time), PS5 (wrong moves) the original probability level from the ANOVA trial main effect was changed by the ANCOVA. For VS1 it was changed from .001 to .009. On VS9 it was no longer significant (from .001 to .95). On M1 (moves) the original probability level (.003) changed to .04, and for steps it changed from .00001 to .0001. For PS2 (moves) the trial main effect was not significant originally ($p = .90$), ANCOVA demonstrated that the main effect was masked by the four covariates and was now at $p < .02$. On PS2 (time) the trial main effect was now not significant (from .02 to .20). On PS5, the original trial main effect was masked by the four covariates and was now significant ($p < .04$). The balance of the original significant trial main effects remained unchanged.

4: Changes in ANOVA interaction effect as a result of ANCOVA

The original significant interaction for F5 remained unchanged as a result of covariance (see Table 5 and Appendix 20). The means in each practice condition by trial were, however, slightly adjusted. It is for this reason that figures for the significant interactions are being presented in this section (see Figure 9). For F9 the interaction probability remained unchanged as a result of ANCOVA. The adjusted means were also used in the figure of the interaction since there were slight change in the means (see Figure 10). For VS9 the interaction was originally significant but this was no longer the case with ANCOVA ($p > .55$) (see Appendix 20).

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Figure 9. Adjusted Mean Reaction Time (Seconds) for F5 on the Significant Interaction Effect (T2 versus T10).

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Figure 10. Adjusted Mean Percentage (%) Correct Hits for F9 on the Significant Interaction Effect (T2 versus T10)

E: Controlling for possible subject selection bias

In order to control for the possibility that there may have been a sampling bias due to the small N on the Foundation exercises the two samples were defined as "fast" or "slow". The Foundation exercise dependent measures were then pooled independently of practice condition (i.e., massed or spaced). If there had existed a small N sampling bias then the fast/slow grouping main effect in the ANOVA should have been significant. This analysis demonstrated that the group main effect (fast vs slow) was not significant ($\underline{F}$ 91,15) = .04, $\underline{p}$ >.85). The reason why df was only 15 was because some subjects were not included in the analysis since they could not be classified into either fast/or slow grouping on all the Foundation exercises.

F: Case Results

For clinical purposes as well as to illustrate the extremeness of response from trial to trial single subject raw data will be presented here. One exercise from each disk was randomly selected and two subjects' raw scores (i.e., the best performer and the worst performer) were plotted for illustrative purposes (see Appendix 21). The independent variable on which the best performer and the worst performer differed most on for these exercises was coma (see Table 6). For F5 mean RT was erratic from trial to trial in a more severe case (determined from coma duration) and varied from .85 s to 2.39 s dependent on the trial. In contrast an individual with lower coma duration did not reduce mean RT from trial to trial but his RT

Table 6

Descriptive Variables for the Clinical Cases

Subject	Sex	Age (years)	Interval Since Trauma (months)	Education (years)	Coma Duration (days)	Percent Deficiencies on neuro-psychological tests	Vocabulary score (WAIS)	Neuro-Surgery Required (post-trauma)	Skull Fracture Reported
A.B.	M	29	128	12	90	21	29	N	Y
O.B.	M	32	182	9	30	53	10	N	Y
F.B.	M	32	170	12	60	38	13	N	Y
C.D.	M	20	68	8	60	21	18	Y	Y
J.D.	M	24	101	12	21	12	28	Y	Y
A.F.	M	34	79	13	960	62	17	Y	Y
C.B.	F	50	15	9	105	38	24	N	N
R.M.	M	21	12	13	15	21	18	N	N
G.M.	M	28	42	9	60	24	17	N	Y
G.T.	M	36	16	9	21	35	21	N	N

manifested less variation in response. Reversals in the performance curves between trials was evident on all the exercises for the severe cases but not for their less severe counterparts with the exception of M5. Both cases on M5 had a comparable performance on T1 but diverged thereafter.

Discussion

A: Overall learning

The results indicated that there were appreciable improvements in performance. Performance improvement, as measured by standard scores for all exercises, increased by a factor of 15 by T10 relative to T1 (see Figure 1). These results concur with those of Prigatano et al. (1984) and Sands et al. (1969) who also found significant improvements in performance past spontaneous recovery two to three years after trauma.

There were improvements in performance on all the disks. Variations in extent of learning from disk to disk were observed, however. CHI appears to differentially influence performance in memory, auditory discrimination, problem solving, visuospatial processing, and attention. Such effects have been reported in other functional systems such as reading, writing, and spelling which are differentially affected by head injury (Hiorns & Newcombe, 1979). In the present study the most consistent improvements occurred for the auditory disk on which performance improved linearly with trials. Neuropsychological profiles indicated that 73% of this sample were not deficient on auditory perception suggesting that intact systems (residual functions) are the ones most likely to support learning. This supports, of course, Luria's model.

Somewhat comparable improvements were observed on the visuospatial and problem solving disks. There were more peaks and troughs in the trial means, however, for the visuospatial disk than for the problem solving disk. Perhaps exercises that require multiple integrative

processing, such as the VS exercises, tend to produce erratic behavioral responding. The VS exercises required the subject to accomplish complex visual scanning, to decode complex spatial relations and to perform complex motor routines as fast as he or she could, simultaneously.

Performance improvements on the memory disk were observed, but were somewhat lower than those observed on the auditory, problem solving and visuospatial disks. There was, as for the visuospatial disk, variation in performance from trial to trial and not always in the right direction. That is, linear improvement was less evident on this disk than was observed on the auditory disk. Nonetheless, performance on the memory exercises did improve with practice in this study and lends support to Glisky et al. (1986) who found improvements in retention when CHI subjects were required to learn simple computer programs. Which type of memory process (e.g., encoding, storage, or retrieval) was involved in improving performance was beyond the focus of this tudy. Brooks (1974) tested various memory functions in CHI and found no significant correlation between memory performance and time since injury. He concluded that memory does not improve beyond spontaneous recovery. The results indicate that memory recovery does not appear to cease at a relatively early stage after injury as had been suggested by Brooks (1974). Conclusions such as Brook's have very important implications in the remediation of CHI individuals. The efficacy of procedures designed to improve memory are thrown into question. Our results do not lend support to such pessimistic conclusions.

The Foundation disk also elicited improvements in performance but less so than other disks. In addition, performance from trial to trial was more variable (i.e., more peaks and troughs) than any other disk.

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Neuropsychological test scores indicated that the majority of these subjects had deficient RT scores previous to rehabilitation (72%). This, once again supports Luria's notion that rehabilitation can only be effective to the extent that it uses residual function (intact brain circuitry) for the establishment of new functional systems. Since these exercises are known not to manifest appreciable practice effects on speed it seems safe to presume that this disk improved speed of processing in these CHI individuals.

Learning over time, determined from slope coefficients of pooled subjects per exercise, showed that there were improvements in performance over time in 88% of the dependent measures and only 12% of dependent measures were in the opposite direction. This 12% was manifest mostly on speed of processing (e.g., Foundations exercises) and not performance accuracy. Perhaps CHI individuals perform better when emphasis is not on speed.

B: Trial effects (Pooled subjects)

Of all the exercises that were used in this project 49% resulted in significant improvements from T2 to T10. Thirty-five percent of the dependent measures were speed related, 28% measured error rate, and 37% measured accuracy. Of the significant trial effects 50% was attributable to exercises that measured hit accuracy rate, 29% from error performance, and 24% to speed of processing. Slope analyses for all subjects indicated that 3 of 17 RT measures and 1 of 14 error measures were in the opposite direction. The exercises that manifested slopes in the opposite direction were not statistically significant.

Neuropsychological test scores indicated that 55% of the subjects had severe memory deficits on the Russell adaptation of the Wechsler Memory Scale (Russel, 1975). Eighty-eight percent of the memory exercises resulted in significant trial main effects with an additional 22% approaching significance. These results are similar to those of Glasgow et al. (1979) and Glitsky et al. (1979) who also demonstrated that amelioration in very short term memory (attention) occurs in CHI individuals with the help of a microprocessor. Bracy's memory exercises do not tap pure memory since the delay between stimulus presentation and recall is insufficient. Perhaps these exercises tap more into the individual's ability to be attentive with particular emphasis on accuracy over speed.

Sixty percent of problem solving exercises resulted in significant improvements with practice and 20% approached significance. This is probably due to improved sustained attention. This supports previous findings by Malec et al. (1984). It may be that practice on previous exercises, on Foundation, Visuospatial and Memory, resulted in generalization to these exercises. Since previous exercises heavily involved spatial relations, the reason why there was no generalization to PS1 and PS3, may be due to the fact that these exercises load on verbal functioning.

On PS3 only 10 subjects were able to complete the exercise (3 massed, 7 spaced). This exercise is similar to PS1 except that there are two levels. On level two the exercise requires serial addition of numbers in two columns simultaneously. This exercise may be a measure of "channel capacity", that is, the amount of information that can be handled at one time. Channel capacity has definite limits (Broadbent,

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1971) and CHI may reduce these limits further. Items requiring simultaneous processing may be somewhat beyond the mental capacity of some CHI individuals. For such exercises, therefore, CHI individuals manifest inadequate information processing. Gronwall and Wrightson (1974) found that as the number of items to be processed are increased, performance of head injured patients was reduced and diverged further from that of controls. Repercussions from such demands in CHI are obvious. These researchers found that there was an emergence of symptoms (i.e., irritability, desire to end the session, and so on) as channel capacity requirements increased. Rather than presenting items simultaneously, perhaps in such situations the individual may cope better by presenting exercises sequentially and by adjusting the rate of presentation to suit individual needs. Unfortunately this option was not afforded by this disk. It may be the reason why only one significant trial effect was observed.

Visuospatial exercises and Foundation exercises seldom resulted in significant trial main effects (33% and 30% respectively). Improvements were nevertheless observed. Subjects spent between two to two and a half months on the Foundation exercises involving speed. Perhaps significant trial main effects on F12 and VS1 may indirectly indicate a form of generalization from one exercise to the next. Kennedy, Bittner, and Jones (1981) bring partial support to this hypothesis. These authors found that results demonstrated generalization from practiced video games to novel games.

Braun, Ethier, and Baribeau (1987) developed norms for most of the software used in this study. After ten repetitions of each

exercise, CHI individuals frequently departed from the normative mean (based on one trial on each exercise by undergraduate·students), depending on the disk. The Foundation exercises permitted six comparisons to be made (i.e., F1, F3, F5, F10, F11, F12) in which pooled subjects were -1.7 to -6.5 standard deviations from the mean. Whereas for F1 they were -6.5 SDs from the mean by T10, by the time F12 was completed these subjects were only -1.7 SDs from the mean by T10.

From the visuospatial exercises only two comparisons could be made with norms (VS2, VS3). Or e ·exercises were completed, CHI individuals were able to achieve performances that differed from normative functioning by between -1.6 and -1.8 SDs.

Memory exercises (M2, M4, M7, M8, & M9) once practiced permitted almost equivalent performance to normals in CHI individuals (SD = -1 to -.3). Recalling letters in a reversed order (M9) which requires mental rotation appeared to be most difficult for CHI individuals on this disk (SD = -1). This is not altogether·unexpected since CHI have been reported to have rotational problems with digits.

With respect to auditory discrimination (AD1) the CHI individuals were able to reach performance levels equivalent to those of normal subjects (SD=0).

Of the problem solving exercises available for comparison PS1 and PS3 proved to be most challenging for CHI. The best performance on PS1 was achieved at T7 but this departed from the normative mean by -23.7 SD. By T10, the mean had deteriorated to -27.5 SDs which was the same as at T1. CHI individuals, however, matched the performance of normals on PS5 (wrong moves) at T1 and by T10 surpassed the normative mean by +.4 SD.

Of the 16 exercises available for comparison 38% reached significance and 19% approached significance. These exercises also manifested smaller deviations from the norm than the nonsignificant exercises. Smaller deviations from the norm were associated with more trial main effects in this CHI sample.

C: Does practice condition influence outcome: the practice condition by trial interaction

Due to the nature of this study and the different dependent measures, it was not feasible to use multivariate analyses of variance (i.e., there would be less than five measures per cell, therefore, making this type of analyses inappropriate). There are chances of attaining statistical significance on at least five percent of the dependent measures. Results must, therefore, interpreted with caution given the large number of univariate tests calculated.

For F5 at T2 the spaced condition manifested a longer RT than the massed condition, but significantly decreased RT on T10 compared to the latter condition. Perhaps the subjects in the massed condition did not manifest as great improvements from T2 to T10, compared to the spaced condition, due to a ceiling effect. Reducing RT may be facilitated when you start off "slow". Previous literature has indicated that rehabilitation outcome may be related to coma duration.

It was demonstrated that coma was a significant covariate for F5. Note, that although subjects in the massed condition had a shorter duration of coma their performance was, nonetheless, inferior to the subjects in the spaced condition. These results are not in keeping with

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Gilchrist's and Wilkenson's (1979) findings that coma duration was closely related to recovery. On simple reaction time exercises (e.g., F4 and F10), however, the longer the length of coma the more time required to process the exercise. Perhaps severely injured individuals have lowered tonus and therefore require more challenge in order to achieve an adequate level of alertness. This would explain why the learning slopes were not always in the expected direction. The subjects in the spaced condition had a longer coma duration though this was due to one subject. If this subject's coma duration is not considered, then a much shorter coma duration results in this condition. It may be that shorter coma duration in the spaced condition put these subjects at a clear advantage despite the "starting time" (i.e., T2). In fact coma approached significance for this exercise.

Another possibility is that extreme cautiousness in the massed condition resulted in less decrements in RT. The raw scores on errors (not analyzed in results chapter) indicated that subjects in the massed condition made fewer errors on T2 (X = .6, SD = .7) than in the spaced condition (X = 1.3, SD = 1.4). On T10 subjects in the massed condition maintained a low error score (X = .7, SD = 1.1) whereas in the spaced condition error rate was still high (X = 1, SD = 1.6). It is interesting to note that the steepness of the slope for these conditions differed only by .005. This implies that decrements in RT across trials were somewhat similar in both conditions. Moreover, trend analyses indicated that complex functions explain the trial effects in each condition. Neither condition, therefore, manifested linear improvements in performance with practice.

Perhaps efficiency in performance declines when CHI patients are

required to maintain vigilance for a prolonged period of time (Van Zomeren, Brouwer & Deelman, 1984). Goldstein (1942) reported that brain injured patients showed that initial simple and choice RTs were well within normal limits. After the first 10 trials (i.e., stimulus exposure) these patients were likely to show both a lengthening in RT and an increase in variability within the limits investigated (30 trials).

Similar effects were observed in the significant interaction on F9. The spaced condition demonstrated a sharp performance increment by T10 compared to the massed condition. It may be argued that spacing of practice improves performance with practice, but why it does not for the other exercises is not clear. Coma approached significance for this exercise. The very same subjects that were in the spaced condition for F5 were also in the spaced condition for F9. The possibility of spurious significant effects are possible given the multiple univariate ANOVAS and ANCOVAS calculated. The most parsimonious explanation for these interactions is that there may be a selection bias effect that is being observed.

The following discussion section will include an integrative and speculative view of all the analyses. Trends, slopes, ANOVAs, and ANCOVAs will be looked at in combination.

Massing of practice in CHI individuals does not necessarily facilitate learning. Combination of all standardized scores into one plot for each condition suggested that spacing of practice leads to greater performance gains than massing of practice. Learning slopes, for all exercises (combined standard scores), were steeper in the spaced

condition on each of the five disks. Moreover, spacing of practice also resulted in less peaks and troughs in the learning curves (for each exercise) which implies that in the massed condition performance was in the opposite direction on more trials than in the spaced condition. It is interesting to note in F8, F9, and F12 that spaced practice over time resulted in less variation from trial to trial since a simpler trend function explained the larger percentage of the practice condition main effect. In addition, the spaced condition for these exercises also manifested a steeper slope, consequently more learning was observed in this condition when all trials were considered. In fact F9 demonstrated a significant interaction and F8 approached significance. The slopes suggest that CHI individuals may benefit more from cognitive rehabilitation if practice of the function to be remediated is spaced over time and does not become too taxing on the individual. Over taxing may generate boredom, fatigue, loss of motivation, feelings of emotional inadequacy. These observations are supported by Gronwall and Wrightson (1974) who found that flooding head injured individuals with information may be detrimental to performance. It is interesting to note that the subjects in the massed condition manifested a slightly better performance on the early trials (i.e., trials one to five) compared to the subjects in the spaced condition (see Figure 8). It may be possible that a short (e.g., 5 minutes) intermediate break from work may help CHI individuals improve or maintain performance. This observation may have important implications in setting up rehabilitation for CHI individuals. Further research on this point may be necessary.

In exercises requiring primarily fundamental functions of attention and concentration (i.e., Foundation exercises) only F11 and

F12 resulted in significant differences between massed and spaced conditions and these differences were not consistently in favor of the massed condition. It appears that the significance observed can be attributed to covariates of age, interval since trauma, education, and coma for F11. For F12 the significance resulted from the difference in age between the subjects in the two conditions. The subjects in the spaced condition were on average four years younger than the subjects in the massed condition, and speed of response was shorter in the former. Although this exercise provided an opportunity for the subject to ready himself for action (i.e., a visual warning appeared prior to stimulus presentation) this was not sufficient to enable the older subjects to match the performance of the younger subjects.

This finding is not altogether surprising because previous studies have found that the older the individual who has sustained CHI the less optimistic the outcome of rehabilitation tends to be (Brooks, 1975; Lewin, Marshal, & Roberts., 1979; Lynch, 1984b). Malec et al. (1984) and Sarno and Levita (1971) did not find age to correlate with changes in performance. Age, however, may not be the only factor affecting performance. Impairments in sustained attention (Benton, 1986) may result from distractibility and fatigue (Lezak, 1983). These impairments are most likely related to lesions seen in the brainstem (Strich, 1979) influencing the individual's level of arousal (Luria, 1973). If the individual's level of arousal is affected by fatigue then the massed condition should be at a disadvantage by T10 compared to the spaced condition. F5 and F9 interactions may suggest that spacing of practice did not lead to fatigue.

It seems that if CHI individuals are monomorphically stimulated (i.e., as in the case of massing of practice) their performance will most likely deteriorate. This becomes clear from F5 and F9 in which the significant interaction resulted from the spaced group's superior performance from T2 to T10 from the subjects in the spaced condition. The inferior performance in the other subjects may be due to fatigue (Lezak, 1983) resulting in a slowness of information processing (Benton, 1986). If fatigue does set in then variation in response should be expected and this is precisely what was observed on these exercises for the massed condition. Benton and Blackburn (1957), however, did not find support for the clinical view that brain injured patients may show an undue susceptibility to fatigue as a result of practice effects in a similar situation. There was, however, a significant increase in within subject variability with continued practice for simple RT exercises in the Benton and Blackburn study. An alternate explanation may be that F5 requires a decision process favoring the left hemisphere, and the subjects in the massed condition were more deficient than the subjects in the spaced condition in the decision process itself.

Due to chance with randomized subject selection, seventy percent of the subjects in the massed condition had to use their left hand. This may have retarded their response since the majority were forced left handers. The subjects in the spaced condition would have been advantaged since 66% were right handers who would probably not have shown as much deterioration in sustained hand use over time.

It has been found that simple RTs are strongly impaired after right hemisphere damage (De Renzi & Faglioni, 1965; Howes & Boller, 1975). In support of Van Zomeran and Deelman's (1978) study, it was indicated that

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choice RT exercises differentiated the massed from the spaced conditions more readily than simple RT exercises. The simpler RT exercises (e.g., F1, F2, F3, etc.) all failed to differentiate the subjects in the two conditions. It may be argued that the subjects in the massed condition on F5 and F9 were already performing at their peak level. Consequently they could not have been expected to improve their performance.

In the Foundation exercises the subjects generally did not reach a plateau (see Appendix 23). The only exception was on F9 where in both conditions a plateau was observed on T7 and was maintained up to and including T10. It is possible that if an attempt is made to improve processing speed in CHI, then 10 trials are insufficient to observe ceiling effects of reaction time. In these exercises there were 15 stimuli per trial, therefore, even 150 exposures to the stimulus was insufficient.

The position of the stimulus in space of all the Foundation exercises varied at each presentation, with the exception of F9. Perhaps processing time was affected as a result of having varied the stimulus location. Verfaellie, Bowers, Williams, and Heilman (1985) found that knowledge about where in space a stimulus will occur does affect processing efficiency both by facilitating responses at the expected position and retarding them at the unexpected position. Perhaps CHI individuals require more static (i.e., predictable) environments in order to improve and stabilize responding over time, given that these individuals are very much affected by change in environmental conditions.

Although the data on each trial were averaged separately for each

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condition, the learning curves failed to demonstrate the smooth characteristic curves reported in previous studies (e.g., Hiorns & Newcome, 1979; Roberts, 1976). Qualitative understanding of performance was not affected by the averaging of learning curves in this sample and did not result in smoothing out of trial to trial variation. Both conditions demonstrated tremendous variability between trials on the Foundation exercises. In fact, even when all the subjects' data were pooled, per trial, we still failed to observe this characteristic learning curve reported in the literature.

For exercises F1, F2, F4, F7, F10, and F11 the subjects who were in the group referred to as the "slow group" (see results section E) did not benefit from either learning across time or rote learning in simple RT exercises. Perhaps it was these subjects who also contributed to the opposite directionality of the learning slopes that were calculated for all subjects combined on F7 and F11. One hundred and fifty repetitions of a stimulus were not enough to reverse the learning curve in the appropriate direction. It is tempting to bring into question whether this particular routine is really doing what it was designed to do (i.e., improve attention/concentration). However, the slope coefficient for these exercises, although they were not in the appropriate direction, was negligible.

On the Visuospatial disk VS4 and VS8 did differentiate between the two conditions. The significant practice condition main effect for VS4 resulted from the better performane in the spaced condition. This exercise is similar to VS3. Perhaps the spaced condition produced significantly superior performance on this exercise because of an advantage of receiving more repetitive stimulation (massed) on VS3. In

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fact, where on VS3 the learning slope in the massed condition was not in the expected direction, these same subject's slope was in the appropriate direction for VS4. The subjects may have required more exposure to the exercise in order to reverse their learning curve in the right direction. The same comments apply to VS7 and VS8.

Miller (1980) found that severely head injured subjects showed considerable improvement on a task relying heavily on visuospatial ability when given extensive practice. Miller further observed that the subjects demonstrated good transfer from one stimulus to another analogous stimulus. In a limited way our results on VS4 may demonstrate this transfer effect observed by Miller. Additionally, massed stimulation resulted in a steeper learning slope.

.It is important to note that across trials the greatest percentage of the practice condition main effect for VS4 was explained by a quadratic function in the massed condition but not in the spaced condition. In terms of "absolute" learning from T2 to T10 (T2 minus T10) it is subjects in the massed condition and not in the spaced condition that improved most. This became obvious from the steepness of the learning slope. The absolute difference in the massed group was 31 whereas in the spaced group it was −1.

For VS9 the ANOVA significant interaction was attributable to the superior fine motor performance of the subjects in the spaced condition for that exercise. This ability to make very fine rotational finger movements, required to manipulate the game paddle does not appear to be affected by the duration of coma since these subjects demonstrated superior performance in spite of the longer coma duration. That is, the

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subjects in the massed condition had "absolute" gains in performance of 60 from T2 to T10 in spite of the shorter coma duration. In contrast, the subjects in the spaced condition had "absolute" gains of 195. Shorter coma duration in this fine motor control exercise does not result in superior performance. In point of fact, the significant interaction for F5 and VS9 point to the possibility that CHI individuals with shorter coma duration do not benefit from rote learning.

The right hemisphere has been found to be dominant for attention and intention (Heilman & Van Den Abell, 1980). Intention concerns preparation for motor action. Patients with right hemisphere lesions appear to have intention deficits for movements of the contralateral hand (i.e., the left). It may be that responding was facilitated more in the spaced condition as opposed to the massed condition ov VS9 for this reason. Neuropsychological profiles demonstrated that 62% of the subjects preferred their left hand in the spaced condition for this exercise. In contrast only 40% of the subjects in the massed condition were more left hand functional. The subjects in the spaced condition, therefore, may have obtained faster RTs because of better preparation of the left hand for action. However, the significant interaction on VS9 that resulted from ANOVA, unlike F5 and F9, was no longer significant once coma was covaried.

These findings are quite surprising since the literature supports the view that severity, determined by length of coma, is related to rehabilitation outcome (Lezak, 1983; Miller, 1984). In order to shed some light on this situation it was decided to return to the raw data. There was a subject in the spaced condition for the exercises that resulted in significant interactions (i.e., F5, F9, and VS9) that had a

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coma duration of 960 days. It was this subjects datum that greatly affected the group mean for coma. After having removed this subject's coma datum from the mean it was found that the subjects in the spaced condition did indeed have shorter coma duration (adjusted from 114 days to 37 days on exercises F5 and F9). On VS9 the coma duration in the two conditions now differed by only 11 days (in favor of the subjects in the massed condition) whereas before removal of this subject the means were apart by 121 days.

However, these explanations may be too simplistic. Visuospatial exercises requiring a motor response require integration and subsequent action of two modalities, visual and sensorimotor. Integration at various levels involves receiving sensory information, analyzing this information, making a decision, and acting upon this decision (Luria, 1973). Suppose that systems in the sensory input (visual and motor) are intact; in addition that the functional systems required in the analyses and decision-making are also intact, but that the systems transmitting information from the visual cortex to the sensory motor cortex or vice versa are compromised by head injury. Adequate feedback in such cases does not reach either functional system to permit correcting the behavioral response. Or perhaps the feedback received is inadequate or somehow incomplete due to microscopic lesions within a functional system.

Lesions ipsilateral or contralateral in the visual and/or motor cortex can result in behavioral disruption. Furthermore, it may be that lesions often observed in the corpus callosum as a result of CHI prevent interhemispheric communication (Strich, 1979). These phenomena

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were observed to some extent in at least one of our subjects. A.B. was a young male whose most functional hand was the right. From the neuropsychological test profile A.B. had deficient to profoundly deficient scores on design fluency, left hand finger tapping, left hand dynamometer, left hand tactual performance, and left hand RT which pertain mostly to integrity of the right hemisphere. He also had deficient scores on five tests used to assess the corpus callosum. When performing one of these exercises requiring visual-motor integration A.B. was observed persisting to manoeuvre the joystick in the wrong direction when he used his right hand. Completion of this exercise, given its loading on visuospatial functioning, which is related to functions of the right hemisphere, required interhemispheric relay when the subject used the right hand. Although A.B. understood the task requirements, he appeared to be unable to correct his behavioral response. Alternate explanations were precluded since A.B. did not demonstrate this problem when using his left hand.

From the Memory disk, only M4 (level reached), which is mostly a visuospatial exercise for location and objects, differentiated the two conditions. M4 appears to be the most challenging exercise on this disk since multiple memories must be activated in order to complete the exercise (i.e., convergence of multiple functional systems such as verbal, spatial, and motor systems). For example, the objects to be remembered tap verbal labelling associated with the integrity of the left hemisphere (e.g., an "H", an "L", etc.). The results indicated that memory was improved and sustained more for this exercise with a massed condition. The massed schedule, however, resulted in explaining less of the practice condition main effect. This implies that there was

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somewhat more variability between trials in this condition. This is further supported by the larger standard error. The learning curves were steeper in the massed condition, however. A massed condition for this exercise not only improved level but also resulted in steeper learning slopes for both the number of objects recalled as well as the exercise completion time.

Both age and interval since trauma-to-project appear to affect recall of sequenced designs (M8) which also does not necessarily load most on right hemispheric functioning. This exercise taps the functions of both hemispheres in that the left hemisphere is activated for logical sequential processing and the right hemisphere for designs.

For M7 which also involves visuospatial memory, but in nonsequenced order, although the practice conditions did not differ and there were no covariates masking performance, a trade-off was observed in the learning slope of the spaced condition between errors and the number of designs recalled. The subjects in this condition were able to reduce the error rate more but at the expense of remembering less. Trade-offs were also observed for verbal excercises (i.e., M5) for which the number of letters recalled went up but so did the errors made in both conditions. There was also a trade-off observed for M2. Although there were on the average less sequenced words recalled per trial by the subjects in the massed condition, the learning slope was steeper for overall score reached across trials. The view that CHI individuals have a cautious approach to learning (Schacter & Cravitz, 1977) is supported by these findings. Brooks (1974) concluded from his results, which were based on Signal Detection Theory, that cautiousness in responding results in poor

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memory performance by CHI patients. When the exercise to be remembered involves mostly verbal span backwards, being older also affects performance negatively.

For M1 (level), although the subjects in the spaced condition reached a slightly steeper learning slope they required more moves to do so. Subjects in the massed condition however, took less time to complete the exercise than subjects in the spaced condition (X= 90 sec. less). In spite of this, the steepness of the learning slopes (with respect to number of moves made) was greater in the massed condition. This may have resulted from the extreme departure from the slope, on T4.

Trend analyses indicated that the linear trend explained most of the practice condition main effect in the spaced condition on seven of the nine exercises and only on three in the massed condition. So massing of practice does lead to greater variability between trials on memory exercises, but this is compensated by steeper learning slopes. Learning slopes on the Memory disk were all in the expected direction except for M1 (time) and M5 (errors). With the exception of M4 the learning curves were not smooth across trials, and a plateau was not observed on any of these exercises.

The results demonstrated that the two practice conditions did not produce different performance on the Auditory exercises. It is, however, important to note that spaced practice on these exercises leads to steeper and simpler learning slopes. Simpler because more of the practice condition main effect was explained by simpler functions in the spaced condition. Although this exercise is designed to remediate difficulties in tonal discrimination, it is somewhat monotonous and long. Completion of ten consecutive trials could entail decrements of

sustained attention as well as of motivation. On the average it took
about one to 1 1/2 hours to complete ten trials, at which time several
subjects expressed irritation. Although improvement across trials was
observed for all subjects combined it is not recommended to use a massed
practice schedule for these exercises.

Some support for the above conclusions for the Auditory exercises
may be provided by a case observation. C.G. was a 50 year old female
who had sustained CHI secondary to a car accident 15 months before she
was seen for remediation. She was in a coma for 105 days and the extent
of her damage resulted in 38% of deficient scores on her
neuropsychological test profile. The sight of impact was to the frontal
lobes. She did not have a skull fracture, therefore, intracranial
pressure if present was not released nor did she require surgical
intervention. On F11 and M3, which are auditory exercises, C.G. was in
a spaced condition. She completed these exercises, albeit with very
little improvements. When she was required to do AD1 in a massed
condition her motivation to complete this task could not be sustained
beyond 4 trials and she expressed in no uncertain terms that she did not
wish to continue. In point of fact, not only did she not complete this
exercise but was also not willing to do the other auditory exercise
(i.e., AD2). There are various impressions which can be drawn from this
anecdotal case observation. One is that this subject suffered
motivational problems due to frontal lobe dysfunction. Since she did
complete all previous exercises in either a massed or spaced condition
this explanation was less likely. Another, and perhaps more likely
possibility is that this exercise is laborious especially in a massed

condition. Most subjects in the massed condition expressed feelings of boredom while performing these two exercises.

The results for the Problem Solving exercises demonstrated that neither practice condition succeeded in significantly improving performance with the exception of PS4 (wrong moves). The subjects in the spaced condition were unable to logically reason out a strategy that minimised wrong moves. Perhaps having been exposed to this exercise only once per session was not enough in order to allow formulation of a plan. This view, however, may be insufficient since a massed condition on a similar exercise (PS5) was inadequate in improving performance. PS5, however, was a puzzle of higher complexity than PS4 and this probably contributed to the lack of a significant practice condition main effect. Another reason why PS4 may have resulted in a significant practice condition main effect may be that longer coma durations of the subjects in the spaced condition hindered performance. Coma was a significant covariate on three of the problem solving exercises and PS4 was one of them. For PS4 the condition effect was not significant after ANCOVA. Trial was, however, significant and the interaction approached but did not reach significance. It may be that the massed schedule paraded as a better condition when in fact it was the reduced coma duration in that condition that had an influence on performance.

Across trials for PS4 there was a learning slope trade-off in the spaced group. These subjects took a cautious approach to the problem consequently making less wrong moves but as a result their slope was steeper for the error delay variable. These same subjects on PS5 had trade-offs similarly between errors and task completion time. They were able to complete the exercise faster but at the cost of making more

wrong moves. Cautious behavior in CHI is not exclusive to memory, but also permeates exercises which require executive functioning, and which may be related to the integrity of the frontal lobes. Rigidity of response is another very common behaviour observed in cases that have sustained frontal lobe damage secondary to CHI. Rigidity of response, therefore, may hamper learning of exercises that require intrinsic planning and sequencing of behavior. That is, the frontal patient is unable to flexibly alter the behavioral response to meet task demands.

The organization of goal directed activity suffers appreciably from frontal lobe lesioning. Patients may show an inability to concentrate on an internal behavior (Luria, 1963). Such functioning implicates Luria's third unit of the brain involved in programming of actions, regulating behavior in relation to the program and verifying that the behavior is adequate for the program and meets the demands of the task (Luria, 1973). Luria (1963) further claims that successful restoration of disturbed functions may require stability of motivation which becomes an essential factor for some brain injured patients. Such a fundamental condition may be significantly modified as a result of frontal lobe damage. This claim became obvious in at least one of our subjects, who failed to complete the remediational protocol due to instability of motivation.

Problem solving exercises were started at approximately four months into rehabilitation. The results demonstrated that for the exercises in which task completion time was recorded (i.e., PS1, PS2, and PS5) the learning slopes were steeper in a massed condition (see Table 4). Perhaps a considerable number of hours in rehabilitation are required

before any relative improvements occur in exercise completion time. In fact processing time in CHI approached (-1.4 SD) that of a normal non head injured group (Braun, et al. 1987). At the beginning of rehabilitation CHI individuals deviated considerably more from the norm than they did toward the end of rehabilitation, with the exception of PS1 errors.

In terms of variability trend analyses indicated that the more complex functions, which comprise greater variability, accounted for the practice condition main effect on problem solving exercises than other exercises performed during the course of rehabilitation. There were more peaks and troughs in the learning curve on these exercises than other exercises. The exception was PS2 in which subjects in the spaced condition manifested a linear function that was unsurpassed by performance on any other exercise or condition. This is surprising in view of the fact that once a person gets the "hang of it" so to speak, the number of moves required should reach floor effects. There was a floor effect (i.e., plateau) observed for this exercise in the massed condition between T3 and T8. In fact this group did get the "hang of it" by the third trial with very little change in their response thereafter. Repeating the exercise, therefore, beyond three trials appears to be of no benefit to this sample.

Problem Solving exercises in this sample resulted in a lot of frustration. The performance of all subjects combined illustrated extreme reversals in the learning curve means from trial to trial with the exception of PS2 moves. It is believed that these subjects were perhaps not ready at this point of rehabilitation to be introduced to such exercises. On the other hand, if lesions in this sample tended

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more toward the frontal lobes (i.e., greater than 50% deficient scores on the frontal tests) perhaps there is no "good time" to introduce these individuals to such exercises. Finally, perhaps CHI individuals independently of locus of lesion become emotionally inundated when flooded with information due to their limited information processing capacity (Gronwall & Wrightson, 1974).

D: Conclusions and suggestions for future research

If a subject is relatively impaired for a specific function then the behavioral response is likely to show tremendous variability across trials compared to his less impaired fellow patient. These individual curves may be used as a reference of recovery potential in a clinical setting. Some individuals manifested substantial performance improvements on a given exercise. Other cases, however did not manifest improvement in performance as a result of practice. Case profiles put the clinician in a dilemma as to what should be reported. Case studies in the literature globally report favourable outcome as a result of rehabilitation. The present project, however, illustrated that as a "group", with no a posteriori exclusions, these individuals, who averaged seven years post trauma, improved on nearly every exercise.

These results beg the question as to whether expenditure in providing specialized cognitive-perceptual rehabilitation with the use of a microprocessor could be justified financially and/or economically. It is concluded that the PSSCRP put forth by Dr. Bracy may be widely used with severely CHI individuals and would not be expected to result in performance deterioration on any of the exercises reviewed here,

except for certain aspects only of a few exercises. Real improvement can be expected on a large proportion of the exercises.

Though an average of between 80 to 100 hours of individual cognitive-perceptual rehabilitation was given to each subject it is not possible at this point to decide which of the two learning schedules, massed or spaced, globally influences the outcome of cognitive-perceptual rehabilitation in severely CHI individuals. The results lean toward favoring spaced practice over time.

Whether further expenditure would be justified to answer this question is difficult to determine. Future research that may be of benefit may involve: 1) Converging evidence from neuropsychological test results, neuropsysiological results (i.e., polygraphic indices, Evoked Potentials) and computer rehabilitation. 2) The creation of norms for these exercises in normals and CHI individuals. 3) The investigation of cognitive-perceptual rehabilitation generalization to neuropsychological test scores and activities of daily living. 4) Investigation of the interface between cognitive-perceptual rehabilitation software and neuropsychological test batteries.

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Appendix 1

NEUROLOGICAL QUESTIONNAIRE

1. Name of respondent

2. Phone number

3. Relation of respondent to patient (parent, sibling, spouse, etc.

4. Present date (day, month, year)

5. Duration of coma (unconsciousness)

6. Duration of post traumatic amnesia (memory lose)

7. Name of patient

8. Date of birth of patient (day, month, year)

9. Date of trauma (day, month, year)

10. Education of patient

11. Highest diploma (specify discipline)

12. Address of patient (include postal code)

13. Patient's phone number

14. Name of patient's medical doctor

15. Phone number

16. Skull fracture   Yes   No

17. Surgical intervention to brain following head trauma   Yes   No

18. Presently employed

     Yes
     No

19. Type of work at present

     a) same as pre-injury
     b) less demanding
     c) sheltered
     d) unemployed
     e) homemaker
     f) don't know

20. Status of present job

    a) full
    b) part
    c) unemployed
    d) don't know

    Income

    a) patient   21) primary
    b) spouse
    c) children   22) secodary
    d) extended family
    e) private insurance   23) tertiary
    f) social welfare
    g) unemployment   24) fourth
    h) court award
    i) investment
    j) don't know

	Position	Dates/time	Part/full
25. Prior to injury			
26. Prior to injury			
27. Prior to injury			
28. Since injury			
29. Since injury			
30. Current			
31. Occupation of father			
32. Occupation of mother			

33. Disability/Compensation   Type   Amount

    a) Yes
    b) No
    c) don't know

Marital status

    a) single
    b) married/cohabiting
    c) separated
    d) divorced
    e) widowed

34) Pre-traumatic

35) Post-traumatic

36) Since last
    questionnaire

Psychiatric history

    a) none
    b) yes, did not seek help
    c) outpatient treatment
    d) hospitalization
    e) don't know

37) Pre-traumatic

38) Post-traumatic

39) Since last
    questionnnaire

40. Transportation

    a) alone
    b) accompanied
    c) none
    d) don't know

41. Pre-injury arrest   Type
                            Sentence

42. Post-injury arrest   Type
                             Sentence

43. Previous cerebral commotion

    Yes   Date
    No

44. Previous trauma

    Yes   Date
    No

    Type

45. Treatment received for present brain trauma

    a) hospital   b) clinic
    c) rehabilitation center   d) other institution
    e) individual treatment   f) psychology, MD etc.

46. Previous Central nervous system damage or disease:

47. Present Medical complaints:

48. Neurological diseases of family members:

	Compare to Pre-injury	Compare to last time questionnaire was answered

49. Dizziness

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

50. Coordination

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

51. Headaches

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

52. Vision

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

53. Gait (walking)

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

54. Fainting

    ba) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

55. Sleep

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

56. Trembling (hands)

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

57. Pronunciation of words

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

58. Muscle twitching

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

59. Bladder control

   a) no change
   b) mild increase
   c) marked decrease
   d) improvement
   e) don't know

60. Bowel control

   a) no change
   b) mild increase
   c) marked decrease
   d) improvement
   e) don't know

61. Sense of balance

   a) no change
   b) mild increase
   c) marked decrease
   d) improvement
   e) don't know

62. Pain (other than headache)

   a) no change
   b) mild increase
   c) marked decrease
   d) improvement
   e) don't know

63. Handwriting

   a) no change
   b) mild worsening
   c) marked worsening
   d) improvement
   e) don't know

64. Reading

   a) no change
   b) mild worsening
   c) marked worsening
   d) improvement
   e) don't know

65. Feeling of numbness in
    a part of the body

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

66. Muscular weakness

    a) no change
    b) mild increase
    c) marked decrease
    d) improvement
    e) don't know

67. Stability of mood

    a) no change
    b) mild unstable
    c) marked unstable
    d) more stable
    e) don't know

68. Speech

    a) no change
    b) mild worsening
    c) marked worsening
    d) improvement
    e) don't know

69. Ability to live independently

    a) no change
    b) mild worsening
    c) marked worsening
    d) improvement
    e) don't know

70. Ability to dress

    a) no change
    b) mild worsening
    c) marked worsening
    d) improvement
    e) don't know

71. Hearing

   a) no change
   b) mild disturbance
   c) marked disturbance
   d) improvement
   e) don't know

72. Taste and smell

   a) no change
   b) mild decrease
   c) marked decrease
   d) improvement
   e) don't know

73. Seizures

   a) none
   b) pre-injury disorder
   c) at time of impact
   d) after initial hospitalization
   e) c and d
   f) don't know

74. Thinking

   a) no decline
   b) mild decline
   c) marked decline
   d) improvement
   e) don't know

75. Concentration

   a) no decline
   b) mild decline
   c) marked decline
   d) improvement
   e) don't know

76. Recent memory

   a) no decline
   b) mild decline
   c) marked decline
   d) improvement
   e) don't know

77.. Remote memory

    a) no decline
    b) mild decline
    c) marked decline
    d) improvement
    e) don't know

78. Depression

    a) none
    b) mild
    c) marked
    d) improved
    e) don't know

79. Appetite

    a) no change
    b) increased
    c) decreased
    d) don't know

80. Sleeping

    a) no change
    b) increased
    c) sleep disturbance
    d) don't know

81. Energy level

    a) no change
    b) increased
    c) decreased
    d) don't know

82. Sexual functioning

    a) no change
    b) mild decrease activity/
      arousal
    c) not marked decreased
    d) increase
    e) don't know

83. Anxiety

   a) no change
   b) mild increase
   c) not marked increase
   d) decrease
   e) don't know

84. Patience

   a) no change
   b) mild decrease
   c) not marked decreased
   d) increase
   e) don't know

85. Temper/impulse control

   a) no change
   b) worse
   c) better
   d) don't know

86. Hallucinations

   a) none
   b) auditory
   c) visual
   d) auditory and visual
   e) don't know

87. Managing household chores

   a) no change
   b) mild decrease
   c) not marked decreased
   d) improvement
   e) don't know

88. Legal dispute

   a) no
   b) patient initiated
   c) against patient
   d) b and c
   e) don't know

89. How getting along with
    spouse?

    a) as well as before
    b) better than before
    c) not as well
    d) does not apply

90. How getting along with
    family/friends?

    a) as well as before
    b) better than before
    c) not as well
    d) does not apply

91. Social activities

    a) as much as before
    b) more than before
    c) less than before
    d) hardly at all

92. Sports/recreation

    a) as much as before
    b) more than before
    c) less than before
    d) hardly at all

    General improvement

93. Physical

    a) improved
    b) no change
    c) decline
    d) don't know

94. Mental

    a) improved
    b) no change
    c) decline
    d) don't know

	95. Pre-injury	96. Post-injury	97. Since last questionnaire
Drug Use			
- Marijuana			
- Hallucinogens			
- Stimulants (cocaine, amphetamines)			
- Sedatives/hypnotics (Qualudes, barbiturates)			
- Narcotics			
- Minor tranquilizers			
- Prescription			
- Other			

	98. Pre-injury	99. Post-injury	100. Since last questionnaire
Alcohol Use			
a) none			
b) occasional			
c) less than 2 drinks per day			
d) more than 2 drinks per day			
e) drinking interfering with job/social functioning			
101. Medication used in the past			
102. Medication presently used			

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Appendix 2

Description of Foundation Exercises

Simple Visual Reaction 1 (F1)

One-inch yellow square is presented at random locations after random delays. The subject reacts as quickly as possible by pushing the joystick buttom. Reaction time (RT), variance, and errors are provided but only RT and variance will be analyzed.

Simple Visual Reaction 2 (F2)

This task is similar to F1 except that stimulus squares are 1/4 as large. The same statistics as F1 are provided and the same dependent measures will be analyzed.

Visual Reaction Stimulus Discrimination 1 (F3)

On a random schedule, either a blue or a yellow one-inch square is displayed at random location after random delays. The subject must react as quickly as possible to the yellow square and inhibit making a response to the blue. RT, variance, and errors are displayed, both RT and variance will analyzed.

Visual Reaction Stimulus Discrimination 2 (F4)

This task is similar to F3 except that the stimuli are smaller. The same dependent measures are provided as F3 and the same measures will be analyzed.

Visual Reaction Differential Response 1 (F5)

The monitor screen is divided into halves. When a small red square appears randomly on the screen after a random delay, the subject is required to push the joystick toward the half of the screen in which the square is displayed. RT, variance, and errors are provided. RT and variance will be analyzed.

Visual Reaction Auditory Prestimulus (F6)

This program operates similarly to F1 except that each target stimulus is preceded by an auditory prestimulus to which the subject must inhibit responding. RT, variance, and errors are provided. RT and variance will be analyzed.

Visual Discrimination Differential Response 1 (F7)

The subject must make a discrimination between two possible stimuli and respond with either the left or right hand, depending upon the stimulus displayed (red stimulus=left hand, blue stimulus=right hand). RT, variance, and errors are provided. RT and variance will analyzed.

Visual Discrimination Differential Response 2 (F8)

Three large squares are presented that vary in color randomly. When either of the outside squares match with the center square in color, the subject must push the joystick toward the matching side. Number of correct hits, number of misses, and the total of possible correct responses are provided. Number of correct hits in proportion to possible correct responses will be analyzed.

Visual Scanning (F9)

A darkline is plotted, one block at a time in a scanning pattern as used for reading, beginning from the upper left corner. On a random schedule, a lighter block is plotted instead of the dark. The subject must react within a time limit. This exercise provides only the percentage correct accuracy

Simple Auditory Reaction (F10)

A tone is presented after random delays. The subject reacts by pushing the joystick button. RT, variance, and errors are provided. RT and variance will analyzed

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Auditory Reaction Stimulus Discrimination (F11)

A target tone is presented for a few seconds. The subject must react by pushing the joystick button whenever this tone is repeated, and must inhibit responding when another non-target tone is presented. The same statistics as F10 are provided and will be analyzed.

Auditory Reactin Visual Prestimulus (F12)

This program operates the same as F10 except that each target stimulus is preceded by a visual prestimulus to which the subject must inhibit responding. This exercise provides RT, variance, and errors measures. RT and variance will be analyzed.

Appendix 3

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Description of Visuospatial Exercises

Maze 1 (VS1)

The subject must use the joystick to move a small block through the maze as rapidly as possible without hitting the walls. The number of wall bumps (moves) and the time required to complete the task are displayed.

Maze 2 (VS2)

This task is similar to VS1 except that a more complex maze is displayed. Same statistics as VS1.

Cube in a Box 1 (VS3)

The computer randomly moves a large open square around the screen. The subject attempts, using the joystick, to keep a small cube within the large square. The number of times the patient touched or was out of the open square is displayed.

Cube in a Box 2 (VS4)

Same as VS3 except the computer's square is smaller. The same statistics as VS3 are displayed.

Bilateral Motor Integration (VS5)

This task is similar to VS3 except that the integrated effort of both hands is required to move the small cube around the screen. The same statistics as VS3 are provided.

Paddle Ball (VS6)

A "ball" must be intercepted at the bottom of the screen to keep it in play. The subject controls the "racket" by turning the knob on the computer game paddle. The ball speed was set at 9, the "racket" length was set at 3 inches, and difficulty option was used. The number of

interceptions over ten trials is provided.

Line Orientation 1 (VS7)

An eleven point compass is presented on the left side of the screen. On a random schedule, one of the lines changes to a different color. Using the joystick, the subject must rotate a single line displayed on the right side of the screen so that it matches the angle of the target line on the compass. The percentage accuracy score after ten repetitions of the stimulus is displayed.

Line Orientation 2 (VS8)

An eleven point compass is presented on the center of the screen. On a random schedule, one of the compass lines changes color. After a few seconds, the screen clears except for a single horizontal line which the subject must rotate. From memory, the subject must try to match the angle of the preceding target line. The same statistics as VS7 are displayed.

Fine Motor 1 (VS9)

Using the game paddle, the subject must turn the knob to move a small cube back and forth and up the screen at a rate that will maximize speed while not exceeding the present maximum rate. If the knob is turned too rapidly, the subject is automatically started over at the beginning. The time to completion (i.e., computer cycles) as well as number of restarts are provided.

Appendix 4

Description of Memory Exercises

Spatial Memory (M1)

A trail, through a maze of rooms, is randomly generated by the computer, consisting of an experimentor indicated number of steps. Without clues, the subject must learn the trail through trial and error. Whenever an error is committed the computer starts, the subject over in room number one. In order to successfully complete the task, the subject must traverse the trail from beginning to end without error. Initially 4 steps were used and passage to a higher step level required two consecutive performances at or below criterion level. Criterion levels were as follows: 5 steps - 50 moves; 6 steps - 69 moves; 7 steps - 81 moves; 8 steps - 106 moves. These criterion levels were set in order to avoid chance performance. The number of moves required to traverse the maze of rooms are displayed. In addition to the moves the time required to complete the task was calculated.

Verbal Memory Sequenced Words (M2)

The program starts with the presentation of three 4-letter words, which the subject must briefly study and then recall in the order presented. If the subject recalls correctly at the current level then the computer adds one word to the next presentation. Word order is randomly chosen so subject gets different sets at every session. Recall is by recognition from a list of sixteen words. The average number of words recalled per presentation as well as the overall total words recalled are displayed.

Auditory Memory (M3)

A series of tones that either slide up or down the scale beginning with

one tone are presented to the subject to mimic (via the joystick).
Success at the current level results in a increase in the number of
tones presented. The same statistics as M2 are provided.

Visual/Spatial Memory (M4)

Objects are presented at random locations on the monitor screen. The
subject must recall which objects were displayed and the locations in
which they were displayed. Success results in the addition of more
objects. The same statistics as M2 are provided. The time required to
complete the task was collected.

Verbal Memory Nonsequenced Letters (M5)

Alphabetical letters are presented, scattered over the monitor screen.
The length of presentation and the number of letters increases
proportionately with each successful trial. After the letters clear
from thescreen, the entire alphabet appears across the bottom of the
screen. The subject must press the letters on the computer keyboard to
indicate the letters seen during the presentation. The errors made as
well as the number of letters recalled per presentation are displayed.

Verbal Memory Sequenced Letters (M6)

Alphabetical letters are presented, one at a time, in the center of the
screen. After the last letter, the alphabet is displayed across the
bottom of the screen. The subject responds as on M5. However, for this
task, the subject must respond in the same order as the letters were
presented. The number of letters recalled per presentation are
displayed.

Visuospatial Memory Nonsequenced Designs (M7)

Graphics characters are presented instead of letters as on M5. A row of
all graphics characters is then presented across the bottom of the

screen. The subject must move (via the joystick) the solid block under the character thought to be the correct response. The choice is selected by pushing the joystick button. Order is not important. The same statistics as M5 are provided.

Visuospatial Memory Sequenced Designs (M8)

Graphics characters are presented, one at a time, in the center of the screen. After the last character, all the graphics characters are displayed across the bottom of the screen. The subject indicates, in order, responses as for M7. The level reached per presentation is provided.

Verbal Memory Letters Reversed (M9)

Alphabetical characters are presented, one at a time, in the center of the screen. The subject must give the appropriate response in reversed order. The average number of letters recalled per presentation are provided.

Appendix 5

Decription of Auditory Exercises

Auditory Discrimination 1 (AD1)

The computer instructs the subject to listen to a target tone. A visual aid, consisting of a vertical line on the monitor, is provided as a reference. The computer then instructs the subject to "Close your eyes" and it presents a second tone accompanied by a short line. Using the joystick, the subject raises or lower the tone until it matches the target. The movement of the short line corresponds with the change in pitch produced by the subject. The short line will line up on top of the longer line when the two tones match.

Auditory Discrimination 2 (AD2)

This program is similar to AD1 except that the subject is able to hear only one tone at a time. The target tone can be reviewed at any time with the press of a button.

For both of these exercises the mean error (difference between the choice and the actual correct response) is produced.

Appendix 6

Description of Problem Solving Exercises

Number Manipulations 1 (PS1).

This is a visually presented serial addition task. For each presentation the subject must add the most currently presented number to the one presented just prior to it. The sum of these two numbers must then be indicated at the bottom of the screen. When the answer is entered into the computer, immediate feedback informs as to the correctness while simultaneously a new number is flashed in the center of the screen. There are twenty presentations. The total number of errors are provided. Task completion time was collected as well.

Number Manipulations 2 (PS2)

A number puzzle must be solved to correctly sequence a string of numbers by appropriate reversals of portions of the string. The exercise starts off by 3 digits in a mixed order and increases by one number if the previous numbers were properly sequenced. The number of moves required to correctly complete the sequence of a string are provided, the time required to complete all the sequences was collected.

Number Manipulations 2 (PS3)

At successive stages, the subject must keep cumulative total of a series of numbers and provide answer. Levels range from one to two sets to simultaneous presentation of both sets. The number of errors per level on each exercise is displayed as well as the speed per level. The speed score, however, is not always accurrate. The errors will be analyzed.

Maze Puzzle 1 (PS4)

A maze of moderate complexity is presented. Each puzzle has only one solution. An orange block that is initially located in the upper left

corner of the display can be moved through the maze via the joystick.
The subject must move the orange block through the maze and land it on
the yellow block.   If the block is kept stationary the
computer scores errors (delays) against the subject. The number of wrong
moves as well as the delays are displayed. Bothe measures will be
analyzed.

Maze Puzzle 2 (PS5)

This task is similar to PS4 except that the puzzle is of high
complexity. The same statistics as PS4 are provided.

Appendix 7

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NAME:_____ TIME SCHEDULE

	TIME						
DATE	start	END	total:	DATE	start	END	total:

Appendix 8

NAME:
UPDATE SCHEDULE

COMPLETED

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	
F_1											
F_2											
F_3											
F_4											
F_5											
F_6											
F_7											
F_8											
F_9											
F_{10}											
F_{11}											
F_{12}											
V_1											
V_2											
V_3											
V_4											
V_5											
V_6											
V_7											

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	
V_8											
V_9											
V_{10}											
M_1											
M_2											
M_3											
M_4											
M_{5A}											
M_{5B}											
M_{5C}											
M_{5D}											
M_{5E}											
A_1											
A_2											
P_1											
P_2											
P_3											
P_4											
P_5											
G_B											
G_S											

Appendix 9
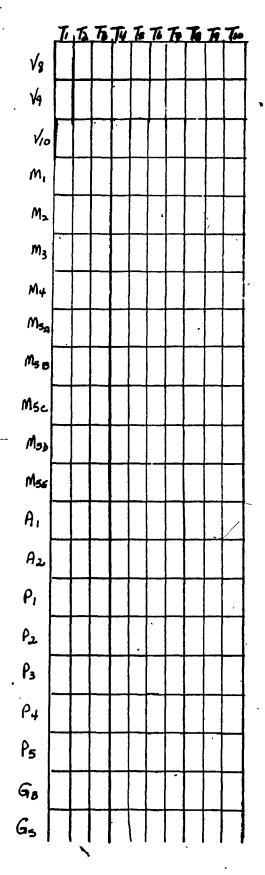
NAME: FEEDBACK

HAND: RIGHT •——•
LEFT X----X

SOFTWARE: FOUNDATIONS

TASK: F8

COND: MASSED

trials:	1	2	3	4	5	6	7	8	9	10
σ^2	145.7	140.1	142.1	135						
R ERRORS:	2	0	0	0	ETC					
MEAN	66	70	75	80						
DATE:	12025			→						
trials:	1	2	3	4	5	6	7	8	9	10
σ^2										
L ERRORS:										
MEAN										
DATE:										

EXPERI.:

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Appendix 10

TESTS RELATED TO INTEGRITY OF THE FRONTAL LOBE SYSTEMS

Design fluency: Tests the ability to generate nonsense designs on command. In the first part of this test the individual is given five minutes in which to draw as many nonsense designs as possible. The second part of the test requires that as many nonsense designs comprising only four lines each be drawn during four minutes (Jones-Gotman & Milner, 1977).

Benton C.O.W.A.T.: This tests the ability to spontaneously generate words on command. During a five minute period the individual is required to write down as many words as possible that begin with the letter "S". The second part of this test required the subject to write down in four minutes as many words as possible that begin with the letter "C" but each word has only four letters (Benton, Hamisher, Varney & Spreen, 1983).

Finger tapping: Tests the individual's ability to initiate and inhibit a motor response (i.e., index finger) as rapidly as possible. The individual is given five 10 seconds trials in which to tap as quickly as possible (Bornstein, 1985).

Dynamometer: This test measures motor strength of the upper extremities. Two trials are employed with each hand, provided that trials do not overlap in excess of five kilograms (Bornstein, 1985).

Kolb Sequential Praxia: Tests the individual's ability to sequence and execute arm movements demonstrated by the experimenter (Kolb & Milner, 1981).

Wisconsin Card Sorting: Tests conceptualization, perseveration, failure to maintain set, and inefficient learning across stages of the

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test. The stimulus cards (n=4) and response cards (n=128) display figures of varying forms (i.e., crosses,. squares, triangles, or circles), numbers (i.e., one, two, three, or four forms), and colors (i.e., yellow, green, red, or blue) (Heaton, 1981).

TESTS RELATED TO INTEGRITY OF THE TEMPORAL LOBE

Russell delayed recall: This test investigates the individuals ability to retain verbal and spatial material half an hour post presentation (Russel, 1975).

Dichotic test: This tests left-right aural differences in the perception of digits and melodies (Kimura, 1961, 1964).

Ekman Facial Affect: This test was designed to test the individual's ability to descriminate primary facial emotional expressions. The stimulus slides (N=44) include male (n=3) and female (n=3) faces expressing a primary emotion (i.e., happy, sad, fear, anger, surprise, or disgust). There are in addition six neutral slides to investigate attributional style (Ekman & Friesen, 1975).

Verbal-contextual test: This test is an analogue test of Ekman's Facial Affect test. It comprises 36 emotional situational sentences (6 each of happy, sad, fear, anger, surprise,or digust) presented to the subjwct by a tape recorder (Ethier, 1985).

Audiometer test: The individual's hearing threshold is assessed using a Fechnerian method. The individual is tested at 500, 1000, 2000, 4000, and 8000 dB with intensity ranging from -10 to 70 Hz (Jerger, 1963).

TESTS RELATED TO INTEGRITY OF THE PARIETAL LOBES

Benton Right-Left discrimination: This test comprises 20 items challenging the individual's ability to discriminate right from left by indicating various right or left body (own and examiner's) parts (Bornstein, 1985).

Tactual Performance test: This tests psychomotor problem-solving ability. Blocks of varying sizes and shapes are to be placed into respective spaces on a formboard by the blindfolded individual. The individual uses the dominant hand first then the opposite hand and then both hands. The individual is also required to reproduce from memory the board and forms (Heaton, Grant & Mathews, 1986).

Aesthesiometer: This is a sensory test designed to measure the individual's perception of the cutaneous two point threshold. Horizontal or vertical palm stimulation of various two point centimetric distances are applied and the person must indicate whether he or she feels one or two points (Semmes, Weinstein, Ghent & Teuber, 1960).

Single and Double Simultaneous Stimulation: This examines the accuracy with which one can identify single or double tactile stimulation to the cheek or/and hand and is sensitive to "extinction" in bilateral presentation (Antofani & Smith, 1979).

Semmes Body Placement: This test investigates autosteriognosia and employs five body parts diagrams (Semmes, Weinstein, Ghent & Teuber, 1960).

TESTS RELATED TO THE INTEGRITY OF THE OCCIPITAL LOBES

Perimetry: This test investigates possible visual field loss or visual field shrinkage. The four visual quadrants of each eye are separately tested while the person keeps her or his gaze centered on a

mirror.

Visual Acuity: Investigates the individual's visual acuity using a visual chart from a 20 feet distance.

AUXILIARY TESTS

D2: This test is a visual-motor cancellation test of attention. The individual is given 20 seconds per line in which to cross out all the letters "d" which have two primes. There are a total of 14 lines (Brickenkamp, 1962).

Vocabulary: this test is a subtest from the Wechsler Adult IntelligenceScale-Revised Manual. It purports to investigate the individual's vocabulary level (Wechsler, 1981).

Token Test: This test is a shortened version (16 items) of the Token Test and investigates possible aphasia. It comprises small and large tokens of various colors (i.e., yellow, blue, green, red, and white) and shapes (circles or squares) (Spellacy & Spreen, 1969).

Tremometer: This test investigates hand stability. The individual is given 10 seconds per circle (i.e., there are 3 circles varying in circumferance from one inch to 1/4 of an inch). The individual is required to insert a stylus into the hole and keep it centered during 10 seconds without touching the sides (Braun, 1985).

Humour test: This test measures appreciation of humour, the individuals response consistency, and the ability to make connections between (non)connected image-test (i.e., funny picture-funny text, funny picture-neutral text, etc.). This test comprises 30 such cards divided into 5 subcategories (Braun, Ethier & Baribeau, in press).

Corpus Callosum tests: These tests measure the following subcategories: 1) Cross replication of hand postures; 2) Unilateral agraphia; 3) unilateral apraxia; 4) Unilateral tactile anomia; 5) unilateral/bimanual sand paper comparisons (Bogen, 1985).

Harris Lateral Dominance test: This tests the individual's hand, foot and eye preference. The individual is asked to perform various hand (e.g., writing with left/right hand), foot (e.g., make belief person is kicking a ball), and eye (e.g., look through a telescope) tasks. This test is believed to help determine the individual's dominance. (Harris, 1958)). Since some individuals may have a forced preferance they are questioned as to whether they always used the left or right hand after the test is completed (Harris, 1958).

Reaction Time: This tests the individual's speed of response. The individual is asked to button press upon detection of a yellow square (n=15) presented by the computer. This task is performed with the left and the right hand given that the individual has two functional hands (Braun, Ethier, & Baribeau, 1987).

Appendix 11

<center>Order of Testing</center>

A.   Questionnaire

First Day

      Design Fluency
1. Visual Acuity
2. Audiometer test
3. Reaction time
4. Tremometer
5. Perimetry (visual)
6. Harris Laterality test
7. D2 Attention test
8. Wechsler Memory Test   1/2 hour. later-Russell Delayed recall
9. Dynamometer
10. Thurstone Verbal Productivity
11. Two point discrimination
     SDSS

<center>BREAK</center>

---

12. Test Dichotique des Digits
13. Kolb Sequential Praxis
14. Semmes Body Placement
15. Stereognosis

Second Day

1. Token Test
2. Ecoute dichotique des Tons
3. Finger Tapping Test
4. Wisconsin Card Sorting Test
5. Benton R-L Discrimination
6. Tactual Performance Test

<center>BREAK</center>

---

7. Ekman   9. Humour Test
8. Verbal Cassette   10. Corps Calleux

<center>173</center>

Appendix 12

NAME:_____   HAND: RIGHT •——•
SOFTWARE:_____   LEFT x---x
EXPERIMENTER:_____   CONDS_____

	.20
	.25
	.30
	.35
	.40
	.45
	.50
	.55
	.60
	.65
	.70
	.75
	.80
	.85
	.90
	.95
	1.00
	1.05
	1.10
	1.15

	TRIALS:	1	2	3	4	5	6	7	8	9	10
	σ^2										
R	ERRORS:										
	MEAN										
	RATE:										
	TRIALS:	1	2	3	4	5	6	7	8	9	10
	σ^2										
L	ERRORS:										
	MEAN										
	RATE:										

Subject:_____   Experimentor:_____

Software:_____

Task:_____   Condition:_____

Date	Trial #	Hand	SCORES	Strategies

Appendix 13

F1

MEAN RT (sec)

TRIALS

F2

MEAN RT (secs)

TRIALS

F3

MEAN RT (secs)

TRIALS

F4

MEAN HT (secs)

TRIALS

F5

F6

MEAN RT (secs)

TRIALS

.43 .41 .39 .37 .35 .33

1 2 3 4 5 6 7 8 9 10

183

F7

MEAN RT (secs)

.78
.76
.74
.72
.7
.68
.66

1 2 3 4 5 6 7 8 9 10

TRIALS

F8

MEAN PERFORMANCE RATIO

TRIALS

F9

MEAN % CORRECT HITS

TRIALS

F10

MEAN RT (secs)

TRIALS

F11

MEAN RT (secs) vs TRIALS

F12

MEAN RT (SECS)

TRIALS

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Appendix 14

VS1

MEAN TIME (secs)

TRIALS

VS2

MEAN TIME (secs)

TRIALS

VS3

MEAN ERRORS vs TRIALS

VS4

MEAN ERRORS

TRIALS

339 333 327 321 315 309 303

1 2 3 4 5 6 7 8 9 10

194

VS5

MEAN ERRORS

TRIALS

195

VS6

MEAN CORRECT HITS

TRIALS

VS7

MEAN % PERFORMANCE

TRIALS

197

VSB

MEAN % PERFORMANCE

TRIALS

VS9

MEAN COMPUTER CYCLES

TRIALS

Appendix 15

M1

MEAN MOVES

TRIALS

M2

MEAN CUMULATIVE WORD RECALL

TRIALS

M3

MEAN CUMULATIVE TONE RECALL

TRIALS

M4

MEAN VISUAL SPATIAL SCORE

TRIALS

M5

MEAN LETTER NONSEQUENCED RECALL

TRIALS

M6

TRIALS

MEAN SEQUENCED LETTER RECALL

M7

MEAN NONSEQUENCED VISUOSPATIAL RECALL

TRIALS.

MB

MEAN SEQUENCED VISUOSPATIAL RECALL

TRIALS

M9

MEAN REVERSED LETTER RECALL

TRIALS

Appendix 16

AD1

AD2

MEAN % ERROR

TRIALS

Appendix 17

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PS1

MEAN ERRORS

TRIALS

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PS2

TRIALS

MEAN MOVES

PS3

MEAN ERRORS

TRIALS

LEVEL 1
LEVEL 2

PS4

MEAN WRONG MOVES

TRIALS

PS5

MEAN WRONG MOVES

TRIALS

PS5

MEAN DELAY

MEAN WRONG MOVES

50   60   70   80   90   100   110   120   130   140

5   7   9   11   13   15   17   19

PS5

MEAN DELAY ERRORS

TRIALS

Appendix 18

Performance Curve Function and Percentage of that Function
that Explains the Trial Main Effect 224...................................225

Performance curve function (F) and percentage(%) of that function that explains the trial main effect.

Exercise	Massed F	Massed %	Spaced F	Spaced %
F1	1	21	1	73
	2	16	4	18
	3	31		
F2	6	19	5	36
	9	59	7	38
F3	1	37	2	23
	7	37	4	16
			7	25
F4	2	46	1	75
	5	34	4	13
			5	14
F5	2	16	1	25
	5	28	3	18
	7	31	4	17
			9	22
F6	5	27	1	32
	7	36	2	40
F7	4	23	3	15
	8	37	4	24
			9	37
F8	1	43	1	38
	4	13	2	34
	5	16	3	10
	6	12		
F9	2	28	1	70
	4	19	2	20
	9	23		
F10	2	16	1	70
	3	15	2	14
	5	36	3	20
F11	1	32	3	33

Exercise	Massed F	Massed %	Spaced F	Spaced %
F12	1	50	1	78
	7	14	2	10
VS1	1	62	1	66
	5	14	3	18
VS2	2	17	1	66
	4	20	2	24
	8	38		
VS3	2	22	1	41
	5	15	6	20
	6	34	7	15
VS4	1	11	1	18
	2	62	2	29
	9	11	5	12
			6	28
VS5	2	33	1	64
	7	19	2	23
	8	14		
VS6	1	65	1	88
	4	13		
VS7	3	40	1	46
	8	27	6	31
	9	21		
VS8	3	21	1	14
	6	13	2	41
	7	27	3	11
VS9	1	40	1	43
	2	14	5	11
	5	17	5	13
M1	1	7.1	1	52
			2	12

	4	31	5	20	M2	1	68	1	.68
	6	17	8	14				
M3	4	23	1	67	AD1	1	35	1	83
	8	29	5	12		6	53		
M4	1	73	1	77	AD2	1	70	1	64
						5	16	2	15
M5	1	29	1	35					
	2	44	2	22	PS1	1	69	1	79
			9	24		3	11		
M6	1	17	1	43	PS2	1	52	1	91
	3	11	2	17		2	33		
	8	18							
	9	39							

PS3 (level one)

					2	11	1	22
M7	5	27	1	19	7	32	7	32
	6	41	4	24	9	16	8	34
			7	29				

(level two)

					1	23	1	20
M8	3	16	1	40	6	16	3	17
	8	19	9	13	8	19	5	16
	9	42			9	24	7	25
M9	1	73	1	25	PS4	2	14	2	15
	3	15	2	25		5	18	4	12
			4	34		6	16	5	38
						9	36	6	18
					PS5	1	23	1	20
						6	16	3	17
						8	19	4	11
						9	24	5	16
								7	25

Legend: Function 1: first order or linear; 2: 2nd order or quadratic; 3: 3rd order or cubic; 4: 4th order or quartic, and so forth. Percentage refers to proportion of total variance explained by the function.

Appendix 19

LEGEND: COND-practice condition, TC-interaction between trial and Practice

F1

DEPENDENT VARIABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	5.93149	1	5.93149		
	COND	.01722	1	.01722	227.35	.0000
1	ERROR	.49571	19	.02609	.66	.4266
	TRIAL	.00095	1	.00095		
	TC	.00397	1	.00397	.13	.7035
2	ERROR	.12145	19	.00639	.62	.4406

F2

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	9.06694	1	9.06694		
	SVCOND	.00473	1	.00473	254.04	.0000
1	ERROR	.71383	20	.03569	.13	.7145
	TRIAL	.00010	1	.00010		
	TS	.00056	1	.00056	.00	.9507
2	ERROR	.48979	20	.02449	.02	.8818

F3

DEPENDENT VARIABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	12.24619	1	12.24619		
	VRCOND	.00832	1	.00832	479.24	.0000
1	ERROR	.48552	19	.02555	.33	.5749
	TRIAL	.04538	1	.04538		
	TV	.00081	1	.00081	2.05	.1684
2	ERROR	.42058	19	.02214	.04	.8499

F4

DEPENDENT VARIABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	12.72715	1	12.72715		
	VR2COND	.25022	1	.25022	141.83	.0000
1	ERROR	1.70494	19	.08973	2.79	.1113
	TRIAL	.02954	1	.02954		
	TV	.03038	1	.03038	.66	.4280
2	ERROR	.85555	19	.04503	.67	.4216

F5

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	24.99201	1	24.99201		
	DRCOND	.38002	1	.38002	158.05	.0000
1	ERROR	3.16255	20	.15813	3.67	.0699
	TRIAL	.11480	1	.11480		
	TD	.09150	1	.09150	6.43	.0197
2	ERROR	.35709	20	.01785	5.12	.0349

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F6

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	5.65485	1	5.65485	151.06	0000
	APCOND	.06031	1	.06031	1.61	2189
	ERROR	.74866	20	.03743		
2	TRIAL	.00976	1	.00976	1.73	2027
	TA	.00267	1	.00267	.48	4986
	ERROR	.11256	20	.00563		

F7

DEPENDENT VARIABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	14.89960	1	14.89960	436.14	0000
	DDCOND	.05290	1	05290	1.55	2313
	ERROR	.54660	16	.03416		
2	TRIAL	.00321	1	.00321	.82	3786
	TD	.00004	1	00004	.01	9165
	ERROR	.06264	16	00392		

F8

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	31.44818	1	31 44818	692 64	0000
	DD2COND	18926	1	18926	4 17	0553
	ERROR	.86279	19	04541		
2	TRIAL	10052	1	10052	6 24	0216
	TD	05576	1	05576	3 46	0784
	ERROR	30607	19	01611		

F9

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	224329.74545	1	224329.74545	146 22	0000
	SCNNCOND	379.74545	1	379.74545	25	6243
	ERROR	30684.55000	20	1534.22750		
2	TRIAL	276.37576	1	276.37576	1 72	2050
	TS	721.64848	1	721.64848	4 48	0478
	ERROR	3220.28333	20	161 01417		

F10

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	5.93018	1	5.93018	149 74	0000
	SACOND	.15268	1	15268	3.86	0636
	ERROR	.79208	20	.03960		
2	TRIAL	.02165	1	.02165	3.03	0971
	TS	.00140	1	.00140	.20	6624
	ERROR	.14295	20	.00715		

DEPENDENT VARIABLE -   F11

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	8.70040	1	8.70040	176.62	.0000
	ARCOND	.25341	1	.25341	5.14	.0366
	ERROR	.83743	17	.04926		
2	TRIAL	.00468	1	.00468	.49	.4927
	TA	.00638	1	.00638	.67	.4247
	ERROR	.16202	17	.00953		

F12

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	6.49379	1	6.49379	217.34	.0000
	AVCOND	.19843	1	.19843	6.64	.0180
	ERROR	.59758	20	.02988		
2	TRIAL	.02775	1	.02775	5.73	.0266
	TA	.00492	1	.00492	1.02	.3255
	ERROR	.09683	20	.00484		

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ANALYSIS OF VARIA
DEPENDENT VARIABLI

VS1

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	108782.38903	1	108782.38903	111.41	.0000
COND	3420.78183	1	3420.78183	3.50	.0767
ERROR	18551.29703	19	976.38405		
TRL	2005.93260	1	2005.93260	13.09	.0018
TC	23.09146	1	23.09146	.15	.7022
ERROR	2912.51783	19	153.29041		

ANALYSIS OF VARIANC
DEPENDENT VARIABLE

VS2

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	326007.17834	1	326007.17834	111.63	.0000
M2COND	8308.45081	1	8308.45081	2.84	.1080
ERROR	55490.56892	19	2920.55626		
TRL	1566.86410	1	1566.86410	3.67	.0706
TM	143.47814	1	143.47814	.34	.5689
ERROR	8113.99240	19	427.05223		

ANALYSIS OF VAI
DEPENDENT VARI/

VS3

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	365205.33532	1	365205.33532	70.89	.0000
C8COND	21463.33532	1	21463.33532	4.17	.0554
ERROR	97894.56944	19	5151.81944		
TRL	.09722	1	.09722	.00	.9943
TC	656.00198	1	656.00198	.35	.5587
ERROR	35175.90278	19	1851.36330		

ANALYSIS OF VARI
DEPENDENT VARIAI

VS4

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	3830157.74382	1	3830157.74382	162.84	.0000
C8COND	164809.07715	1	164809.07715	7.09	.0154
ERROR	446900.39904	19	23521.07363		
TRL	2322.39583	1	2322.39583	.95	.3408
TC	2635.63393	1	2635.63393	1.08	.3110
ERROR	46225.93750	19	2432.94408		

DEPENDENT VARIABLI

VS5

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	1381619.62976	1	1381619.62976	80.00	.0000
B1COND	40894.42976	1	40894.42976	2.37	.1413
ERROR	310872.84524	18	17270.71362		
TRL	20790.52500	1	20790.52500	5.02	.0380
TM	382.72500	1	382.72500	.09	.7647
ERROR	74619.75000	18	4145.54167		

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VS6

DEPENDENT VARIABLE

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	25050.02500	1	25050.02500	23.04	.0001
PBCOND	1404.22500	1	1404.22500	1.29	.2707
1 ERROR	19570.25000	18	1087.23611		
TRL	1476.22500	1	1476.22500	3.25	.0889
TP	570.02500	1	570.02500	1.25	.2775
2 ERROR	8180.25000	18	454.45833		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

VS7

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	238110.63117	1	238110.63117	823.41	.0000
LOCOND	141.76063	1	141.76063	.49	.4923
1 ERROR	5494.35823	19	289.17675		
TRL	15.94328	1	15.94328	.12	.7366
TL	48.13995	1	48.13995	.35	.5601
2 ERROR	2599.94811	19	136.83937		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

VS8

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	238252.07992	1	238252.07992	1387.50	.0000
LO2COND	1538.46666	1	1538.46666	8.96	.0075
1 ERROR	3262.55413	19	171.71338		
TRL	2.55046	1	2.55046	.02	.8894
TL	2.13646	1	2.13646	.02	.8987
2 ERROR	2438.01011	19	128.31632		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

VS9

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	6082767.21930	1	6082767.21930	156.57	.0000
FMCOND	35747.21930	1	35747.21930	.92	.3509
1 ERROR	660460.83333	17	38850.63725		
TRL	143176.34211	1	143176.34211	15.87	.0010
TF	40585.81579	1	40585.81579	4.50	.0489
2 ERROR	153337.50000	17	9019.85294		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

M1 MOVES

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	80562.77689	1	80562.77689	75.92	.0000
MEM1COND	2326.30630	1	2326.30630	2.19	.1594
1 ERROR	15916.16429	15	1061.07762		
TRL	6605.55672	1	6605.55672	12.95	.0026
TM	383.20378	1	383.20378	.75	.3997
2 ERROR	7648.67857	15	509.91190		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -

STEPS

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
MEAN	1170.40378	1	1170.40378	950.08	.0000
MEM1COND	.40378	1	.40378	.33	.5755
1 ERROR	18.47857	15	1.23190		
TRL	29.06261	1	29.06261	32.85	.0000
TM	.00378	1	.00378	.00	.9481
2 ERROR	12.87857	15	.85857		

M1 TIME,

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
1	MEAN	630029.71807	1	630029.71807	20.06	.0004
	MEM1COND	119961.60042	1	119961.60042	3.82	.0696
	ERROR	471119.16429	15	31407.94429		
2	TRL	9928.28613	1	9928.28613	2.36	.1456
	TM	54.75672	1	54.75672	.01	.9108
	ERROR	63210.47857	15	4214.03190		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

M2 SCORE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	6636.01667	1	6636.01667	85.84	.0000
	VMEMCOND	.41667	1	.41667	.01	.9423
	ERROR	1391.45833	18	77.30324		
2	TRL	395.26667	1	395.26667	19.27	.0004
	TV	13.06667	1	13.06667	.64	.4352
	ERROR	369.20833	18	20.51157		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

LEVEL

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	476.01667	1	476.01667	294.61	.0000
	VMEMCOND	.81667	1	.81667	.51	.4842
	ERROR	29.08333	18	1.61574		
2	TRL	3.26667	1	3.26667	5.69	.0283
	TV	.06667	1	.06667	.12	.7372
	ERROR	10.33333	18	.57407		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

M3 SCORE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	10013.18409	1	10013.18409	52.70	.0000
	AMEMCOND	2.78409	1	2.78409	.01	.9050
	ERROR	3420.09091	18	190.00505		
2	TRL	139.40631	1	139.40631	4.09	.0583
	TA	10.40631	1	10.40631	.31	.5875
	ERROR	613.86869	18	34.10382		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

LEVEL

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
1	MEAN	373.39798	1	373.39798	44.16	.0000
	AMEMCOND	1.69798	1	1.69798	.20	.6594
	ERROR	152.20202	18	8.45567		
2	TRL	3.51616	1	3.51616	1.95	.1791
	TA	.01616	1	.01616	.01	.9255
	ERROR	32.38384	18	1.79910		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - M4 SCORE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	629.76190	1	629.76190	31.01	.0001
	VSMCOND	105.19048	1	105.19048	5.18	.0420
1	ERROR	243.66667	12	20.30556		
	TRL	26.29762	1	26.29762	3.57	.0833
	TV	.58333	1	.58333	.08	.7832
2	ERROR	88.41667	12	7.36806		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - LEVEL

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	107.44048	1	107.44048	63.93	.0000
	VSMCOND	4.29762	1	4.29762	2.56	.1358
1	ERROR	20.16667	12	1.68056		
	TRL	.42857	1	.42857	.89	.3629
	TV	.42857	1	.42857	.89	.3629
2	ERROR	5.75000	12	.47917		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - TIME

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	1177653.76190	1	1177653.76190	144.15	.0000
	VSMCOND	5217.19048	1	5217.19048	.64	.4397
1	ERROR	98034.41667	12	8169.53472		
	TRL	90.10714	1	90.10714	.02	.9034
	TV	8.67857	1	8.67857	.00	.9699
2	ERROR	70371.50000	12	5864.29167		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - M5 ERRORS

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	518.40000	1	518.40000	291.60	.0000
	MTACOND	1.60000	1	1.60000	.90	.3553
1	ERROR	32.00000	18	1.77778		
	TRL	2.50000	1	2.50000	1.04	.3220
	TM	.10000	1	.10000	.04	.8409
2	ERROR	43.40000	18	2.41111		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - LEVEL

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	403.22500	1	403.22500	147.97	.0000
	MTACOND	4.22500	1	4.22500	1.55	.2290
1	ERROR	49.05000	18	2.72500		
	TRL	18.22500	1	18.22500	32.00	.0000
	TM	.02500	1	.02500	.04	.8364
2	ERROR	10.25000	18	.56944		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -   **M6**

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	817.78571	1	817.78571	268.67	.0000
	MTBCOND	.64286	1	.64286	.21	.6510
1	ERROR	57.83333	19	3.04386		
	TRL	4.57143	1	4.57143	5.01	.0374
	TM	.00000	1	.00000	.00	1.0000
2	ERROR	17.33333	19	.91228		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -   **M7   ERRORS**

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	501.66806	1	501.66806	257.78	.0000
	MTCCOND	.11250	1	.11250	.06	.8130
1	ERROR	31.13750	16	1.94609		
	TRL	5.16806	1	5.16806	2.46	.1365
	TM	1.16806	1	1.16806	.56	.4668
2	ERROR	33.63750	16	2.10234		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -   **LEVEL**

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	264.02222	1	264.02222	143.44	.0000
	MTCCOND	1.80000	1	1.80000	.98	.3374
1	ERROR	29.45000	16	1.84063		
	TRL	2.93889	1	2.93889	2.03	.1738
	TM	.93889	1	.93889	.65	.4328
2	ERROR	23.20000	16	1.45000		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -   **M8**

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	236.01667	1	236.01667	274.82	.0000
	MTDCOND	2.01667	1	2.01667	2.35	.1428
1	ERROR	15.45833	18	.85880		
	TRL	3.75000	1	3.75000	6.67	.0188
	TM	.15000	1	.15000	.27	.6119
2	ERROR	10.12500	18	.56250		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE -   **M9**

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	656.00198	1	656.00198	180.89	.0000
	MTECOND	.57341	1	.57341	.16	.6953
1	ERROR	8.90278	19	3.62646		
	TRL	6.90875	1	6.90875	7.07	.0155
	TM	.04960	1	.04960	.05	.8242
2	ERROR	8.56944	19	.97734		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>AD1</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB
	MEAN	5652.72184	1	5652.72184	38.44	0000
	AD1COND	585.39217	1	585.39217	3.98	0606
1	ERROR	2793.92965	19	147.04893		
	TRL	572.01416	1	572.01416	14.06	0014
	TA	14.96709	1	14.96709	.37	.5514
2	ERROR	773.12926	19	40.69101		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>AD2</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	3062.43063	1	3062.43063	63.18	0000
	AD2COND	42.91858	1	42.91858	.89	3599
1	ERROR	824.06180	17	48.47422		
	TRL	195.58255	1	195.58255	6.24	0230
	TA	26.92823	1	26.92823	.86	3669
2	ERROR	532.68570	17	31.33445		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>PS1   ERRORS</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	1853.89591	1	1853.89591	80.08	.0000
	PB1COND	30.31696	1	30.31696	1.31	.2683
1	ERROR	393.57778	17	23.15163		
	TRL	2.72398	1	2.72398	.65	.4312
	TP	2.72398	1	2.72398	.65	.4312
2	ERROR	76.44444	17	4.49673		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>TIME</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	1307144.67103	1	1307144.67103	199.05	.0000
	PB1COND	17502.76809	1	17502.76809	2.67	.1209
1	ERROR	111635.08776	17	6566.76987		
	TRL	60730.06101	1	60730.06101	12.91	.0022
	TP	2833.39435	1	2833.39435	.60	.4483
2	ERROR	79954.16929	17	4703.18619		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>PS2   TIME</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	4240062.28680	1	4240062.28680	27.19	.0001
	PB2COND	838287.78834	1	838287.78834	3.65	.0741
1	ERROR	3671822.29711	16	229488.89357		
	TRL	526797.73674	1	526797.73674	7.34	.0155
	TP	76270.78947	1	76270.78947	1.06	.3179
2	ERROR	1147944.84964	16	71746.55435		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE - <u>MOVES</u>

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	85458.77778	1	85458.77778	467.72	.0000
	PB2COND	2.77778	1	2.77778	.02	.9034
1	ERROR	2923.44444	16	182.71528		
	TRL	124.11111	1	124.11111	2.03	.1726
	TP	5.44444	1	5.44444	.08	.7784
2	ERROR	1073.44444	16	67.09028		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

PS3   LEVEL ONE

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	7.20238	1	7.20238	7.16	.0281
	PERCOND	.00238	1	.00238	.00	.9624
1	ERROR	8.04742	8	1.00595		
	TRL	.02143	1	.02143	.03	.8743
	TP	.02143	1	.02143	.03	.8743
2	ERROR	6.42857	8	.80357		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

LEVEL TWO

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	4646.48810	1	4646.48810	21.52	.0017
	PERCOND	.48810	1	.48810	.00	.9564
1	ERROR	1727.76190	8	215.97024		
	TRL	2.91667	1	2.91667	.04	.8463
	TP	2.91667	1	2.91667	.04	.8463
2	ERROR	582.33333	8	72.79167		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

PS4   WRONG MOVES

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	1756.71178	1	1756.71178	25.93	.0001
	PERCOND	293.95388	1	293.95388	4.33	.0528
1	ERROR	1151.76190	17	67.75070		
	TRL	.36216	1	.36216	.01	.9394
	TP	3.52005	1	3.52005	.06	.8127
2	ERROR	1033.69048	17	60.80532		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

DELAYS

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	35440.00501	1	35440.00501	15.68	.0010
	PERCOND	11444.21554	1	11444.21554	5.06	.0380
1	ERROR	38421.04762	17	2260.06162		
	TRL	9155.65038	1	9155.65038	4.53	.0482
	TP	6773.96617	1	6773.96617	3.35	.0847
2	ERROR	34353.72857	17	2020.81933		

PS5   WRONG MOVES

	SOURCE	SQUARES	FREEDOM	SQUARE		PROB.
	MEAN	5401.46531	1	5401.46531	28.25	.0001
	PERCON	196.20215	1	196.20215	1.03	.3232
1	ERROR	3250.11364	17	191.18316		
	TRL	632.21172	1	632.21172	4.22	.0557
	TP	147.36962	1	147.36962	.98	.3354
2	ERROR	2548.84091	17	149.93182		

ANALYSIS OF VARIANCE
DEPENDENT VARIABLE –

DELAYS

	SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
	MEAN	249983.92374	1	249983.92374	12.19	.0028
	PERCON	44540.66059	1	44540.66059	2.17	.1588
1	ERROR	348719.39205	17	20512.90541		
	TRL	1406.84633	1	1406.84633	.24	.6290
	TP	7817.81370	1	7817.81370	1.34	.2622
2	ERROR	98816.08841	17	5812.70755		

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Appendix 20

Summary of the probability and degrees of freedom (df) for covariates of age, Interval since trauma to project, education, duration of coma, Practice condition main effect, trial condition main effect, and interaction (CxT) as a result of ANCOVA for all exercises.
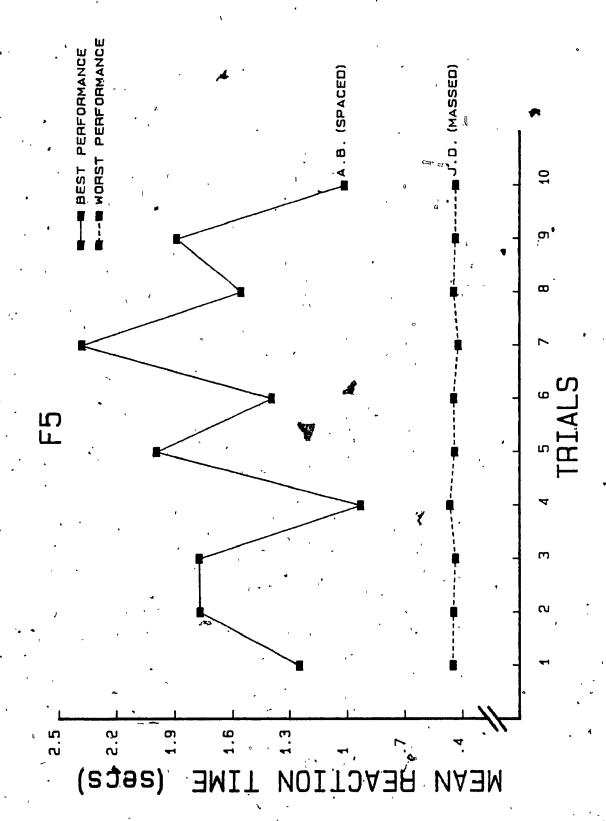
						Probability			
			Covariate			Combined	Main Effect		
Exercise	df	Age	Interval	Education	Coma	Covariates	Condition	Trial	CxT
F1	16	.62	.19	.95	.28	.38	.27	.29	.23
F2	16	.15	.24	.44	.29	.29	.33	.95	.88
F3	16	.51	.45	.93	.11	.33	.48	.50	.72
F4	16	.74	.63	.40	.009	.06	.08	.75	.76
	19				.005		.06	.75	.76
F5	16	.77	.19	.74	.07	.18	.09	.02	.03
F6	16	.12	.96	.73	.13	.20	.51	.20	.50
F7	14	.31	.88	.79	.17	.40	.51	.28	.27
F8	15	.97	.15	.52	.16	.21	.10	.02	.08
F9	16	.39	.81	.27	.08	.22	.92	.21	.05
F10	16	.69	.42	.12	.007	.03	.64	.097	.66
	19				.004		.09	.097	.66
F11	15	.22	.34	.59	.52	.58	.60	.72	.25
F12	16	.05	.85	.89	.38	.17	.08	.03	.33
	19	.01					.03	.03	.33
VS1	16	.29	.33	.85	.71	.52	.19	.009	.89
VS2	16	.47	.12	.42	.66	.44	.68	.34	.22
VS3	16	.97	.24	.82	.72	.78	.12	.87	.44
VS4	15	.96	.39	.41	.28	.47	.14	.34	.31
VS5	14	.06	.22	.30	.17	.12	.61	.04	.76
VS6	16	.07	.80	.23	.94	.37	.49	.09	.13
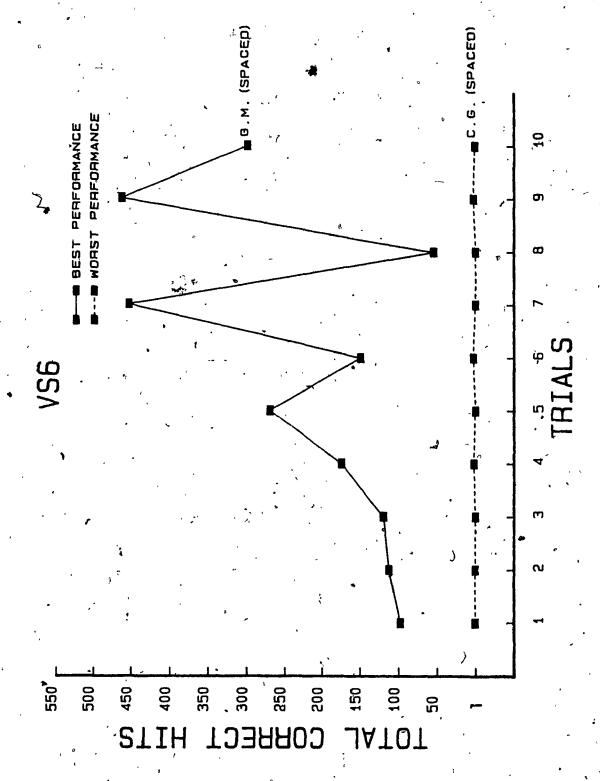
VS7	15 .04	.34	,27	.41	.23	.70	.74	.56
	18 .08					.95	.74	.56
VS8	16 .01	.25	.46	.22	.06	.34	.80	.61
	19 .02					.27		
VS9	14 .53	.13	.91	.00001	.0001	.90	.92	.55
	17			.00001		.41	.92	.55
M1								
moves	14 .78	.29	.92	.23	.52	.75	.04	.66
steps	.38	.59	.28	.56	.47	.18	.00001	.84
time	.34	.26	.34	.35	.25	.85	.61	.31
M2								
score	14 .06	.80	.91	.03	.02	.64	.0004	.44
				.009		.20	.004	.44
level	.18	.81	.38	.06	.13	.99	.03	.74
M3								
score	14 .10	.94	.98	.57	.31	.90	.06	.59
level	.10	.98	.99	.81	.42	.78	.18	.93
M4								
score	8 .65	.18	.10	.12	.11	.09	.08	.78
level	11 .54	.92	.22	.27	.50	.37	.36	.36
time	.44	.49	.98	.83	.91	.79	.90	.97
M5								
error	14 .86	.76	.84	.99	.99	.44	.32	.84
level	.55	.96	.97	.43	.82	.53	.00001	.84
M6	15 .50	.64	.56	.21	.56	.54	.04	.99
M7								
error	13 .21	.56	.12	.12	.25	.34	.24	.31
level	.19	.94	.49	.85	.66	.36	.13	.35
M8	14 .02	.05	.70	.22	.05	.04	.02	.61
	16 .009	.04			.02	.02	.02	.61
M9	15 .01	.78	.41	.04	.01	.79	.02	.82
	17 .004			.04	.002	.48	.02	.82
AD1	15 .12	.06	.63	.88	.32	.17	.001	.55
AD2	13 .30	.49	.06	.04	.10	.61	.02	.37
	16.			.11		.70	.02	.37
PS1								
error	14 .33	.65	.99	.001	.02	.51	.73	.73
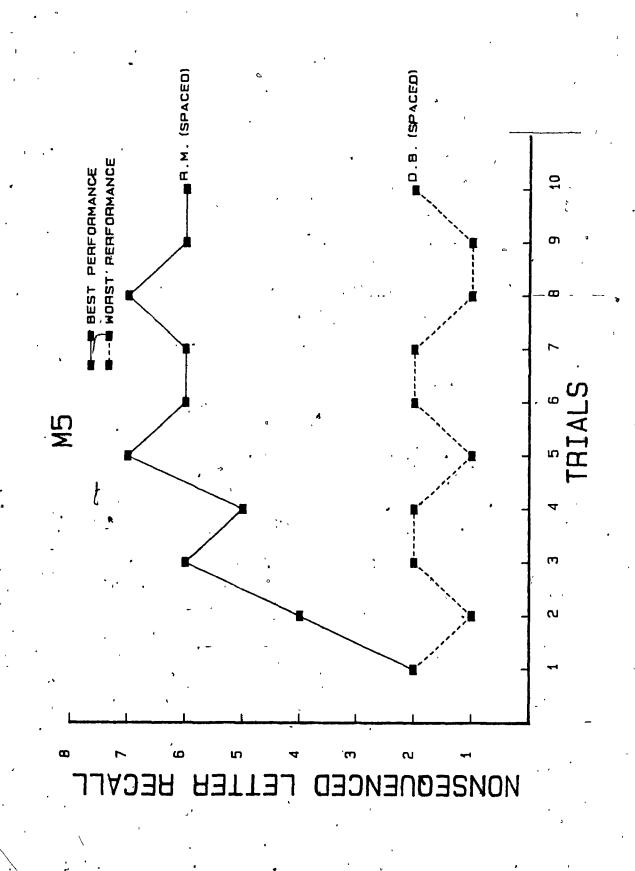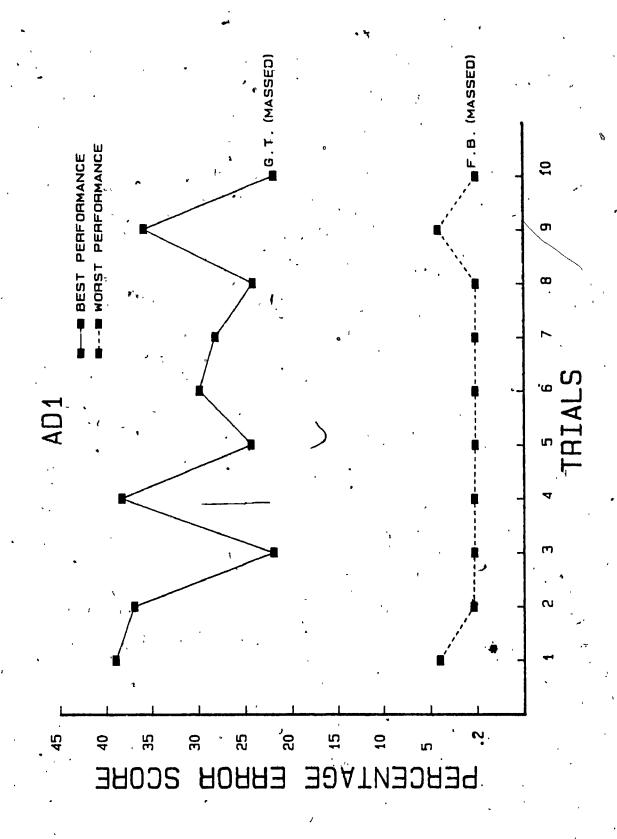
	N								
17					.0004		.27	.73	.73
time	14	.93	.10	.01	.00001	.00001	.53	.002	.49
18					.00001		.11	.002	.49
PS2									
moves	13	.96	.31	.87	.06	.22	.79	.02	.94
time		.34	.87	.17	.43	.32	.09	.20	.33
PS3 level 1 errors									
	4	.71	.63	.77	.33	.63	.62	.87	.87
level 2 errors									
		.40	.17	.93	.89	.51	.80	.85	.85
PS4 wrong moves									
	13	.19	.24	.95	.02	.17	.17	.94	.81
	16				.03		.19		
delays									
	13	.49	.73	.74	.61	.86	.27	.05	.08
PS5 wrong moves									
	14	.16	.35	.35	.51	.54	.64	.04	.39
delay									
	14	.04	.13	.04	.78	.05	.58	.52	.31
	16	1.10		.01		.03	.86	.52	.31
time		.34	.39	.35	.00001	.00001	.75	.66	.26
	14				.00001				
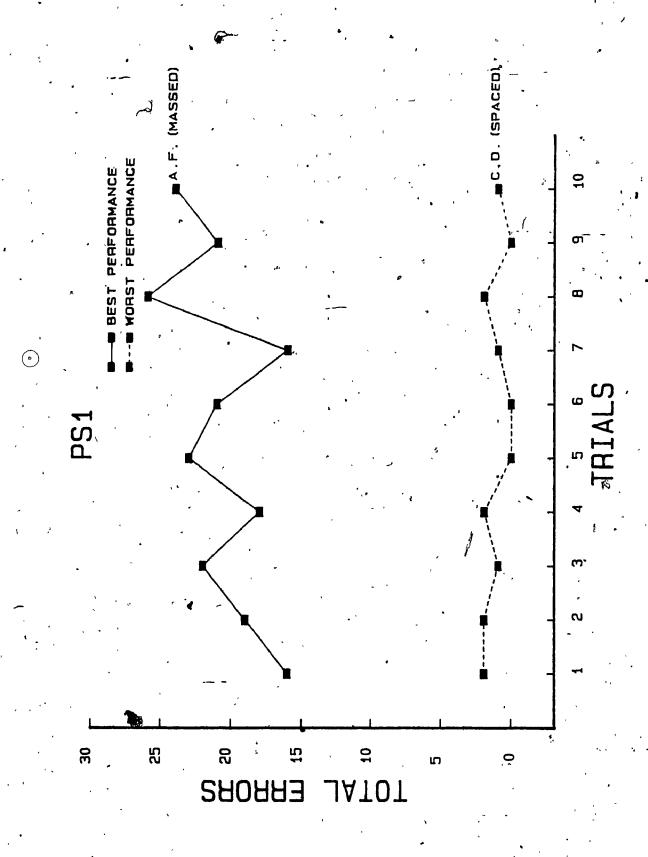
Appendix 21

F5

MEAN REACTION TIME (secs)

BEST PERFORMANCE
WORST PERFORMANCE

A.B. (SPACED)

J.D. (MASSED)

TRIALS

2.5 2.2 1.9 1.6 1.3 1 .7 .4

1 2 3 4 5 6 7 8 9 10

VS6

BEST PERFORMANCE
WORST PERFORMANCE

G.M. (SPACED)

C.G. (SPACED)

TRIALS

TOTAL CORRECT HITS

M5

NONSEQUENCED LETTER RECALL

TRIALS

BEST PERFORMANCE
WORST PERFORMANCE

R.M. (SPACED)

D.B. (SPACED)

AD1

BEST PERFORMANCE
WORST PERFORMANCE

G. T. (MASSED)

F. B. (MASSED)

PERCENTAGE ERROR SCORE

TRIALS

PS1

TOTAL ERRORS

TRIALS

BEST PERFORMANCE
WORST PERFORMANCE

A.F. (MASSED)

C.D. (SPACED)

Appendix 22

FORMULAIRE DE CONSENTEMENT

_____ j'accepte de participer à un programme
d'entrainement et de stimulation perceptuo-cognitives au moyen de micro-
ordinateurs. Ce programme consiste de jeux video et d'exercises sur les
microprocesseurs qui me permettront de pratiquer mes habiletés
auditives, visuelles, verbales et mnémoniques, ma coordination motrice
et mon attention et concentration.

La durée du testing, avant et apres l'entrainement, sera environ 3
demi-journées avec des periodes de repos. Le testing consiste
d'enregistrement de potentiels évoqués utilisant une technique de EEG.
Des électrodes de plastiques seront collées sur ma chevelure, 2 derrière
les oreilles, 2 autour des yeux. Il n'y aucune douleur ou incomfort.

Si je suis choisi pour participer dans ce programme de stimulation,
je devrai venir au laboratoire deux fois par semaine pour environ deux
heures, ce, pour une periode de 3 à 6 mois. Les détails du programme
m'ont ete présentés verbalement.

Je comprend que je suis libre de me retirer à n'importé quel moment,
quelle que soit la raison, avec l'entente que les donnees déjà
accumulees pourront être utilisées en toute confidentialité, pour des
fins de recherche scientifique. Du feedback sur ma performance sera
donne a mes thérapeutes aux centre de rehabilitation.

On me promet que mes dossiers sont strictement confidentiels et
seules les personnes impliquees dans ce projet y ont accès.

Je suis libre de participer à ce programme.

Je_____declare qu'on m'a expliqué la procédure et les
raisons de cette étude.

_____(client)_____(date).

_____(moniteur)_____(date).

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Appendix 23

F1

MEAN REACTION TIME (msecs)

TRIALS

MASSED
SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F2

MEAN REACTION TIME (msecs)

TRIALS

- ■ MASSED
- ■ SPACED
- O MASSED S.E.M.
- △ SPACED S.E.M.

F3

MEAN REACTION TIME (msecs)

TRIALS

- ▲—■ MASSED
- ■--■ SPACED
- O MASSED S.E.M.
- △ SPACED S.E.M.

F4

MEAN REACTION TIME (secs)

TRIALS

■ MASSED
■ SPACED
○ MASSED S.E.M.
△ SPACED S.E.M.

F5

MEAN REACTION TIME (msecs)

TRIALS

MASSED
SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F6

MEAN REACTION TIME (secs)

TRIALS

MASSED
SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F7

MEAN REACTION TIME (msecs)

TRIALS

■ MASSED
■ SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F8

PERCENTAGE MEAN CORRECT HITS

TRIALS

MASSED
SPACED
O MASSED S.E.M.
SPACED S.E.M.

F9

F10

MEAN REACTION TIME (msecs)

TRIALS

MASSED
SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F11

MEAN REACTION TIME (msecs)

TRIALS.

MASSED
SPACED
O MASSED S.E.M.
△ SPACED S.E.M.

F12

MEAN REACTION TIME (msecs)

TRIALS

■ MASSED
■ SPACED
O MASSED S. E. M.
△ SPACED S. E. M.

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