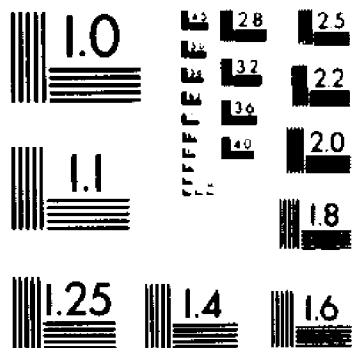
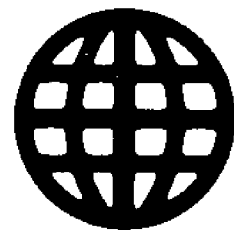


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THE EFFECTS OF BRAIN STEM
COMPRESSION ON ATTENTION AND MEMORY

by


RENA MATISON GREENBLATT

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
The City University of New York.

1986

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

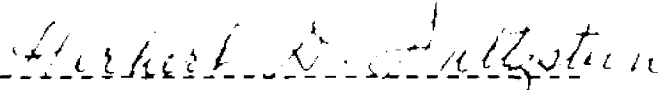
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Abstract

THE EFFECTS OF BRAIN STEM
COMPRESSION ON ATTENTION AND MEMORY

by

Rena Matison Greenblatt

Adviser: Professor Jeffrey Rosen

This thesis evaluated attention and memory in 26 patients with posterior fossa tumors of varying sizes. It was hypothesized that compression of brain stem structures --specifically, of the reticular activating system-- by large tumors would lead to impairments in attention and memory.

Psychometric and behavioral measures were administered to the patients first pre-operatively and then five to seven months after the surgical removal of the tumor. Since tumor size was expected to play a significant role, the patients were divided into a small tumor group and a large tumor group. Control subjects were also evaluated in order to assess practice effects.

Three competing hypotheses were explored. First, the tumor impairs auditory-perceptual processing and consequently the encoding of information; second, brain stem compression from large tumors affects only the memory processes, without affecting perceptual or attentional

functioning; and third, brain stem compression interferes with both the attention and the memory processes.

The results supported the third hypothesis that both attention and memory are affected; auditory-perceptual processing was not found to be impaired for either patient group. The large tumor group's pre-operative performance on measures of attention and memory was significantly worse than that of both the small tumor group and the controls. Moreover, of the three groups, only the large tumor group showed significant improvement post-operatively on measures of these functions. This suggests that it was the compression of the brain stem --not tissue damage-- that led to the cognitive deficits. Had the deficits been caused by tissue damage, the impairments would have been permanent.

Of the standard psychological models examined in this thesis, the "controlled versus automatic processing" model was found to be most consistent with the current findings. Controlled versus automatic processing purports that there is a limited capacity available for attention. Based on the current findings, those tasks that showed pre-operative impairment and post-operative improvement require conscious effort for retrieval of a span of information. Since there is a limited attentional capacity, these tasks are most sensitive to an impairment. Future research is discussed in which the effect of span of information on attentional capacity could be assessed.

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Preface

This thesis examines the possible effects of posterior fossa tumors on attention and memory functions. These tumors are located in the cerebellopontine angle. By compressing against the brain stem, a tumor may interfere with the reticular activating system (RAS), a network of neurons that has been associated with attention and memory (Bloch, 1970), and thereby impair these processes. Moreover, if the tumor compresses the auditory pathways, it might also affect the auditory-perceptual function. An in-depth study of the effects of posterior fossa tumors before and after surgery contributes to the neuropsychologist's understanding of the correlations both between cognitive processes and different brain regions and between attention, memory and auditory perception.

Three competing hypotheses are explored in this thesis: first, brain stem compression impairs auditory-perceptual processing and consequently the encoding of information, the initial stage of memory; second, brain stem compression only affects the memory process, without affecting perceptual or attentional functions; and third, brain stem compression interferes with both the attention and the memory processes.

To test these hypotheses, I evaluated twenty-six patients afflicted with posterior fossa tumors on a battery of psychometric and neuropsychological measures. The

majority of these patients were then evaluated five to seven months after the surgical removal of the tumor. Among the neuropsychological tests selected for this research were the Continuous Performance Test, the Selective Reminding Test and the Visual Retention Test--all of them valid measures for assessing attention, memory or perception. Also chosen was a psychometric test, the Wechsler Adult Intelligence Scale, because it not only measures general intelligence but also is comprised of subtests that have been shown to assess attention and memory. For each test, the patient's performance was compared to that of control subjects and evaluated in relation to two independent variables: the size of the tumor and a measure of interpeak latency from the brain stem auditory evoked potential.

Since the majority of patients performed normally on tests of auditory perception, the findings do not support the first hypothesis--that posterior fossa tumors affect auditory-perceptual processing and consequently the encoding of information. However, patients with tumors exceeding two centimeters did evidence attention and memory dysfunctions. Since many of these patients scored low on tests of memory as well as on the Continuous Performance Test, a measure of attention, it seems clear that memory was not affected independently of attention. These findings suggest that only the third hypothesis is valid--specifically, that a posterior fossa tumor large enough to compress against the

brain stem affects both attention and memory.

My research supports the results of past studies that associated the brain stem RAS with both attention and memory--most conclusively with alertness and memory consolidation (Bloch, 1970). In my findings, this association is evidenced by the large tumor groups's low performance both on the Continuous Performance Test, which measures alertness, and on the Selective Reminding Test, which assesses memory consolidation.

Given the evident connection between attention and memory, the results of my research were evaluated within the context of standard psychological models that address the relationship between these processes. In one model, called "controlled versus automatic processing," the link between memory and attention is addressed in a comprehensive study of the three different kinds of attention, as delineated by Posner (1975): selective attention, alertness and conscious effort. The distinction between controlled and automatic processing is based on the presence or absence of conscious effort: while controlled processing requires deliberate attention to a task in order for the information to be encoded and consolidated in long-term memory, automatic processing requires no voluntary attention for encoding to occur. In a second model, called "levels of processing," it is postulated that there are two stages in the encoding of information. First, information is encoded superficially as

the listener receives only the smallest units of speech (phonemes), such as the "p" in "pin." Then, the information is processed at a deeper level and consolidated in memory as the listener translates the sounds into meaning.

The first model, controlled versus automatic processing, helps demonstrate the association between attention and memory, thereby showing why a tumor cannot affect one process without affecting the other. Sharpless and Jasper (1956) take the analysis of attention one step further by differentiating between two kinds of alertness: "tonic and "phasic." Tonic alertness refers to the various levels of arousal that a person maintains throughout the day--the difference between waking and sleeping, for example. Phasic alertness refers to momentary fluctuations in attention, such as the sudden increase in alertness caused by the ringing of a telephone.

Previous studies have related controlled and automatic processing to long-term and short-term memory, respectively.

These studies have shown that controlled processing, which requires conscious effort, is necessary in order for information to be consolidated in long-term memory. In contrast, automatic processing, which does not require conscious effort, is sufficient for storage in and retrieval from short-term memory. Like controlled processing, phasic alertness requires conscious effort and may therefore be

associated with long-term memory as well. In contrast, tonic alertness, like automatic processing, does not require conscious effort and may therefore be associated with short-term memory. It is the type of processing, then, that defines the connection between attention and memory and determines whether information is consolidated in long- or short-term memory.

The models described above are also useful for exploring the relationships between the different processes that comprise attention and memory. For instance, a lowered level of alertness, a kind of attention, will limit the amount of available conscious effort, another kind of attention. Because conscious effort has been shown to be necessary for memory consolidation, such a decrease would mean that information could only be processed at a superficial level, not consolidated in long-term memory. Indeed, a decreased level of alertness, which can result from a posterior fossa tumor compressing against the brain stem, may explain why the patients with large tumors scored low on a test of memory consolidation.

One of the most pertinent aspects of the research involved assessing the post-operative recovery for attention and memory functions. For example, on tests of memory, most patients performed better after surgery than before. Pre-operative testing on attention was not extensive enough to warrant a comparison between pre- and post-operative

performance. However, many subjects did show attentional dysfunction after surgery. Although seven months may not allow for adequate recovery, the impairment of attention suggests both that irreversible damage has occurred and that attention is more vulnerable than memory to this type of insult.

Also of import was a final aspect of the study designed to evaluate whether the relationships between attention and memory altered in any way after the removal of the tumor. The various tests were correlated with one another first pre-operatively and then post-operatively. Since there were a greater number of significant correlations between attention and memory on pre-operative testing, it seems likely that brain stem compression leads to an increased dependence between these cognitive processes.

The examination of brain stem compression sheds light on the interrelationships between attention, memory and perceptual dysfunction. By using the models of "controlled versus automatic processing" and "levels of processing," it is also possible to determine how processes or stages that comprise these categories are related to one another. Further, by assessing which functions improve after surgery and how the interrelationships between these functions differ on pre- and post-operative testing, we may better assess the effects of a malfunctioning system on cognitive processes.

Compression of the brain stem caused by extramedullary posterior fossa tumors has been related to impairments in attention and memory (Wilson and Rupp, 1946; Jedrezejewska-Iwanowska, 1974). This compression leads to a mechanical displacement of the brain stem which can be observed both by radiography and during microsurgery. Compression of the brain stem may affect the functioning of the brain stem reticular activating system (RAS) which has been associated with the processes of both attention and memory (Jedrezejewska-Iwanowska, 1974).

This thesis examines the possible effects of brain stem compression on attention and memory functions. Both explicit models of attention and memory as well as some possible interrelationships are explored. Since brain stem compression may affect the auditory pathways, a mechanism affecting attention and memory may be the impairment in the early stages of auditory-perceptual processes. This impairment then could affect both the acquisition and quality of auditory information. The possibility that auditory-perceptual deficits cause attention and memory deficits as an alternative or mutually compatible hypothesis is also explored. A second hypothesis is that compression may affect memory alone without affecting perceptual or attentional processes. A third hypothesis is that compression interferes with both the attention and the memory processes.

The Relationship of Attention and Memory.

Brain stem compression would be expected to have an effect on brain stem structures that comprise the ascending reticular formation. Both experimental (e.g. Sokolov, 1963; Fuster, 1958; Mirsky and Kornetsky, 1964) and clinical studies (Lansdell and Mirsky, 1964; Fedio and Mirsky, 1969; Gazzaniga and Hillyard, 1973) implicate the brain stem reticular formation in the maintenance of phasic alertness, momentary fluctuations in attention, typically measured by fluctuations in the subject's performance on a vigilance task such as the continuous performance test (CPT). A vigilance task measures the ability to sustain attention over a period of time. Dysattention associated with disrupted functioning at the level of the brain stem reticular formation may account for earlier observations of attention and memory deficits in patients with posterior fossa tumors (Jedrezejewska-Iwanowska, 1974).

In order to explore this possibility, attention will be related to memory processes by examining several models of cognitive processing. Evidence to support the influence of attention on memory will be compared to and contrasted with evidence supporting the independence of memory from attentional processes.

Certain models were chosen which address the relationships between attention and memory. One model,

called "controlled versus automatic processing" is discussed because it addresses the link between attention and memory by examining a component of attention (conscious effort) and its relationship to both long-term and short-term memory. This model is a "capacity" model and as such is in the same category as Kahneman's (1975) model. It may also be differentiated from models such as those of Broadbent (1971) or Deutsch and Deutsch (1967) which emphasize selective attention and alertness. Another model, called "levels of processing" is discussed because it addresses the link between attention and memory by describing the impact of two components of attention (conscious effort and alertness) on encoding in memory. In addition, the levels of processing model addresses the role of auditory-perceptual processes in memory encoding.

In the dual process theories of information processing (Shiffrin and Schneider, 1977; LaBerge, 1977), performance on memory tasks results from one of two forms of information processing: automatic or controlled processing. Controlled processing is slow, serial, effortful and capacity limited (Fisk and Schneider, 1984). It is voluntary, under direct subject control, and through the use of controlled processing, subjects can deal with novel or inconsistent information. Automatic processing has been characterized as fast, parallel, and fairly effortless processing. These distinctions were introduced into the literature to account

for the phenomenon that people are able to learn to automatically process certain information and to react appropriately depending on the context of the situation. For example, drivers will automatically brake when they approach a red light. Since controlled processing determines long-term memory storage, it has been predicted (Fisk and Schneider, 1984) that stimuli can be automatically processed with no lasting long-term memory effect. That is, although automatic processes have access to long-term memory, automatic processes do not directly cause new learning of information to be stored in long-term memory. However, if controlled processes are used in order to enable the subject to automatically learn a task, then automatic processes can be said to indirectly modify long-term memory.

In order to test the predictions relating automatic and controlled processing to memory modification while attempting to control for intermittent dysattention, two different experiments were administered to subjects (Fisk and Schneider, 1984). In the first experiment, subjects were required to estimate the frequency of occurrence of words under different conditions. Frequency encoding has been shown to be insensitive to strategy manipulation (e.g. following explicit instructions about how to carry out the task) and practice effects (e.g. practice for improvement in the task) (Hasher and Zacks, 1979). The presence of

controlled processing was manipulated by requiring the subject either to attend directly to a word or to digits that were simultaneously presented tachistoscopically.

The form of controlled processing was varied in several different ways which required the subject to perform semantic or orthographic judgements about words. In some conditions, subjects were required to intentionally learn the words while in other conditions subjects only had to identify digits. In fact, in one condition subjects were told that the words were inserted as distractors.

Recognition, defined as the ability to distinguish the old from the new words, was significantly impaired in the condition in which subjects ignored the words. Fisk and Schneider (1984) conclude that long-term storage sufficient for recognition does not occur without conscious attention. That is, the effortful, voluntary and conscious aspect of controlled processing is necessary for long-term storage sufficient for recognition.

In Fisk and Schneider's (1984) second experiment, subjects were required to process words automatically from a specified semantic category. Subjects had extensive pre-training prior to the actual experiment. This training enabled subjects to maintain their primary task performance, searching for digits while automatically performing a category classification task; responding if a word were from a particular semantic category. The pre-training consisted

of requiring a subject to respond in a reaction time paradigm by pressing a key if a word were from a particular category. The results showed that there was no long-term storage of words when automatic processing was employed. Evidence for this was no frequency learning as measured by the subject's ability to estimate the frequency of the different words. Also, there was little recognition of words as assessed by a forced-choice recognition test.

Not all evidence has supported the necessity of conscious attention for long-term memory storage (Kellogg, 1980). In Kellogg's (1980) study, subjects were instructed to perform a multiplication task while pictures of faces were presented to which they were instructed not to attend. The subject's ability to perform the multiplication task was then assessed in order to show that they followed the instructions. The results indicated that performance on the multiplication task was not impaired and that there was some long term memory storage of the information that was not consciously processed--the pictures of faces. However, the above interpretation is open to criticism because the multiplication task may not have been a sensitive enough measure to indicate the presence of conscious processing of the pictures. The conscious processing of pictures may take as little as 125 milliseconds (Potter, 1976), which would only reduce the time on the arithmetic task by 1.3%. This may not be enough of a reduction in time to cause impairment

on an arithmetic task (Fisk and Schneider, 1984). Further, it could indicate that subjects need to consciously attend to information for long-term memory storage and that they may do this by attending momentarily to one task instead of the other task. This could be viewed as a filtering mechanism (Broadbent, 1967). Thus, the evidence suggests that controlled processing and voluntary attention are necessary for long-term memory storage.

Controlled and automatic processing may also be related to selective attention. The studies cited above have examined the conscious or controlled processing of information through the manipulation of the subjects' ability to selectively attend to sensory information. Theories that address this interaction of attention and perception include those of Broadbent (1971), Cherry (1953) and Treisman (1960) who describe selective attention and early or late models of perceptual processing. Neisser (1967) has described an interactive model in which two processes account for the selective processing of sensory input. These two processes include a preattentive model in which input is first analyzed in a global and parallel manner. Then, there is an analysis of certain aspects of the stimulus which receive focal attention.

The advantage of Posner's (1971, 1975) description of attention is that it includes selective attention as well as conscious effort and alertness. Alertness, involves

receptivity to external stimuli and includes two subdivisions: "tonic" and "phasic". Selective attention refers to the selection of certain perceived stimuli for further processing. Selective attention may be distinguished from alertness because it is a more active than passive form of attention. Further, selective attention is one step beyond receptivity to stimulus input in that the subject selects only certain information from the input which has been received. A third component of attention is conscious effort. Conscious effort and alertness may be analogous to controlled processing. Further, there may be a parallel between controlled processing and phasic alertness because both are voluntary while there may also be a parallel between automatic processing and tonic alertness because both are involuntary.

In order to determine if the above analogies are valid, it is important to examine the difference between tasks which may assess phasic as compared to tonic alertness. The CPT is a vigilance task which measures sustained attention and is also sensitive to momentary fluctuations in attention such that any lapse in attention may cause the subject to miss a target (Rosvold, Mirsky, Sarason, Bransome, Jr., and Beck, 1956). On the Digit Span and the Digit Symbol subtests of the WAIS-R, the subject may be able to compensate for momentary fluctuations in attention during

the overall time of responding. For example, in Digit Symbol, the subject may increase his/her speed and response time during the interval between momentary lapses in attention. Thus, the CPT may assess both tonic and phasic aspects of alertness while Digit Span and Digit Symbol may assess tonic alertness since the subject may compensate for fluctuations in phasic alertness.

One other way of examining the relationship between the types of alertness and the forms of processing is to observe the effects of different sites of seizure activity on behavioral measures. By examining the differences between the performance of patients with centrencephalic or subcortical epilepsy and temporal lobe epilepsy on attention and memory, the worker may better ascertain the relationship between certain structures and functions. Patients with centrencephalic epilepsy were more impaired in their performance on the CPT than patients with temporal lobe epilepsy, thereby indicating the importance of subcortical structures for sustained attention (Lansdell and Mirsky, 1964). Because there was a correlation between Verbal and Performance I.Q. and the percentage of correct responses on the CPT, the authors (Lansdell and Mirsky, 1964) suggest that there may be a permanent disruption of alertness. The research emphasizes the importance of subcortical structures for tonic alertness. This does not rule out the possibility that momentary fluctuations in attention or

phasic changes in alertness also may have occurred.

A disruption in phasic alertness is also reflected in CPT performance (Mirsky and Van Buren, 1965). Patients with centrencephalic epilepsy showed behavioral impairment on the CPT which preceded electroencephalographic (EEG) signs of seizure activity. This indicates that subcortical seizures may precede the cortical signs of EEG activity which again supports the importance of subcortical structures for phasic attention.

Long-term memory storage and specifically memory consolidation may be related to phasic alertness by examining the effects of spiking in the EEG on memory tasks (Mirsky and Van Buren, 1965). These changes in the EEG could be considered to represent phasic changes in alertness. A test of recall was administered to subjects and performance on this test was evaluated in relationship to the presence of burst activity in the EEG. Visual or auditory stimuli were presented at the rate of several per minute and after an interval of five to sixty seconds, the patient was required to recall the stimuli. When bursts of spike activity occurred during the presentation of the stimulus or between the presentation of the stimulus and the response, there was a significant impairment in recall. Mirsky and Van Buren (1965) interpret this impairment in recall as a reflection of an impairment in memory consolidation that affects the subject's ability to retain

the stimulus in memory.

Thus, the presence and timing of bursts of spike and wave activity appears to have a differential effect on attention and memory tasks. In one task, behavioral impairment on the CPT preceded spiking in the EEG (Mirsky and Van Buren, 1965). In the other task, spiking occurred concurrently with impairment in memory processes.

It appears that the attention rather than memory component is more severely and permanently affected by seizures. The centrencephalic patients were significantly inferior on the number of correct responses on the "X" task as compared to the "AX" task of the CPT. The X task requires attention while the AX task also requires immediate memory. The X task requires the subject to respond by pressing a button whenever an X appears. The AX task requires the subject to respond to an "X" only if it occurs immediately after the letter "A". However, the finding of fewer correct responses on the "X" task occurred whether or not the seizure periods were included in the analysis. It may not be the seizures alone but rather the subcortical damage resulting from the seizures that is affecting performance on attentional tasks. Further, this suggests that phasic alertness has a greater effect on tasks that require pure attention.

A differential effect on attention and memory tasks was also found between children with centrencephalic epilepsy

and children with temporal lobe epilepsy (Fedio and Mirsky, 1969). Children with centrencephalic epilepsy were significantly more impaired on the CPT but were not significantly impaired on memory tasks. In contrast, children with temporal lobe epilepsy were significantly impaired on memory tasks.

As described above, both changes in phasic alertness, as reflected by spiking in the EEG, and controlled processing may be evident in tasks that require long-term memory. However, the finding that tasks such as the CPT are significantly impaired whether or not seizure periods are included in the analysis (Mirsky and Van Buren, 1965) suggest that there is also an effect on tonic alertness.

Phasic alertness and set both affect reaction time. The subject's readiness to respond to a particular stimulus or to a particular characteristic of the stimulus (set) may lead to improved reaction time as well as to a reduction in errors (Posner et al., 1973). Phasic alertness may be associated with the readiness to respond whereas set is related to the stimulus characteristics. Therefore, both phasic alertness and set interact. Set has been defined as the selection of the stimulus on the basis of a unique property which distinguishes it from another stimulus and which requires its prior identification (e.g. select consonants rather than vowels (Posner, 1975). Both phasic alertness and set improved reaction time in a letter

matching task (Posner and Boies, 1971). Subjects were provided with a warning signal or a letter which set the subject for the matching task. In this latter condition, a letter "X" was presented and then a second letter was shown and the subject had to respond as to whether the letters were similar or dissimilar. Reaction time was better in both conditions as compared to a condition in which no warning signal or set was provided. When the letter served both as a warning signal as well as the set (i.e. the first letter both warned and "set" the subject in preparation for the second letter), there was a combined improvement which was superior to either condition alone. That is, providing a letter which the subject has to remember and then discriminate from another letter may be sufficient to increase alertness. Therefore, the letter also may serve as a warning signal.

Although alertness and set can be examined separately (Posner and Boies, 1971) and both make independent yet additive contributions to processing, the CPT measures would in all likelihood be evaluating both the phasic component of alertness as well as set. Since tonic alertness is a measure of general level of alertness and the CPT assesses the ability to sustain alertness, then an index of tonic alertness should also be provided by the CPT. As described above, a letter which sets the subject for a trial may decrease reaction time. Since a letter "X" sets the subject

for the entire CPT task because the subject must respond when another letter matches it, then the original set of the target letter "X" may serve as a warning signal. Further, the overall mean reaction time may serve as a measure of tonic alertness since it assesses the reaction time over the course of the entire task. Although the CPT has not been used to assess tonic alertness, it seems reasonable to hypothesize that by examining differences in the overall mean reaction time, it would be possible to obtain an index of tonic alertness.

Performance on the CPT is affected by subject's tonic and phasic alertness. The research has also demonstrated a close association between attention and other internal conditions within the subject such as set and saliency. However, certain variables within the CPT can influence the subject's alertness, specifically, the rate at which the stimuli are presented. In fact, high event rate tasks, stimuli that are presented at a frequent rate, have been associated with tonic aspects of alertness (Broadbent, 1971), while low event rate tasks, stimuli that occur at an infrequent rate, have been associated with phasic alertness (Posner, 1975).

Vigilance Tasks and Rate of Stimulus Presentation.

High event rate tasks resemble the tonic effect seen in diurnal rhythm studies. Evidence for this has been an

increase throughout the day in the subject's ability to discriminate signals in vigilance tasks as shown by an increase in signal detection or response speed accompanied by a decrease in false alarms (Broadbent, 1971). According to Posner (1975), low event rate tasks show effects like phasic studies of alertness. Since phasic alertness has been associated with set as described above, and low event rate tasks may be particularly affected by set, it seems reasonable to postulate that low event rate tasks may show phasic alertness effects. That is, since subjects may be at a high level of expectancy during the performance of a low event rate task, then when the subject sees the target letter for which s/he is "set", this may serve as a warning signal. The letter or "set" may serve a similar function as a warning signal does in a study of phasic alertness (Posner et al, 1973). There may be a decrease in reaction time although there may not be a decrease in errors (Posner et al, 1973). When the warning signal is presented briefly then faster reaction time and fewer errors may result (Fuster, 1958).

Although Posner (1975) does not explain why high and low event rate tasks each may be associated with both tonic and phasic alertness, one way of understanding it is the following. Tonic alertness may be ascertained by examining the overall mean reaction time which would reflect overall level of arousal. Similarly, errors of omission and

commission would reflect set and phasic alertness. Further, phasic effects may be documented by variation from the mean which could be assessed by the overall standard deviation.

This association of tonic and phasic alertness and their effect on CPT performance would correspond to the interaction of level of arousal and saliency of stimulus input, respectively, as proposed by Deutsch and Deutsch (1963). In this model of the interrelationship of attention and perception, the importance of saliency of stimulus input for attentional processes is emphasized. Although all input stimuli are perceived, it is only after items are perceived that they are selected for attentional processes.

The criterion for whether a stimulus is selected for attention depends on the level of arousal and on the relative importance or saliency of the stimulus. If the stimulus is less salient than another stimulus, but the level of arousal is high, then both stimuli may receive attention. If the level of arousal is very low, even the more important and salient stimulus may not receive attention. Thus, both saliency of stimulus input and level of arousal are important for attention (Deutsch and Deutsch, 1963). Saliency as described by Deutsch and Deutsch (1963) is similar to Posner's (1975) description of set. Set and saliency both rely on the subjects' criterion for identifying the important characteristics of the stimulus, in a given task such as the CPT, before making a response.

In summary, it could be inferred that the set in a task such as the CPT is more salient than the nontarget stimuli. The subject must remember the critical stimulus, match this to the displayed stimulus and respond. This requires perception, attention, discrimination and response, all of which are in the realm of recognition memory. Mirsky and Van Buren (1965) describe the three task requirements for the CPT as reception of information, motor output and integrative process. The integrative process involves combining the sensory processing with the motor response. In this way, the reception of sensory input may lead to a motor response. Performance on a motor task, in which the subject had to repetitively press a response key in the absence of stimuli, was not associated with spiking in the EEG in a group of patients with centrencephalic epilepsy (Mirsky and Van Buren, 1965). Therefore, it is the perceptual aspects of the task and not the motoric which are associated with impairment in attentional processes.

Perception, Attention and Memory

Phasic alertness influences the response to input already in sensory memory (Posner et.al., 1973). A warning signal had an effect on phasic alertness as documented by decreased response time to the stimulus. The signal did not affect the rate of information build up in the sensory-memory system as documented by fewer errors, but rather it affected the rate at which the subject could respond to the stimulus. The inference is that if the rate of information build up is too slow, there may be a greater number of errors of omission or commission. Errors of commission occur when responses are made to non-target stimuli. This runs counter to the view that alertness affects perception but rather suggests that it affects a later system. The later system would be a system involving the actual response to the stimulus or as described above, the integrative process (Mirsky and Van Buren, 1965). The implication of this study is that reaction time is greatly affected by phasic alertness and that if there are effects on phasic alertness due to a tumor, these effects will be documented by reaction time performance.

In the above study (Posner et.al.,1973), alertness did not affect errors, while in a different study (Fuster, 1958) increased alertness led to fewer errors. These discrepant findings may be based on the different stimulus characteristics in the two studies. In the first study

(Fuster, 1958), the stimulus was present for a brief duration after which the subject could respond. If the subject was at a high level of alertness and responded more quickly, it is possible that the response would be based on a sensory-memory trace that was less decayed and of a higher quality. In Posner's (1973) study, since the stimulus was present until the subject responded, level of alertness did not affect the quality of information and therefore higher levels of arousal which would allow a faster response did not lead to a reduction in errors. If the stimulus duration is short and the subject has to respond after the stimulus is no longer present, then higher alertness may lead to a reduction in errors. It would be interesting to determine what effect combining the paradigms of the two studies would have on performance. For example, there would be a short duration of time as in Fuster's (1958) study but the subject would have to respond while the stimulus was still present as in Posner's (1973) study. It would be hypothesized that because the stimulus is present during the time the response must occur, higher levels of alertness may not affect the number of errors, but may affect reaction time since the subject must respond during a short exposure duration.

The evidence and conclusions of Posner's (1973) study are not as convincing as those of Fuster (1958). However, the functions of percentage of correct responses and mean reaction time as a function of duration of exposure of the

signal are different (Fuster, 1958). If one further examines these functions and plots the difference between the control and experimental conditions (for performance as a function of stimulus duration), the functions show a linear upward trend on mean reaction time but a zero slope indicating no difference as a function of duration of signal exposure on percentage of correct responses. The difference in the functions indicates that there may be two separate systems, one involved in response rate and the other in discrimination. Posner's (1973) evidence was that a warning signal did not affect the number of errors but rather affected the rate of subject response. The distinction is important for the current work in that it may be important to examine both reaction times and quantity of correct responses and errors. Perception may be affected as indicated by performance on discrimination measures of a reaction time task.

This may also be compared to tasks which require perception and visual discrimination. Both errors of commission on the CPT and performance on a digit symbol task (e.g. Digit Symbol substitution) were found to be related to barbiturate dosage (Mirsky and Kornetsky, 1964). The authors suggest that the RAS is affected and this subsequently affects performance on both tasks. In fact, barbiturates have been known to inhibit memory consolidation suggesting that they affect brain regions essential for arousal (Bloch,

1970). There may be a common mechanism underlying both performance on a digit symbol task and errors of commission on a CPT task. Both require matching two stimuli correctly.

In Digit Symbol, errors will occur if the target stimuli are not matched with the stimuli to which they have been paired. On the CPT, errors of commission will occur if non-target stimuli are incorrectly perceived or responded to as target stimuli. If this is so, then one would predict that errors of commission and performance on Digit Symbol should be correlated. If performance on the CPT is affected as evidenced by the number of errors of commission, then one could conclude that the disturbance occurs in phasic attention and is specifically related to the integrative process or response to information already in sensory-memory.

Models to explain the relationships between perception, attention and memory.

Several models have been used to describe the relationship between attention, memory and auditory perceptual processes. Often these models have focused on the manner in which information is encoded and maintained in short-term memory (STM) and subsequently transferred to long-term memory (LTM). Both perceptual variables and attention are important for recall from STM (Sanders, 1975).

Perceptual variables would include stimulus characteristics, such as presentation rate, serial position of words on presentation and modality of presentation (Kintsch and Polson, 1979). The recall of a list is affected by the serial position of words such that there is better recall of the words from the beginning as opposed to the end of the list (Glanzer and Cunitz, 1966; Murdock, 1962). Selective attention, the allocation of attention to a specific task, can also interact with perceptual variables such as presentation rate and thus alter the expected finding of better recall at the beginning as compared to the end of a list (Brodie and Murdock, 1977). Attention has also been shown to be influenced by rehearsal. Functional serial position curves show overt rehearsal order and indicate that the superiority of slow presentation rates manifests itself at the end of the list (Kintsch and Polson, 1979). That is, subjects may rehearse items from the end of the list more when the presentation rate is slow.

Deficits in encoding and acquisition may lead to memory deficits. From the dual process viewpoint, the information may not be transferred from short-term to long-term memory or it may be transferred in a degraded or inaccurate form. In this way, deficits in encoding or acquisition may be related to both perceptual and memory processes. From the levels-of-processing viewpoint, information may never reach a deep level of processing.

Levels-of-processing is an important theory to examine in the context of this thesis because it makes the distinction between the different ways in which information may be processed (Craik and Lockhart, 1972). For example, in the auditory modality, information may be processed in a superficial manner on the basis of sound or phonemic similarity of information. Further, information may reach a deeper level-of-processing when it is processed for meaning.

This distinction is a quantitative rather than a qualitative one because information may reach this deeper level of processing if certain strategies, such as rehearsal, are practiced. Although Craik and Lockhart (1972) have described these quantitative levels of processing, which are continuous, they also adhere to the stages of memory models. This may not be contradictory because levels of processing may occur within both primary and secondary memory as well as in the transition between primary and secondary memory. This model is useful because it provides a means of describing the relationship of auditory processing to attention and memory. For example, auditory-perceptual processes encompass the first stage of processing while processes involving semantic memory encompass the second stage of processing.

Atkinson and Wescourt (1975) discuss the degree of activation necessary to process information and relate this to levels-of-processing (Craik and Lockhart, 1972). These

levels include a deep level of processing usually associated with semantic material and a superficial level of processing usually associated with non-semantic material. Each level is similar to the more traditional terms LTM and STM, respectively. Although phonemic material had previously been associated only with STM and semantic material with LTM, more recent research has demonstrated that semantic material also may be represented in STM (Glanzer, 1972). Levels-of-processing represents a continuous process rather than a more discrete division similar to the stages of memory distinction. Retention depends upon the degree of processing such that highly processed information, which is information that is subject to a continuous process of organization and integration, is available for a longer duration of time (Craik and Lockhart, 1972). This active approach of processing is complementary to Kahnemann's (1973) limited resources model. The main resource for attention is the amount of effort or arousal available which will consequently influence memory functions. If there are limited resources for attention due to a lowered level of arousal, then the amount of attention available for memory encoding and processing will be substantially decreased. Just as fluctuations in attention may affect performance on various tasks, an intervening task may lead to a diversion of attention which will consequently affect memory.

Memory may be affected both because of a limited amount

of available attentional resources and interference with selective attention. Interference may be more likely to occur if a subject does not have an adequate opportunity to rehearse information in order to maintain it in STM until it is transferred to LTM. It is possible that the effect of information not being encoded properly may be similar to the effect of an external manipulation of rate. For example, as presentation rate is increased there may be less opportunity for rehearsal to occur and interference by the subsequent word will take place. In a selective reminding task, a list of words is presented verbally to a subject (Buschke, 1973)

The subject is required to recall the list after it is presented until all the words have been recalled. Before each recall trial, the subject is reminded of only those items that were not recalled on the previous trial. Items which are recalled without additional presentation are those items that have been retained from the list (Buschke, 1973).

It is also postulated that items which are recalled without further presentation have entered long-term storage in that they do not require selective reminding. Words that are not remembered have been affected by the remaining words that were being presented. The inference is that STM and not LTM is affected by interference. The rationale for interference being effective for only short-term and not long-term memory is that items that enter LTM have been thoroughly processed and therefore these items would not be subject to

interference. Some type of encoding which includes associations with words already in LTM, is part of the process necessary for storage of information. An alternative approach to understanding interference is that as information is being encoded there is a decreased vulnerability to interference. This approach encompasses the model of levels-of-processing.

Rate of presentation may play a role in performance on free-recall tasks. The auditory system is highly tuned to small temporal changes. Therefore, a conduction delay can alter the stimulus appreciably and degrade the incoming information. Although the Selective Reminding Test requires a presentation rate of one word every two seconds, the stimulus may be degraded for posterior fossa tumor patients.

This may affect performance in a similar way that a higher rate would affect performance in normals. For instance, if the delay is a constant and rate of input is fixed, because the information may take longer to enter the system, this may be experienced as a faster rate of stimulus input. If indeed, this is the case, then there would be less opportunity for rehearsal to occur.

Therefore, a dual process approach may explain a deficit in learning on the Selective Reminding Test. That is, since these items are already in long-term memory, it is possible that both controlled and automatic processing may be used in this task. It is possible that access to

well-learned items of information in long-term semantic memory is an automatic process. However, since the task involves the recall of a specific list chosen from many possible items in a given well-learned category such as animal names, controlled processes may be necessary. In order for this task to become an automatic task, the category names would have to be processed automatically and therefore would not enter long-term memory.

In summary, the Selective Reminding Test (Buschke, 1974) may be affected by an interruption in any one process, ranging from attention to encoding to consolidation to retrieval. Each of these components are necessary for memory. The component of attention or memory that is affected and its overall impact on the task may be fully appreciated by evaluating specific deficits associated with these components. Further, if there is a deficit in encoding, the information may not reach a deep level of processing and may not be consolidated in memory. As a consequence, the memory trace may be lost.

The Relationship of Perception, Attention and Memory to Brain Regions

Consolidation processes have been associated with hippocampal regions (Penfield and Milner, 1959; Milner, Corkin, and Teuber, 1968). Bilateral lesions of the hippocampus have resulted in an inability to maintain traces

of current experience (Penfield and Milner, 1958; Milner, 1970). An inability to learn and retain traces of new information has also been documented in patients with deep lesions of the hemispheres which include limbic structures and are proximal to the upper brain stem RAS (Luria, 1971, 1973). Luria (1971, 1973) attributes the deficit to the impingement on the RAS by the lesion. Patients were presented with a list of words, then were asked to perform another intervening activity and finally were asked to recall the first list of words. The intervening activity interfered with recall of the list. However, the patients were able to perform within normal limits if an intervening task was not presented. Therefore, any encoding deficit can be ruled out since performance was affected only when new information from the intervening task replaced old information in working memory. In other words, recall was within normal limits when there was no intervening task. This suggests that it is the intervening task that is causing a disruption in the recall processes. This might be due to a disruption in attention because of interference with rehearsal.

Surgical removal of the thalamus or globus pallidus has resulted in impairment on Arithmetic, Digit Span, and Digit Symbol of the WAIS (Riklan, 1960). Initially, it would seem that performance deficits in these tasks were caused by dysattention. However, additional findings showed that

performance was significantly diminished after left as compared to right ventrolateral thalamotomy or pallidotomy on the above tasks. Therefore, it would be difficult to explain the differential effect by attention alone. This would suggest that either encoding or consolidation also has been affected. Encoding may be affected and result in information not reaching a deep level of processing. This would also lead to a deficit in consolidation of the material and to a possible loss of the memory trace.

The thalamus has been associated with disorders in verbal memory and learning (Ojemann, 1971; Fedio and Van Buren, 1975). Furthermore, a decline in verbal fluency (retrieval of words from a specified phonemic or semantic category) that may be related to retrieval difficulties also has been noted in patients with left ventrolateral thalamic lesions (Vilkki, 1979). However, if a differential effect occurs in which fluency is not affected but free recall of a list is affected, it might be concluded that the deficit would lie in encoding and consolidation. If the deficit were in retrieval, then verbal fluency also should be impaired.

The relationship of subcortical structures to memory encoding and consolidation has been examined using a levels-of-processing and dual process approach. The impact of lesions involving different subcortical structures on attention will be described by several studies. To assess

the impact of lesions involving different subcortical structures on attention, Mirsky and Oshima (1973) compared rhesus monkeys with upper brain stem-mesencephalic lesions to monkeys with thalamic lesions on a CPT-like task. The monkeys with the upper brain stem-mesencephalic lesions performed significantly worse than the monkeys with thalamic lesions. The dependent measure was errors of omission which are errors which occur when there is no response to the target stimulus. The upper brain stem-mesencephalic lesions included damage to the superior and inferior colliculi of the mesencephalon, the lateral lemniscus and reticular neurons. The thalamic lesions included damage to midline and medial thalamic structures and large areas of cell loss in surrounding areas. If there was damage to the thalamic reticular neurons, this was not specifically indicated by the authors. The authors suggest that a temporary functional disturbance in brain stem and mesencephalic regions can result in impairment on an attention task which was well-learned through pre-operative training. Because of the training, it is reasonable to infer that automatic processing was utilized. It should be noted, however, that some of the dysattention may have resulted from the damage to the reticular neurons documented in the monkeys with brain stem lesions.

Just as there were differences in performance on an attentional task associated with lesions to the upper brain

stem mesencephalic region as compared to the thalamus (Mirsky and Oshima, 1973), there are also documented differences in EEG activity associated with stimulation of these different regions. Tonic changes in alertness have been associated with midbrain levels of the RAS while phasic changes in alertness have been associated with thalamic levels of the RAS (Sharpless and Jasper, 1956; Thompson, 1963). Sharpless and Jasper (1956) found that stimulation of the midbrain RAS in cats was related to a tonic arousal reaction as documented by changes in the EEG of longer latency and greater duration after the termination of stimulation. Stimulation of thalamic levels of the RAS was related to phasic changes in alertness which were demonstrated by changes in the EEG of shorter latency and briefer duration after stimulation. The tonic reaction was more susceptible to habituation as documented by the fact that after habituation to a tone, more time was required for the stimulus to elicit a sustained tonic activation pattern. This is an EEG pattern which is sustained for seconds or minutes beyond the cessation of the stimulus. However, only a few minutes were required in order to restore a phasic activation pattern, a pattern which barely outlasts the stimulus.

Although tonic changes in alertness have been associated with midbrain levels of the RAS while phasic changes in alertness have been associated with thalamic

levels of the RAS (Sharpless and Jasper (1956)), it is likely that the brain stem RAS is involved in both types of alertness. In one study (Fuster, 1958), stimulation of the rostral brain stem RAS (at the level of the reticular formation of the midbrain tegmentum) in rhesus monkeys decreased reaction time and increased the percentage of correct responses on a CPT-like discrimination task presented tachistoscopically. It was concluded that phasic changes resulting from stimulation of the reticular formation induces general activity of the cortex and thus, increases cortical receptivity to ascending sensory impulses. Stimulation of the RAS was shown to facilitate perceptual performance as demonstrated by shorter reaction times and a higher percentage of correct responses. This study implicates phasic attention in perceptual processes such as discrimination and suggests that the RAS is important for the transmission of sensory information to higher cortical areas.

In the Sharpless and Jasper (1956) study, there was a distinction made between tonic and phasic alertness and the levels of the brain associated with each. Stimulation of the midbrain was associated with tonic changes in the EEG while stimulation of the thalamus was associated with phasic changes. The difference in the two studies may be a result of the different regions of the brain stem that were stimulated. In Fuster's (1958) study, the area stimulated

was the rostral part of the brain stem reticular activating system, mostly composed of the reticular formation of the midbrain tegmentum. In Sharpless and Jasper's (1956) study, the midbrain area was stimulated although the specific part of the midbrain was not specified.

Tonic and phasic changes in the EEG have been associated with the midbrain and thalamus respectively (Sharpless and Jasper, 1956) while both forms of alertness have been associated with brain stem regions (Fuster, 1958). Dysattention, as noted by performance on the CPT, was associated only with brain stem regions. It has been noted that level of alertness may have a greater effect on memory consolidation than on retrieval. This would correspond to the findings discussed above, that deep lesions affecting limbic regions proximal to the upper brain stem RAS have been associated with consolidation processes (Luria 1971, 1973) while thalamic regions have been associated with retrieval processes.

Alertness has been demonstrated to influence memory consolidation but not retrieval (Bloch, 1970). Bloch (1970) found that stimulation of the RAS at the level of the mesencephalic tegmentum facilitated learning in a discrimination learning task based on single trial water reinforcement. Although a drug, fluothane anaesthesia, was used to prevent learning, reticular stimulation annulled the effect of the drug. It appears that there is a critical

period for the effects of the stimulation to be optimal. This period, up to 90 seconds, appears to be the time necessary for consolidation. Bloch (1970) found that although stimulation can affect consolidation processes, retrieval processes appear to be independent of level of arousal. Rats were taught a six-choice T maze. When the rats reached criterion, they were separated into two groups equated for learning ability and were left in their cages for a five day forgetting period. Then, the rats were placed back into the maze. The experimental group received reticular stimulation of about 90 seconds duration, the amount of time that had been needed for consolidation, while the control group ran the maze without stimulation. Performance on the maze was identical for the two groups indicating that stimulation did not affect retrieval processes.

The Relationship of Attention and Auditory Perception to Encoding.

Level of alertness, whether phasic or tonic, may affect memory in the following manner. If there is a vigilance disturbance and level of alertness is affected, there may be a lower threshold for admission of salient stimuli. Oswald, Taylor, and Treisman (1960) found that individuals when asleep will attend only to very important messages, such as their own name or the sound of their infant crying whereas when awake, they will attend to any message provided that it does not occur concurrently with a more salient message. Thus, there may be a difficulty in matching stimulus input to the stimulus in memory. In fact, without arousal, awareness and response to peripheral stimulation will be absent, attention will be inoperative and there will be no stimulus input. Thus, it appears that alertness is related to perception which then affects memory.

Just as level of alertness and saliency of stimulus input affects encoding and acquisition of information in memory, auditory-perceptual processing also affects memory. A deficit in auditory-perceptual processing could result in deficient encoding and acquisition of information. This could occur in the following manner. Conduction time may be affected as noted by an increase in the interpeak latencies (IPLs) of the BAER in patients with posterior fossa tumors (Wielgaard and Kemp, 1979; Zappulla, Karmel and Greenblatt,

1981; Zappulla, Greenblatt and Karmel, 1982).

Central conduction time within the brain stem has been quantified by calculating the I-III and III-V IPLs for ipsilateral recordings to the ear stimulated. This method of quantifying central conduction time also enables one to determine if the disturbance in conduction occurs in the proximal (extra-axial and pontomedullary) or distal (rostral pontine-midbrain) segments of the brain stem auditory pathway as noted by increases in the I-III and III-V IPLs, respectively (Stockard, Stockard, and Sharbrough, 1978). Increases in conduction time have been documented in patients with posterior fossa tumors using ipsilateral recordings of the BAER from stimulation of the unaffected ear. Posterior fossa tumors usually occur on just one side and therefore are unilateral rather than bilateral tumors. In the population studied, only patients with unilateral tumors were selected.

Neural structures dysfunction resulting from compression has caused delays in conduction time as noted in patients with CPA tumors who were tested using BAERs (Zappulla et al, 1981). Documented delays in the IPLs on the side contralateral to the tumor were attributed to the tumor's compressive effects on the brain stem (Zappulla et al, 1981). Tumor size was correlated with the III-V IPL and it was suggested that dysfunction of neural structures may have produced delays in conduction time on both the affected

and unaffected sides.

If, indeed, delays in conduction time may be attributed to compression, then this should be evidenced by a differential effect on the BAER in patients with large as compared to small tumors. Delays in the III-V IPL of the BAER from the ear contralateral to the large acoustic neuromas were attributed to a delay in conduction time associated with a disturbance in the rostral pontine-midbrain segments of the brain stem's auditory pathway (Zappulla et al, 1982). The acoustic neuroma patients were divided into two groups on the basis of tumor size in order to determine the effect of compression on peak latencies. The authors state that surgical experience had indicated that tumors 2.0 centimeters or greater were found to be associated with compression of the brain stem, while compression was rare in tumors of 2.0 centimeters or less.

Wielgaard and Kemp (1979) also found prolonged latencies in ipsilateral recordings of the unaffected ear in patients with posterior fossa tumors. The authors documented latency and amplitude abnormalities in peaks IV and V and also attributed this to the effects of brain stem compression on the BAER. These abnormalities in peak IV and V were associated with rostral pontine and lower midbrain levels (Stockard and Rossiter, 1977). Interestingly, the structures associated with peaks IV and V of the BAER, the rostral pontine-midbrain structures of the brain stem

auditory pathway, is the same area that when stimulated caused decreased reaction time and superior discrimination performance in a task tachistoscopically presented (Fuster, 1958). This also suggests that the reticular activating system may be affected by compression as noted by the III-V IPL.

Clinical Studies of Attention and Memory.

In patients with intrinsic or extrinsic tumors of the brain stem, deficits in attention and memory have been associated with damage to the brain stem and to the RAS. Intrinsic tumors, tumors within the brain stem, may have a direct effect on the RAS since they affect structures that comprise the ascending RAS whereas extrinsic tumors, tumors external to the brain stem, may have an indirect effect since they compress the brain stem. The cognitive deficits associated with both intrinsic and extrinsic tumors of the brain stem are similar in that they affect attention, memory, and language.

In several studies, damage to the lower brain stem has been found to cause attention and memory impairments, typically as measured on mental status examination. Post-mortem morphological analysis revealed damage to the RAS without cortical damage in patients with tumors of the pons or medulla-oblongata (Cairns, 1952). The patients' deficits in vigilance and memory were associated with the

RAS damage. Cairns (1950) attributes the cognitive symptoms associated with tumors of the pons and medulla-oblongata to damage to the lower brain stem and concludes that interference with functions of the lower brain stem may affect higher cortical functioning. The symptoms that were evident in the patients with pontine tumors included language disturbances. For example, dysarthria, an inability to maintain the coherence of a spoken sentence, word-finding difficulty and a slight impairment of speech comprehension were evident. These symptoms were assessed by clinical observations of speech and language during the neurological examination. In those patients with pontine tumors, cognitive symptoms were present in the absence of hydrocephalus. This indicates that these cognitive symptoms can be attributed to the effects of the tumor rather than to the effects of hydrocephalus.

Another study also associated cognitive symptoms with RAS deterioration in patients with lower brain stem tumors (Arseni and Goldenberg, 1959). This study documented clinical symptoms in 92 patients with infiltrating gliomas of the brain stem. There was a greater percentage of patients with lower brain stem lesions who exhibited cognitive deficits as compared to those with higher lesions.

Arseni and Goldenberg (1959) believed that the symptoms were determined by the degree of deterioration of the nonspecific reticular activating system. The alternative

conclusion is that there may have been damage to other brain stem structures which would have an adverse effect on patients with lower lesions because of the hierarchical nature of brain functioning.

The authors (Arseni and Goldenberg, 1959) assert that the brain stem is important not only for consciousness but also for the level of cortical activity responsible for higher nervous functions including voluntary activity, attention and memory. The symptoms associated with these tumors included diminished affectivity, decreased volition, and impaired attention and memory. These symptoms were assessed through clinical examination, observation and certain mental status assessment techniques. Attention and memory were measured through learning tests, orientation questions, and reading and calculation tasks.

There was no statistically significant difference between the number of cases with cognitive and behavioral disturbances with increased intracranial pressure and the number of cases with cognitive and behavioral disturbances but without increased intracranial pressure. The authors conclude that there is no causal relationship between increased intracranial pressure and cognitive and behavioral disturbances. This conclusion, however, is not consistent with the documented association of increased intracranial pressure with cognitive and behavioral symptomatology (Keschner, Bender and Strauss, 1937; Barnett and Hyland,

1952; White, 1963). Also, although there may not be a significant difference in the frequency of symptomatic patients with or without increased intracranial pressure, the quality of the symptomatology may differ.

Evidence for this was derived from a pilot study for this thesis. Two acoustic neuroma patients with hydrocephalus were evaluated before and after shunting. One of these patients was also tested six months post-surgery. Results indicated that both patients could not perform tasks requiring the reversal of digits or words. For instance, they could not spell "world" backwards and they could not sequence digits in reverse order. However, other deficits included short-term memory and attention that were similar to deficits later found in the patients with posterior fossa tumors but without hydrocephalus. The inability to perform a task in reverse order improved after shunting for the patient for whom the shunting was successful in removing the intracranial pressure. Further, the patient's performance improved in many tests post-surgery.

Zsady, Ovary and Halasz (1967) attributed cognitive behavioral symptoms in brain stem tumor patients to the effects of the tumor on the ascending RAS. The authors noted that in eight cases of patients with brain stem lesions, the higher the lesion, the greater were the number of symptoms. In cases of medulla-oblongata lesions, there were no symptoms while in cases of pontine lesions, there

were disorders of thinking, attention, emotion, and a diminution of activity as assessed by mental status examination. In addition to the above symptoms, there were memory deficits, also as assessed by mental status examination, that were more severe in patients with ponto-mesencephalic lesions. The authors did not describe how these symptoms represented disorders in cognitive processes nor did they operationally define the constructs of attention and memory. In all of the above studies with the exception of the Cairns (1950) study, RAS changes were not measured but rather were inferred from the behavioral evidence. One study (Arseni and Goldenberg, 1959) was more valid and reliable than the other studies in that there were a greater number of subjects as well as better dependent measures.

Other studies of patients with intrinsic tumors of the brain stem have documented similar symptoms. Wallack, Reavis and Hall (1977) described a patient with primary brain stem reticulum cell sarcoma, a neoplasm of the connective tissue, who had concomitant loss of short-term memory and disorientation. The authors do not elaborate on their methods for assessing these symptoms. However, besides a neurological examination, they did use several mental status examination techniques such as calculations, proverbs, and orientation to place. The association of short-term memory deficits with the sarcoma is notable

because other authors described general memory deficits but did not distinguish between stages of memory. The patients may have short-term memory deficits resulting from lack of attention which has been associated with disorientation. Wallack, et. al. (1977) documented that increased intracranial pressure did not exist in this case.

Netsky and Strobos (1952) described a cluster of symptoms in patients with neoplasms within the midbrain. Symptoms included memory impairments for both recent and past events, disorientation, confusion, and apathy. These symptoms were noted clinically and through the use of mental status techniques such as measures of spatial orientation, the calculation of simple sums, examination for recent and past events, and tests of symbolic performance.

There are very few studies that have measured attention and memory using tests rather than clinical impressions. However, in one study of patients with infiltrating gliomas of the brain stem, these processes were measured more objectively (Araeni and Volenschi, 1967). Mental disturbances were documented through the use of clinical records which contained history, results of neuropsychological examination, and observation of the patients mental state during hospitalization. The authors do not specify what constituted the neuropsychological examination. However, additional tests of attention and memory that were administered were described. Concentration

was studied using a letter-cancellation task in which the patient had to cross out specific letters among an array of letters. What the authors term "mobility of attention" was measured by a card-matching task in which subjects had to match images. Mobility of attention was defined as the time required to search and find the matched image in an array. This might be similar to a cancellation task which measures concentration. Recognition memory was measured using a delayed response to the above stimuli. Subjects had to recognize which member of the pair of pictures had been presented to them.

Results from these tests of attention and memory showed deficits that had not been evident using the clinical records. The authors attribute these deficits to diminished cortical activity resulting from involvement of the brain stem reticular activating system. That is, the reticular activating system determines the level of cortical activity responsible for cognitive processes such as attention and memory.

In comparison to intrinsic tumors of the brain stem, extrinsic tumors appear to cause similar although less severe disturbances. One possible explanation for this observation is that compression of the brain stem by the tumor may cause impingement upon brain stem structures and consequently affect the RAS. Wilson and Rupp (1946) described mental symptoms including memory disturbances

which were prominent in 16 out of 21 cases of extramedullary posterior fossa tumors. There was no discussion of how memory was measured. Six of these 16 cases showed no evidence of increased intracranial pressure. However, the authors did not distinguish between those patients with and without increased intracranial pressure in their presentation of the clinical symptoms. The symptoms of all of the patients were attributed to brain stem compression.

Damage to the RAS was found on post-mortem examination of patients with extrinsic tumors of the brain stem who were diagnosed with cortical dementia (Jedrezejewska-Iwanowska, 1974). There was no discussion of what criteria were used to make the diagnosis of cortical dementia. All of these patients had cerebellopontine angle tumors. Clinical characteristics including disturbances of memory, time sequel, sleep and vigilance associated with the tumor were assessed by noting their presence or absence. The author did not specifically note what characteristics of each of these disturbances were being assessed. It was postulated that the cause of the deficits was both the tumor's compressing against the brain stem as well as reticular activating system changes.

However, the conclusion should be regarded with caution. A confounding variable was the incidence of increased intracranial pressure evident in several of the patients. The increased intracranial pressure may have

contributed to the severity of or to the qualitative aspects of the cognitive deficits. Although other authors (Arseni and Goldberg, 1959; Netsky and Strobo, 1952) found no difference in the frequency of cognitive disturbances in patients with or without increased intracranial pressure, the quality of the disturbance may have differed.

It is clear, however, that there does appear to be an association of cognitive deficits with either extrinsic or intrinsic tumors of the brain stem. This may be associated with a direct effect on the RAS in the case of the intrinsic tumors. In the case of the extrinsic tumors, these deficits may be associated with compression on structures of the brain stem which comprise the ascending RAS. In order to more adequately assess the deficits, objective measures must be used and the confound of concomitant increased intracranial pressure must be eliminated.

The mechanism of the involvement of the RAS in the deficits described in some of the above studies appears to be a function of its role in arousal and alertness which consequently affects memory. However, in one study, a head trauma patient showed a selective impairment in memory without an impairment in general arousal. Memory was assessed by the Buschke Selective Reminding Test, the Wechsler Memory Scale, and the Boston Retrograde Amnesia Test. This patient had retrograde amnesia without anterograde amnesia and no impairment in general arousal

(Goldberg et al, 1981). The authors did not specifically indicate how arousal was assessed. The deficit was in retrieval and not in consolidation and therefore corresponds to the earlier finding that alertness affects consolidation rather than retrieval (Bloch, 1970). As determined by CAT scan, there was damage to the ascending RAS projecting to limbic structures without damage to the ascending mesencephalic RAS projecting to the thalamus and neocortex. The authors conclude that if there was impairment to both areas, then an arousal deficit would override a selective memory impairment since the brain stem RAS is involved in arousal and attention which affects memory (Luria, 1976; Jedrezejewska-Iwanowska, 1974).

Disturbances of attention, orientation and memory have also been described in patients with deep midline tumors involving the hippocampus, mamillary bodies, and the thalamus (Luria, 1976). Further, deep midline tumors may be unaccompanied by memory disturbances provided they do not involve the thalamus and the medial zones of the hemispheres (Luria, 1976). This finding supports the early work of Moruzzi and Magoun (1949) which implicated the ascending RAS in arousal processes. This work also pointed to the role of the diffuse thalamic projection system as a mediator between the brain stem and cortex which has been more recently documented (Rocha, 1980). In the work of Goldberg et al (1981), the ascending RAS to the thalamus and neocortex was

spared and there were no arousal deficits. This further highlights the association between arousal functions and the ascending brain stem RAS projecting to the thalamus and neocortex.

Rocha (1980) describes the importance of the RAS projections to the thalamus and neocortex in sensory processes. The reticular neurons that were stimulated have been associated with attentional processes (Lindsley, 1973).

Rocha (1980) studied the sensory behavior of reticular neurons by stimulating parts of the reticular formation in anesthetized cats. The responses of the reticular neurons located at the bulbar (brain stem), pontine, and mesencephalic levels were found to attenuate upon repetition of the same stimulus. The attenuation of the response usually increased with a higher rate of stimulation. This indicates that saliency of stimulus input is important and that consequently, a faster rate of stimulation can result in a decrease in responses. Rocha (1980) also found that stimulation of the reticular neurons triggered evoked activity in the thalamus.

The difficulty with many early studies is that although attention and memory deficits were documented and associated with tumors in subcortical structures, the constructs of attention and memory were not operationally defined and sensitive measures of attention and memory were not used. Whereas the authors of the above studies have found deficits

associated with brain stem structures and the reticular formation and associated this with an influence on higher cortical functions, other authors have found deficits in cortical functioning and inferred from this a deficiency in reticular activation (Gazzaniga and Hillyard 1973; Holtzman and Gazzaniga, 1982).

Gazzaniga and Hillyard (1973) demonstrated the importance of the brain stem in selective attention using primates with severed corpus callosums. The primates were able to process a greater quantity of information when each hemisphere was working separately on two different tasks than when only one task was being solved. Further, when a lateralized motor response was induced by a particular task, reaction time was longer, indicating that the warned right hemisphere caused interference in the control of the left hand by the right hemisphere. Evidence from the EEG suggested that disruption of activity from one hemisphere by the other hemisphere affects the motor response rather than the sensory or perceptual process. The task required the subject to press a button to a loud tone burst after a warning signal had been flashed to one hemisphere or the other. The mean reaction times for the response from the dominant hand followed by the warning signal to the nondominant hemisphere were significantly prolonged as compared to the other hand-hemisphere combinations. On the basis of the EEG evidence, it was determined that perceptual

processing was not disrupted. The EEG findings indicated that when the right hand was in use, the right hemisphere did discriminate the warning signal from the no-warning signal condition. The EEG results from the foreperiod reaction time task were bilaterally symmetrical and indicate that the waves are governed from bilaterally activated structures in the brain stem or thalamus (Gazzaniga and Hillyard, 1973). In other words, the brain stem would equally activate each cerebral hemisphere and therefore, the EEG results would be bilaterally symmetrical.

In a study of split-brain patients, tasks which were presented to the right hemisphere competed for response output with tasks which were presented to the left hemisphere (Holtzman and Gazzaniga, 1982). In describing the concept of limited resources, Reisberg, Rappaport, and O'Shaughnessy (1984), postulated that the underlying resource which was needed for both tasks in the study of split-brain patients described above (Holtzman and Gazzaniga, 1982) was reticular activation.

Predictions on the Effects of Posterior Fossa Tumors on Attention, Memory and Perception.

In order to determine what deficits are present that can be attributed to the effects of the tumor, it is necessary to obtain measures both pre-operatively and post-operatively. Since removal of a posterior fossa tumor

may lead to subsequent decompression of the brain stem, recovery of function may be expected to take place. This is supported by previous research; a post-operative study was conducted with posterior fossa tumor patients following surgery (Fischer, Schmidt, Wanke, and Peterson, 1968) in which there was a slight impairment of intelligence attributed to concentration disturbances.

General predictions about the effects of posterior fossa tumors on performance include the following. There would be an association between performance on tests of attention and memory and tumor size. This would occur because of compression on the brain stem and consequent impingement on the RAS. Further, there would be an association between the III-V IPL, as a measure of compression, and performance on tests of attention and memory. The CPT, as a behavioral measure of attention, would be more sensitive to attentional impairment and would correlate significantly with both size of tumor and the III-V IPL. There would be an impairment in memory tests that specifically involves memory consolidation since attention and level of alertness has been associated with memory consolidation. Certain auditory-perceptual tests might be affected as a result of involvement of the auditory pathways and these tests should be significantly correlated with the III-V IPL. Verbal fluency should also be affected. Large tumor subjects should perform significantly worse on

tests of attention and memory which were correlated with size of tumor.

Predictions about post-operative or second testing performance include the following. There should be no significant difference among groups on tests of memory and attention. There should no longer be a significant correlation with size of tumor or the III-V IPL and tests of memory and attention. Predictions of change between pre- and post-operative testing include the following. There should be improvement on all affected tests for large tumor patients post-operatively. Small tumor patients and controls should not significantly improve on tests since it was predicted that there would be no significant impairment.

Specific predictions about pre-operative performance include the following. Since brain stem compression should result in impingement on the reticular activating system (RAS) and the RAS is associated with attentional processes, then the III-V IPL and size of tumor should be associated with performance on tests of attention and memory. These tests would involve either the visual or the auditory modality. If auditory-perceptual factors also play a role, then size of tumor and the III-V IPL should be associated with modality-specific auditory-verbal tests of attention and memory. The attentional and/or perceptual deficit may be related to impairment in tests such as Digit Span. The

attentional disturbance should result in impairments on tests of memory consolidation. There should be an association between size of tumor and the CPT reaction time measure. If there is an auditory-perceptual deficit, this should also affect performance on verbal fluency tasks. This might especially be true for phonemic as opposed to semantic tasks. That is, a difficulty in retrieving phonemic items may result from an encoding deficit.

Specific predictions of change include the following. Those tests that were impaired should improve post-operatively. The pattern of improvement of these tests should indicate the way in which memory, attention and perception are related. If attention and memory are related, then both should improve. If auditory-perceptual factors were also involved then improvement should occur in tests of auditory-verbal functioning.

Method

Subjects

The overall subject group consisted of 26 patients from the Neurosurgery Department at Mount Sinai Hospital and a control group consisting of ten spouses of patients and thirteen other volunteers. All patients had posterior fossa tumors of the cerebellopontine angle (CPA) as determined by computerized axial tomography (CAT) scan. Criteria for inclusion in this study for the patient group consisted of the following: fluency in English (all Ss were native English speakers with one exception, a patient who spoke Yiddish as a first language); no signs of distress regarding the testing, no motor deficits as assessed by neurological exam, and no increased ventricular size as assessed by CAT scan. English was the first language of all normal controls.

The patients were subsequently divided into two groups based upon size of tumor with those having tumors larger than 2.0 cm being placed in the large tumor group (LTG) and those with tumors 2.0 cm and smaller being placed in the small tumor group (STG). There were 15 subjects in the LTG and 11 subjects in the STG. Size of tumor was determined by CAT scan and size at operation. Operative size was the measurement of the intracranial extension of the tumor at the time of surgery underneath the operating microscope.

Where CAT scan and operative size disagreed, operative size was used. The control group consisted of volunteers and spouses.

The control group was composed of ten spouses as well as thirteen other volunteer subjects. These volunteers were used, when needed, in order to provide every patient with an age and education matched control for the CPT. Spouses were chosen in an effort to keep the age and educational level of the two groups similar. The similarities of spouses in age and educational level has been documented (Rubin, 1973). Spouses would also be likely to return for testing in five to seven months.

Subjects for Pre-operative Testing on Psychometric Tests.

Subjects for the pre-operative testing on the psychometric tests included the complete LTG, STG and 10 spouses for the control group. Table 1 describes the education and age for the three groups and the tumor size for the LTG and STG. The means, standard deviations and ranges of these characteristics are given.

Subjects for Preoperative Testing on the Continuous Performance Test.

Ten patients were tested on the CPT pre-operatively. These were the last ten patients of the same 26 assessed on

the psychometric measures as described above. The reason that all 26 patients were not included was that the CPT measure was added to the study after the study had begun in order to provide a more sensitive measure of attention. Mean tumor size for these patients was 2.4 cm (SD=1.3; range=1.0-5.0). Six of these ten subjects were small tumor patients while four of these ten subjects were large tumor patients. The mean age for this patient group was 42.9 (SD=16.5; Range=16-61). Their mean educational level was 13.7 (SD=3.1; Range=8-18).

Ten age and education matched control subjects were used as a control group on the CPT in order to provide the CPT patient group with an age and education matched control group. Since the CPT of this study is a novel measure and did not have pre-established norms, it was considered important to reduce the variability between groups by keeping age and education matched between subjects and controls. For this reason and in order to obtain enough control subjects, age and education matched subjects consisted of both five spouses as well as five other age and education matched normal control volunteers. The mean age for this group was 42.8 (SD=17.4; Range=16-62). The mean educational level for this group was 14.1 (SD=3.9; Range=7-21).

Subjects for Post-operative Testing on Psychometric

Tests.

The patients in the second testing group consisted of 18 subjects who returned for testing 5-7 months after surgery. One additional patient was dropped from the analysis of the psychometric data because of incomplete data. These 18 patients were further subdivided into two groups based on pre-operative tumor size. The LTG consisted of 12 patients and the STG consisted of 6 patients. Demographic characteristics of those subjects who returned for testing are also shown in Table 2. (Subjects who did not return lived a great distance from the hospital. It was not possible to contact one subject.)

A total of nine of the original ten control subjects (spouses) on the psychometric tests returned for testing. Seven out of the ten original controls were tested 5-7 months after the first testing. Two of the original ten control subjects were tested 11 months after the first testing.

Table 3 summarizes the number of patients and controls that were tested at the first and second testing sessions on the psychometric measures and the CPT.

Subjects for Post-operative Testing on the Continuous Performance Test.

The total number of patients tested post-operatively on the CPT was nineteen (see table 3). As stated above, ten

patients were tested on the CPT pre-operatively. These consisted of six small and four large tumor patients. Of these ten original patients, four large and three small tumor patients were retested. Therefore, eight large and four small tumor patients were added for the post-operative testing. The characteristics of the post-operative patient group for the CPT are described in table 4.

Nineteen age and education matched control subjects were used in order to provide the patient group with an age and education matched control group. The characteristics of the CPT control group are described in table 4.

Tests, Materials, and Equipment.

Tests.

Tests included the Wechsler Adult Intelligence Scale-Revised (WAIS-R), the Mini-Mental State Examination (Folstein, Folstein and McHugh, 1975), the Wepman Auditory Discrimination Test (Wepman, 1958), the sound blending subtest of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, and Kirk, 1968), the Memory and Learning Evaluation by Selective Reminding (Buschke, 1973), the Benton Visual Retention Test (Benton, 1974), Administration A (Benton memory) and Administration C (Benton copy) and the Controlled Word Association Test (Benton and Hamsher, 1977) as well as two measures of semantic fluency (Newcombe,

1964)

The dependent measures included the scaled scores for the WAIS-R subtests and the number of errors for the Mini-Mental State Examination subtests, the Wepman test of Auditory Discrimination, the sound blending subtest, Benton Memory and Benton Copy. Other dependent measures included the number of trials to criterion which is the number of trials required to recall all ten items from the list for the Selective Reminding Test and the number of words for the tests of verbal fluency.

The dependent measures from the Selective Reminding Test include consistent long-term retrieval, long-term storage and short-term retrieval which are measured in the following manner. First, those words that have been recalled from a particular trial to the final trial are considered words from consistent long-term retrieval. Those words that have been recalled two consecutive times --that have not required selective reminding during the recall trial-- have entered long-term storage. Those words that have not yet entered long-term storage are retrieved from short-term storage and therefore, reflect short-term retrieval. On each trial, the number of words from consistent long-term retrieval, long-term storage, and short-term retrieval are calculated (Buschke, 1973). Then, they are plotted on a graph of number of items by number of trials. In other words, the graph reflects the number of items that should be retrieved

from a given category --consistent long-term retrieval, long-term storage and short-term retrieval-- by the time a subject reaches a given trial. The dependent measure for LTS, CLTR and STR reflects the number of points across all trials that are greater than three standard deviations from the mean of the norms (Buschke, 1973).

In characterizing the constructs that were considered important to assess--attention, memory and perception--it can be noted that it may be possible to group the tests to reflect several constructs. If this is the case, then these tests may be grouped together in a pattern to signify a deficit reflecting a particular construct. If, in addition, a group of tests reflect more than one construct, then this may be ascertained by common intercorrelations of tests (Anastasi, 1968).

Many authors have associated certain tests with the measurement of certain functions. If this is indeed the case, then these tests should be significantly correlated with tests known to assess these functions (Anastasi, 1968).

Further, these tests may be associated with particular independent measures such as tumor size and the III-V IPL. This would then indicate whether a particular function is affected by damage to a particular structure. It can then be inferred that this structure is associated with this function, and especially since the structural damage may be occurring at the brain stem level, the brain stem may be

where the influence on this particular function begins.

Because of the possible association of particular cognitive functions with certain subtests of the WAIS-R, the WAIS-R was chosen for this battery. Russell (1972b) has shown that those tests loaded on particular factors continued to load on the same factors even though overall performance declined with cortical brain damage. A factor analysis showed that the weight of each factor did not change. The tests that constituted each factor remained the same (Russell, 1972b). It would be important to examine whether the same process of a decline in performance without a change in the relationships of the subtests occurs with subcortical damage. In order to get a measure of "g" or overall biological intelligence (Spearman, 1972), the entire WAIS-R was administered. In addition to providing a measure of "g" in order to determine if "g" is affected by subcortical tumors, there was another advantage to administering the entire WAIS-R. In addition, to examining overall "g", one may compare factors that comprise "g" (Thurstone, 1938). That is, components of "g" such as verbal and performance I.Q. may be compared with one another. Further, the effects on certain functions (attention, memory and perception) that have been associated with particular groups of subtests may also be ascertained.

Attention may be assessed by Arithmetic, Digit Span, and Digit Symbol of the WAIS-R which have been described as

the attention triad. These tests are all intercorrelated with one another (Wechsler, 1981). Attention may also be assessed by serial sevens from the Mini-Mental State Examination (Folstein, Folstein, and McHugh, 1975) as well as by the CPT.

Certain tests have been associated with memory as well as attention. Immediate memory has also been purported to be tapped by those tests comprising the attention triad. Russell (1972b) found that memory was a factor in certain WAIS-R subtests. The memory factor was loaded with Arithmetic, Digit Span, and to a lesser extent, with Digit Symbol. The modalities used for these tests also differed so that it might be expected that Arithmetic and Digit Span would have in common more correlations with other tests as compared to Digit Symbol.

Memory may also be assessed by other subtests of the WAIS-R as well as by neuropsychological tests. Memory may be tapped by Information and Vocabulary of the WAIS-R and by verbal fluency. Memory may be approached in two ways from the standpoint of modality specificity: auditory and visual.

Visual memory may be assessed by Benton Memory and the CPT.

Auditory memory may be tapped by Information, Vocabulary, verbal fluency, the Selective Reminding Test, and the three word memory test from the Mini-Mental State Examination.

The Benton Test of Visual Retention (Benton, 1974) was administered by using two forms as well as two standard

administrations. Benton memory consists of a ten second exposure of the stimuli followed by immediate reproduction of the stimuli. This is Administration A and Form D is used. Benton copy allows the stimuli to be viewed while it is being copied by the subject. This is Administration C and Form C is used.

The Mini-Mental State Examination assesses several functions including attention, concentration and memory. The subject was given the standard administration of the test. Items that were analyzed include serial sevens, a measure of concentration, in which the subject is required to subtract "7" from "100" and then to subtract "7" from that response and so forth. The three word memory test requires that the subject recall three words. After some intervening tasks that the subject performs as part of the Mini-Mental State Examination, the subject is again required to recall the three words. Presumably, the words have been consolidated in memory by this time and thus, this is a good measure of consolidation and LTM.

Memory may also be approached by examining its three processes: encoding, consolidation, and retrieval. These processes may be measured by using the Selective Reminding Test. The trials-to-criterion measure was used as a measure of memory consolidation. The long-term and short-term stages of memory may also be tapped by the Selective Reminding Test. Separate components of memory including

long-term storage, short-term retrieval, and consistent long-term retrieval are also purported to be assessed by the Selective Reminding Test. The operational definition of long-term storage is the number of items which have been recalled two consecutive times. The recall of an item on two consecutive trials does not necessarily indicate that the item is in long-term storage. It may instead indicate that the item is in the process of being consolidated in memory, but is still being retrieved from a short-term store. By definition, items that have not yet entered long-term storage are retrieved from short-term storage. Items in consistent long-term retrieval are defined as those items that are consistently recalled from any given trial to the last trial. Rather than designating these items as items from consistent long-term retrieval, these may be items that have been consolidated in memory.

Perceptual processes may be assessed by examining both visual and auditory perception. Visual perception may be assessed by Benton copy, Benton memory, and the CPT. Auditory perception may be assessed by the Wepman Test of Auditory Discrimination (Wepman, 1958) and the sound blending subtest of the Illinois Test of Psycholinguistic Abilities.

The Wepman Test of Auditory Discrimination (Wepman, 1958) consists of 40 word pairs which are either identical or different. Those word pairs that are not identical

differ because of different phonemes: either vowels or different consonants such as stop consonants, nasals, or fricatives occurring either at the beginning or the end of the word. The subject is required to identify whether the word pairs are the same or different. The test is scored for overall errors as well as for error type as described above: vowel errors, stop consonants, nasals, fricatives at the beginning or at the end of the word. Norms show that greater than three errors indicates inadequate development of auditory discrimination.

The sound blending subtest of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, and Kirk, 1968) consists of 32 words, some of which are real words while others are nonsense words. The examiner enunciates the phonemes of each word at the rate of one phoneme per one-half second. The subject then is required to blend the sounds to form a word. The test is scored for number of errors.

Apparatus for the Continuous Performance Test (CPT).

This test was used as a measure of (tonic and phasic) alertness. The dependent measures were reaction time, variance to the reaction time measure, errors of omission and errors of commission. Errors of omission occur when the subject does not respond to a target letter while errors of commission occur when the subject responds to a non-target

letter. The letters that were used included the following: A,B,C,E,F,L,M,N,P and the target letter "X". These are the same letters which are used on the standard CPT originally devised by Rosvold and Mirsky (1956). A standard cathode ray tube (CRT) was used to present the letters. The CRT was a Televideo terminal. The program was run on a Northstar (Z80 based) computer. Presentation time was 2.44 seconds. The interstimulus interval was zero. The CPT consisted of 800 stimuli; of these, 180 stimuli (22.5%) were target stimuli. The test was divided into ten time epochs of 80 stimuli per epoch. In each time epoch, there were eighteen target stimuli and 62 non-target stimuli.

Electrophysiological Apparatus and Procedure.

The III-V interpeak latency (IPL) was used as a dependent measure because it was found to be sensitive to brain stem compression and was also associated with the rostral pontine-midbrain area, which has been linked to alertness and attentional processes.

The procedure for all subjects included preparing the skin with acetone and Omni Prep at location Cz, forehead and each earlobe. Gold electrodes were then secured with Grass paste at these sites. All impedances were below 3000 ohms as determined by a Grass impedance meter (Grass Instrument Co., Quincy, Massachusetts). The patient then was directed into an electrically shielded room and instructed to lay in

a supine position on the bed. Electrodes then were connected to a Grass P-5 pre-amplifier which in turn was connected to a Nicolet 501A amplifier (Nicolet Instrument Corp., Madison, Wisconsin). The analog amplified signal was digitized by a Nicolet Med-80 computer system.

Patients were then fitted with Nicolet headphones. A 100 usec click was presented to one ear at 10.1 Hz while the other ear was presented with 50 dBHL (hearing level) of white noise to ensure no cross-talk. Thresholds were obtained by asking the subject when s/he did or did not hear the click as the intensity was changed using an ascending and descending order of presentation. The threshold was then noted and the subject received a click at 60 dB above their threshold. Both ears were tested if hearing was present.

Ten msec artifact free epochs were averaged 3000 times using a Nicolet Med-80 while clicks were presented to the unaffected ear. Filter settings for the amplifier were from 150 Hz to 3KHz.

Procedure

Patient Group.

Patients were evaluated shortly after entering the hospital prior to surgery. All patients gave informed consent. Patients were tested during a three hour testing session. There were ten minute breaks after every fifty

minutes of testing. Demographic characteristics first were acquired and rapport was established between the examiner and the subject. All patients then were administered the psychometric tests in the following order: WAIS-R, Mini-Mental State Examination, Wepman Test of Auditory Discrimination, Illinois test of Psycholinguistic Abilities: sound blending subtest, the Selective Reminding test and the Visual Retention Test (Benton memory and Benton copy). The verbal fluency test was added to the protocol after the study had begun, and thus was administered to the last 14 subjects. Standardized instructions were used for all tests. Verbal fluency was assessed with the Controlled Word Association Test and two measures of semantic fluency.

The CPT was then administered. Since no standard instructions were available, the following was read to the subject prior to beginning the test:

"In the center of the screen, you will see a random series of letters appear, one at a time. Whenever you see the letter "X", press the red button as quickly as you can. Don't press it for other letters - only for "X". If you miss an "X" or press the button accidentally for another letter, keep going - don't stop. I will tell you when the test is over. Do you understand? Remember, every time an "X" appears on the screen, press the red button as quickly as you can."

The subject had to respond by pressing the response button during the 2.44 seconds that the target letter was displayed. If not, an error of omission was recorded. The subject was told not to respond when a letter other than the

target was displayed. If the subject did respond, an error of commission was recorded.

The BAER was administered after the psychometric battery; either later that day or within the next day or two. The exact procedure was repeated approximately 5 to 7 months post-operatively.

Control Group

The control group was tested at a first testing session. All controls gave informed consent. The following tests were administered to the control group in the following order: WAIS-R subtests: Information, Digit Span, Vocabulary, Arithmetic, Comprehension, Similarities and Digit Symbol. Other performance subtests were not used in order to keep the battery to a reasonable length of time for testing volunteer control subjects. The Mini Mental State serial sevens and three word memory test were administered. The Selective Reminding Test was then administered followed by the Visual Retention Test (memory and copy), verbal fluency and the CPT. The same procedure was repeated approximately five to seven months later.

Data Analysis

The correlation between patient's tumor size and psychometric tests was calculated using Pearson product-moment correlations. The Pearson was used instead

of the Spearman because the dependent measures in this study are interval data. Pearson product-moment correlations were also calculated between the patient's tumor size and CPT measures of reaction time, overall standard deviation of reaction time, errors of commission, and errors of omission.

The correlations both between the III-V IPL and psychometric tests and between the III-V IPL and CPT measures were calculated using Pearson product-moment correlations. This was again the statistic of choice because the dependent measures were interval data. Pearson product-moment correlations were also calculated between psychometric tests and the CPT measures of reaction time, errors of commission, and errors of omission. In order to determine which tests clustered together and thereby, reflected a common function, Pearson product-moment correlations were also calculated among all of the psychometric tests. This was done for the patient group at the pre-operative and post-operative testing sessions and for the control group at the first testing session.

It was determined that orthogonal comparisons between groups were appropriate. The justification was the following: (1) the groups were not randomly selected but were predetermined and (2) specific group differences as well as the direction of these differences were formulated a priori. Since there should be no compression in patients with small tumors, it had been predicted that there would be

no significant differences between the small tumor group and the control group on tests of attention and memory.

However, it was predicted that the large tumor group should perform significantly worse than the control group. Because the ANOVA would omit the a priori determination of directionality of effects, the t-test was considered a better statistic to use for the purposes of these comparisons. Kirk (1968) recommends using a t ratio for planned orthogonal comparisons (p 73).

Further, an ANOVA is only used to determine if there are any differences at all. Post hoc comparisons are then used to determine which groups are accounting for a significant ANOVA. An ANOVA should not be used when predictions of group differences have already been made (Kirk, 1968 p 73). Since differences were already predicted, the ANOVA would not be appropriate and a t-test should be used. In addition, on the basis of the correlations, it had been predicted that the performance of the large tumor group would be significantly worse than the performance of the small tumor group. However, in order to be conservative in the analysis, a 2 tailed t-test was used.

By using a 2 tailed t-test, one decreases power and loses directionality. However, one gains a stricter criterion for significance. Directionality and power were considered important to retain for the comparisons between the large tumor group and the control group because it had been

predicted that the large tumor group's performance should be significantly worse than that of the control group. In the case of the comparison between the small tumor group and the control group, it was believed that using a one-tailed t-test to compare the small tumor group and the controls would work against the prediction of no differences between the two groups. That is, if there were indeed differences, this would be more likely to be detected by a one-tailed t-test. In this case, this was deemed "more conservative" because it would be important to detect any differences between the small tumor group and the control group which would indicate impairment in the small tumor group.

Differences between first and second testing for each group were considered important to examine. These particular comparisons would indicate what improvement could be attributed to the effects of the removal of the tumor rather than to practice effects. For example, a comparison could be made between performance on those tests that showed improvement in the control group which might be attributed to practice effects and performance on those tests which showed improvement in the patient group but not in the control group which might then be attributed to the effects of tumor removal. In order to do this, correlated t-tests were used (Hays, 1963, pp.334). The advantage of this statistic is that each subject could serve as his/her own control and in this way, inter-subject variability could

be reduced and sampling error could be lowered (Hays, 1963, pp.334). Thus, the issue of the difference between performance as a function of time of testing could be examined. Because of the necessity for data at both testing times, the procedure could use only those subjects who had completed both testing sessions.

When groups were contrasted on such measures as the CPT (for reaction time as well as errors of omission and commission) where the N was small, Mann-Whitney U's were used. It was determined that the Mann-Whitney U as a non-parametric measure might be more sensitive to group differences (Lezak and Gray, 1984). Non-parametric techniques sometimes provide the statistical means for identifying group differences that parametric techniques because they require a larger N and are sensitive to variance may fail to detect (Lezak and Gray, 1984). For example, the Mann-Whitney U is able to control for outliers because it employs the ranks of observations. The Mann-Whitney U was used as opposed to the t-test because the samples are small and there is a possibility that the form of the population distribution is not normal (Guilford and Fruchter, 1978). Because of the unequal N's, the Mann-Whitney U was chosen as the nonparametric statistic. Further, it is recommended as a good and relatively powerful alternative to the t-test (Hays, 1963, pp.633).

In order to determine how the change from pre-operative

to post-operative testing correlated with pre-operative size of tumor and both the pre-operative and post-operative III-V IPL, difference scores were derived by subtracting the post-operative from the pre-operative score. The mean was substituted for any missing data points for any variable. Spearman rank order correlations were then used since the difference scores had a limited range.

Results

One tailed t-tests revealed no significant differences between the large tumor and control groups in age ($t=1.33$, $df=23$) or education ($t=1.12$, $df=23$). In addition, there was no significant difference between the small and large tumor patients in age ($t=-0.75$, $df=24$) or education ($t=-1.16$, $df=24$). The above tests were done for subjects for pre-operative testing on psychometric tests. For pre-operative testing for subjects on the continuous performance test, t-tests showed that there were no significant differences between the patient and control group in age ($t=0.16$, $df=9$) or education ($t=0$, $df=9$).

Pre-operative Measures.

Correlations for Psychometric Measures.

Pearson correlations were performed between tumor size and psychometric tests on pre-operative testing. Table 5 lists all of the psychometric tests with their respective correlations with tumor size, the number of subjects, and the p values. There was a significant correlation between tumor size and the following tests: Verbal I.Q., Forward Digit Span, Digit Span, Vocabulary, Arithmetic, Benton memory and the Selective Reminding Test. Tests that did not show a significant correlation with size of tumor included Benton copy, Backward Digit Span and tests of verbal fluency. The number of subjects ranged from 22 to 26

because four subjects wanted to terminate the session before completion. The number of subjects for verbal fluency is between 10 and 14 because this test was added after the study had begun.

There was a significant correlation between size of tumor and the III-V IPL ($r=.588$, $n=18$, $p<.01$). Pearson correlations were performed between the III-V IPL and psychometric measures on pre-operative testing. Table 6 indicates that there was a significant correlation of the III-V IPL with vowel errors from the Wepman Test of Auditory Discrimination, Verbal I.Q., Performance I.Q., Full Scale I.Q., Backward Digit Span, Digit Symbol, Benton memory and a marginally significant correlation for Digit Span and Vocabulary. The remaining psychometric tests were not significantly correlated with the III-V IPL. The maximum number of subjects were 20 and not 26 because only 20 subjects were tested on the BAER. Again, the reason that there was a range of subjects from 12-20 was that verbal fluency was added later.

Correlations with the Continuous Performance Test

There was a significant correlation between the Continuous Performance Test (CPT) and tumor size on pre-operative testing. In the pre-operative testing session, overall latency of response (mean reaction time) was significantly correlated with tumor size as described in

table 7. However, since the function of tumor size with mean reaction time did not appear linear on inspection of the scatterplot, logarithmic transformations of the data were made and a significant correlation was still obtained ($r=.80$, $n=10$, $p<.01$). Errors of commission and errors of omission were not significantly correlated with size of tumor. The mean number of errors of omission and commission was very low for the tumor group. Only three subjects made errors of omission and seven subjects made errors of commission, but the range of errors was very restricted (0-4) except in the case of one subject (19). The III-V IPL was not significantly correlated with any CPT measures (see table 8).

T-tests on Psychometric Measures

Table 9 shows the means of the psychometric tests for each of the patient groups and the control group. One tailed t-tests significantly differentiated the large tumor group from the control group on Arithmetic and the Selective Reminding Test. There were no significant differences between these two groups on any other psychometric measures.

Table 10 shows that there was no significant differences between the small tumor group and the control group on any measures. Two tailed t-tests, used as a more conservative measure, were calculated between the large tumor and the small tumor groups. Significant differences were found

between these groups on the following tests: Digit Span, Forward Digit Span, Arithmetic, Vocabulary, Verbal I.Q., and the Selective Reminding Test (see table 11).

T-tests on the Continuous Performance Test

One tailed t-tests revealed no significant difference between the large tumor patients and their matched control subjects on mean reaction time, errors of omission, and errors of commission (see table 12). There was also no significant difference between the small tumor patients and their matched controls or between the large and small tumor patients on the same above measures. Table 13 shows that there were no significant differences between the entire patient group and control group on mean reaction time, errors of omission, errors of commission and the overall standard deviation of reaction time. Since the number of subjects in both the large and small tumor groups was small (six were small tumor patients and four were large tumor patients) and since the distribution was not normal, Mann-Whitney U's were calculated. There was no significant difference between the large tumor patients and controls on the CPT mean reaction time measure ($u=5$, 2 tail $p=.387$) nor between small tumor patients and controls ($U=17$, 2 tail $p=.873$) and the large and small tumor patients ($U=5$, 2 tail $p=.136$).

Pre-operative correlations of CPT measures with Psychometric Tests.

In order to assess the relationship of the CPT to the cognitive measures of both memory and attention, Pearson product-moment correlations were calculated between the CPT measures of mean reaction time with the various psychometric measures. As noted above, the N of subjects with errors of omission (N=3) or commission (N=7) was small and therefore, correlations were not done between these measures and psychometric tests.

Mean reaction time of the CPT was significantly correlated with Arithmetic ($r=0.56$, $p<.05$) and Benton memory ($r=0.56$, $p<.05$). The logarithmic transformed measure for mean reaction time was also significantly correlated with Arithmetic ($r=-0.56$, $p<.05$) and Benton Memory ($r=0.59$, $p<.05$). However, it must be noted that the N of subjects on pre-operative testing for the CPT was only ten.

Post-operative Measures

Correlations of Psychometric Measures

Eighteen subjects were included in the post-operative analysis. There was no significant correlation between pre-operative size of tumor and post-operative performance on psychometric measures. Pre-operative tumor size and the post-operative III-V IPL measure were significantly correlated ($r=.559$, $n=14$, $p<.05$).

Pearson correlations were performed between the III-V IPL and psychometric measures for patients on post-operative testing. Backward Digit Span correlated significantly with the III-V IPL ($r = -.447$, $n = 14$, $p < .05$). However, no significant correlations were observed between other tests and the III-V IPL.

Correlations with the Continuous Performance Test

In the post-operative testing session on the CPT, there were no significant correlations between tumor size and mean reaction time. The only time epochs that showed a significant correlation with tumor size were epochs one ($r = .431$, $n = 19$, $p < .05$) and two ($r = .461$, $n = 19$, $p < .05$). Again, there was no significant correlation between the III-V IPL and any CPT measures post-operatively.

T-tests on Psychometric Measures

T-tests were calculated between the large tumor and control group, small tumor and control group, and large and small tumor groups and there were no significant differences between the groups on any measures.

T-tests on the Continuous Performance Test.

The results of correlated t-tests between the entire patient group and the control group are the following. There was a significant difference between the groups on the

mean reaction time measure ($t=2.08$, $df=18$, $p<.05$) and on errors of omission ($t=2.73$, $df=18$, $p<.05$). The patient group's performance was significantly worse than the control groups's performance. The large tumor group was compared to controls and there was a significant difference in the overall mean reaction time ($t=5.00$, $df=11$, $p<.001$) and errors of omission ($t=2.35$, $df=11$, $p<.05$). There was no significant difference in errors of commission.

The small tumor group was compared to controls and there was no significant difference in the overall mean reaction time, errors of omission, or errors of commission. There was no significant difference between the large tumor group and the small tumor group on these measures.

Pre-Post Operative Measures

T-tests and Mann Whitney U's on Psychometric Measures

Correlated t-tests were performed to compare the entire patient groups pre-operative and post-operative scores. The increase in mean level of performance was significant for the following tests on the one-tailed level: Verbal I.Q., Digit Span, Arithmetic, Digit Symbol, and the Selective Reminding Test, Performance I.Q. and Full Scale I.Q. (see table 14). There was no decrease in performance on any psychometric test. Tests in which there was no difference from pre- to post-operative testing included Benton Copy, Benton Memory, Information, Vocabulary, Comprehension and

Similarities.

Correlated t-tests were also calculated between the large tumor patients' pre- and post-operative performance. Table 15 shows that there was significant increase in performance on the following tests: Verbal I.Q., Forward Digit Span, Digit Span, Performance I.Q., Digit Symbol, Full Scale I.Q. and the Selective Reminding Test.

Correlated t-tests were also calculated between pre- and post-operative performance on tests for the small tumor patients. The only test that showed a significant improvement was Full Scale I.Q. ($t=2.70$, $df=5$, $p<.05$). Since the N was small, Mann Whitney U's were also performed between pre- versus post-operative performance on Full Scale I.Q. There was no significant difference on the Mann-Whitney U ($U=11.5$, n.s.).

Correlated t-tests were calculated for controls first versus second testing performance on psychometric tests. There was no significant difference on any of the tests for first versus second testing performance except Vocabulary ($t=2.29$, $df=8$, $p<.05$) and Verbal I.Q. ($t=1.85$, $df=8$, $p<.05$).

Pre-Post III-V Interval Measures

Mean interpeak latency was not significantly different from pre-operative to post-operative testing for the tumor group ($X_1=2.187$, $S.D.=.63$, $X_2=2.076$, $S.D.=.195$, $T=.85$, $DF=13$). Mean interpeak latency also did not significantly

differ from pre- to post-operative testing for the large tumor group alone ($X_1=2.266$, S.D.=.734, $X_2=2.118$, S.D.=.200, $T=.803$, $df=9$).

Difference scores were derived by subtracting the pre-operative performance of each measure from the post-operative measure. If there was missing data, the mean was substituted for the missing data. This occurred in only one case for Benton Copy, four cases for the pre-operative interpeak latency measures and five cases for the post-operative interpeak latency measure. The change in interpeak latency correlated significantly (Spearman rank-order) with the change in the following test scores: vowel errors from the Wepman Test of Auditory Discrimination ($r=.394$, $n=18$, $p<.05$), Performance I.Q. ($r=-.529$, $n=18$, $p<.01$), Full Scale I.Q. ($r=-.434$, $n=18$, $p<.05$), Forward Digit Span ($r=-.424$, $n=18$, $p<.05$), Digit Span ($r=-.440$, $n=18$, $p<.05$), Digit Symbol ($r=-.454$, $n=18$, $p<.05$), and Benton Memory ($r=.508$, $n=18$, $p<.05$). Although size of tumor was significantly correlated with change in peak latency ($r=.500$, $n=18$, $p<.05$), the only test that correlated significantly with size of tumor was Forward Digit Span ($r=.441$, $n=18$, $p<.05$). This was a positive correlation which means that an increase in performance on Forward Digit Span was associated with larger tumors.

Post-operative correlation of CPT with Psychometric Tests.

Mean reaction time of the CPT was significantly correlated with Forward Digit Span ($r = -.464$, $p < .05$), Benton Memory ($r = .413$, $p < .05$), and Digit Symbol ($r = -.414$, $p < .05$).

Pre-operative and post-operative correlations among Psychometric Tests.

The attention triad has been described as being comprised of Arithmetic, Digit Symbol and Digit Span. For the patient group on pre-operative testing, Digit Span was correlated significantly with Forward and Backward Digit Span, Arithmetic, Benton memory, and the Selective Reminding Test. Significant correlations were observed between Arithmetic and all of the above tests with the exception of Backward Digit Span. In addition to its significant correlations with the above tests, Arithmetic was significantly correlated with Digit Symbol. Digit Symbol was significantly correlated with Arithmetic and Benton memory.

On post-operative testing, Digit Span was correlated significantly with all of the same tests with which it had been correlated pre-operatively: Forward and Backward Digit Span, Arithmetic and Benton memory. Arithmetic was still correlated with the same tests with the exception of Forward Digit Span and Digit Symbol. An additional significant correlation was observed on post-operative testing between Arithmetic and Backward Digit Span. On post-operative

testing, Digit Symbol was correlated significantly with Benton memory.

Memory may be assessed by the Selective Reminding Test and Benton memory. On pre-operative testing, Benton memory and the Selective Reminding Test are significantly correlated with one another. They also have the following significant correlations in common: Digit Span, Backward Digit Span, and Arithmetic. In addition to the significant correlations with the above tests, Benton memory was significantly correlated with Digit Symbol. The Selective Reminding Test was significantly correlated with Forward Digit Span. On post-operative testing the Selective Reminding Test was significantly correlated with Arithmetic. Benton memory was correlated significantly with Digit Span, Backward Digit Span, Arithmetic and Digit Symbol.

Discussion

This thesis examined the effects of brain stem compression from posterior fossa tumors on memory, attention and auditory-perceptual functions in man. Three hypotheses were tested: (1) posterior fossa tumors impair auditory-perceptual processing within the linguistic domain and consequently the encoding of information; (2) posterior fossa tumors selectively affect the memory process; and (3) these tumors interfere with both attention and memory processes.

Twenty-six patients with posterior fossa tumors and 10 age-matched controls were evaluated using a battery of psychometric and neuropsychological tests that was designed to assess various aspects of auditory-perceptual functioning, attention, memory and overall cognitive ability. The patient group was subdivided into those with large tumors and those with small ones. Subsequently, 18 of the patients were reevaluated five to seven months after the surgical removal of the tumor, and nine of the controls were retested after approximately six months. The data were analyzed so that test performances were compared both across the three groups and for changes within each group.

The findings from the initial testing showed no differences in performance between the small tumor and the controls. The large tumor group, however, performed

significantly poorer than the control group on the Arithmetic subtest of the WAIS-R and the Selective Reminding Test and significantly worse than the small tumor group on the Digit Span, Forward Digit Span, Arithmetic, and Vocabulary subtests of the WAIS-R, as well as on Verbal I.Q., Full Scale I.Q., and the Selective Reminding Test.

Following the surgical removal of the tumor, the small tumor group improved significantly only on Full Scale I.Q. The large tumor group, however, improved on Digit Span, Forward Digit Span, Digit Symbol, Verbal I.Q., Performance I.Q., Full Scale I.Q. and the Selective Reminding Test. For the control group, performance on Verbal I.Q. and Vocabulary improved on retesting. No psychometric tests significantly differentiated the groups on post-operative testing.

The relationship between tumor size, as assessed by CAT scan and size at operation, and performance on each psychometric measure was evaluated using Pearson product-moment correlation coefficients. Significant correlations were obtained between tumor size and pre-operative scores on Verbal I.Q., Digit Span, Forward Digit Span, Vocabulary, Arithmetic, Benton Memory, and the Selective Reminding Test. No tests were significantly correlated with pre-surgical tumor size on post-operative testing.

Pre-Operative Group Differences

No psychometric or neuropsychological tests significantly differentiated the small tumor group from the control group, and only two tests differentiated the large tumor group from the controls: the Arithmetic subtest of the WAIS-R and the Selective Reminding Test, both of which are believed to assess auditory memory and attention. Although one may hypothesize that large tumor patients have deficits in these functions, such deficits did not appear on other tests that measure short-term auditory memory and/or attention such as Digit Span, the three word memory test and serial sevens of the Mini-Mental State Examination.

The apparent inconsistencies may result from subtle differences between the tests. Whereas Arithmetic and the Selective Reminding Test primarily involve words, Digit Span involves numbers and there is data to suggest that number span may be easier to recall (Newcombe, 1969). Similarly, unlike Arithmetic and the Selective Reminding Test, serial sevens involves simple calculations requiring little memory. Likewise, the three word memory test places only minimal demand with regard to span and memory load. Therefore, it appears that certain tests may be less sensitive than others to the cognitive deficits.

Pure concentration and memory consolidation did not appear to be affected by brain stem compression from large tumors as reflected by the lack of differences between the large tumor group and controls in performance on the serial

sevens and three word memory test of the Mini Mental-State Examination. For the large tumor group, the findings show some evidence of a deficit in tasks requiring an interaction between attention and memory. There is no evidence, however, of a deficit in tasks specific to attention or memory alone. Cognitive deficits also did not appear on Benton Memory which is a visual memory test. No deficits specific to auditory-language functioning were found for the patient group.

Surprisingly, the large and small tumor patients were found to differ significantly on several --not just two-- of the pre-operative measures. As with the large tumor and control subjects, the differences between the two tumor groups seemed to center primarily on attention and memory as evidenced by their performance on the Arithmetic subtest and the Selective Reminding Test. The tumor groups also differed on Digit Span and specifically on Forward Digit Span, a task of attention and immediate memory. They did not differ, however, in visual memory or in their performance on serial sevens and the three word memory test of the Mini Mental-State Examination, as was the case with the large tumor and control groups.

One unexpected finding was that the small tumor group also scored significantly higher than the large tumor group on the Vocabulary subtest of the WAIS-R. This finding is difficult to explain and is not consistent with the findings

of other verbal tests (i.e., Similarities, Information and Verbal Fluency), which did not significantly differentiate groups. Therefore, it is unlikely that these patients experience a real language deficit.

The differences between the two groups in their performance on Verbal I.Q. and Full Scale I.Q. are probably not attributable to differences in overall cognitive functioning. Rather, they may be reflective of the differences in performance on the Arithmetic, Vocabulary and Digit Span subtests, all of which make up these I.Q. measures.

It is curious that fewer tests significantly differentiated the large tumor from the control group than from the small tumor group. This unexpected finding may be explained by the fact that the control subjects were the oldest of the three groups (although not significantly), since it is well known that one's ability to sustain attention and memory generally decreases with age (Williams, 1970b).

Group differences in errors of omission and commission were not found on the Continuous Performance Test pre-operatively, which one would expect to find if the patients had true attentional deficits. However, it is possible that this was due to a floor effect: the task may have been too easy. Errors on the CPT occurred at a very low frequency in all three groups. There were also no

significant differences in reaction time.

Pre- and Post-operative Comparisons

Subsequent to pre-operative testing, all groups were reassessed on the psychometric and neuropsychological measures. The control group showed significant improvement on Verbal I.Q. and Vocabulary --an improvement most likely attributable to practice effects. The fact that the performance of the control group on other measures did not differ from pre- to post-operative testing suggests that other improvements that occur in the patient groups are consistent with the hypothesis of recovery of function and not reflective of practice effects.

Similarly, the small tumor patients who showed no deficits on pre-operative testing relative to the controls demonstrated significant improvement only on Full Scale I.Q. Performance on the tests of specific neuropsychological functioning, however, remained unchanged. Small but significant practice effects have been found in an evaluation of the performance of a similar age group on Full Scale I.Q. (Wechsler, 1981).

Of all the groups, only the large tumor group showed several changes from pre- to post-operative testing. These patients improved post-operatively on Forward Digit Span, Digit Span, Digit Symbol, Selective Reminding Test, as well as on Verbal, Performance and Full Scale I.Q. Five of these

seven measures were among those tests on which the large tumor patients showed significant impairment pre-operatively relative to either one or both of the other groups. In addition, of the seven measures on which the large tumor group showed pre-operative impairment (i.e. Forward Digit Span, Digit Span, Arithmetic, Vocabulary, Verbal I.Q., Full Scale I.Q. and the Selective Reminding Test), five showed post-operative improvement. Thus, the areas of post-operative improvement appear to be relatively specific to the areas of impairment.

The two tests on which the large tumor group showed significant impairment pre-operatively and no subsequent improvement were Arithmetic and Vocabulary. Although there were fewer subjects on second testing, there was no significant difference in educational level for large tumor subjects from first to second testing. Therefore, the lack of improvement on the Arithmetic and Vocabulary subtests could not be attributed to a lower level of education on second testing.

The lack of improvement on the Vocabulary subtest is not surprising since performance on this subtest is known to be relatively resistant to brain damage in the absence of aphasia (Gonen and Brown, 1968). Furthermore, the poorer pre-operative performance on this subtest may well be statistically artifactual and not reflective of linguistic processing deficits because of the relatively normal

performance on all other tests of linguistic ability.

The lack of the large tumor group's improvement on the Arithmetic subtest may be explained by the fact that this task requires maximal concentration: it requires the manipulation of numbers in short-term working memory simultaneous to the performance of arithmetic operations on these numbers. Possibly, when the system is pressed, the improvement appears not to be complete.

Performance on Digit Symbol, which improved post-operatively, was not significantly impaired pre-operatively for the large tumor group relative to the other groups. Increased attention could lead to increased learning on Digit Symbol which would then result in improved performance. Moreover, this was also characterized by the improvement in the Selective Reminding Test. Although Performance I.Q. did not show an impairment and mean Performance I.Q. did increase on post-operative testing, this is probably not reflective of improvement in a specific cognitive ability. Rather, Performance I.Q. is affected by the higher performance on the Digit Symbol subtest.

In summary, following the removal of the tumor, patients with large tumors appear to improve in most measures of attention and memory with the exception of the Arithmetic subtest. Furthermore, the improvements are relatively specific to the tests on which the large tumor group demonstrated pre-operative impairment. The tasks for

which performance improved are those that require immediate retrieval of a span of information. Interestingly, these patients reported that they observed along with other symptoms of the tumor, a mild memory loss, which appeared, for example, when they would try to recall a telephone number. Like Forward Digit Span, this task requires apprehension of a span of information.

Post-operative Group Differences

The large tumor group, which clearly was impaired prior to the removal of the tumor, showed such improvement in post-operative testing that there were no longer any significant differences between the groups on any psychometric or neuropsychological measure. This indicates that the mechanism that was affecting pre-operative performance decrements for the large tumor group is no longer operative.

Brain Stem Compression

Most likely, it was the compression of the brain stem --not tissue damage-- that led to the cognitive deficits. Had the deficits been caused by tissue damage, the impairments would have been permanent.

Further corroborative evidence for the effects of brain stem compression on attention and memory functions were the significant correlations between tumor size and the various

test measures. Moreover, the significant correlations between the III-V IPL, a measure indicating brain stem compression (Zappulla et al., 1982), and various psychometric measures also provides evidence for the role of brain stem compression in attention and memory functions. Along with the I.Q. measures of general cognitive ability, these measures included Backward Digit Span, Digit Symbol and Benton Memory.

Overall, the data indicate that patients with large posterior fossa tumors show deficits in attention and memory relative to a control group. These patients improve following the removal of these tumors. Further, there are no significant differences between the groups on second testing.

Review of Hypotheses

Of the three hypotheses that were tested in this study, the first hypothesis was not supported --that tumor patients have deficits in auditory-perceptual processing in the linguistic domain and therefore an impairment in encoding in memory. It appears that auditory-perceptual processing is not affected as evidenced by the fact that performance on the Weepman Test of Auditory Discrimination and the sound blending subtest of the Illinois Test of Psycholinguistic Abilities was within normal limits. There were no differences between the large and small tumor groups on

these measures, and both groups performed within the normal range on norms provided for these tests.

The manner in which the tests are given -both the memory tests and the Wepman Test of Auditory Discrimination- are face valid to the mode of presentation. That is, at the level of the whole word, the information that is presented auditorily is not distorted enough to affect encoding in memory. But, it is clear that there are perceptual processing problems. The following is evidence of this. Yet, these perceptual problems are not related to the task demands of the tests that were employed.

However, other tests within the Central Auditory Test Battery may be more sensitive to brain stem dysfunction than the Wepman Test of Auditory Discrimination and the sound blending subtest of the Illinois Test of Psycholinguistic Abilities. The rapid alternating speech reception (RASP) and the binaural fusion test have been shown to be sensitive to brain stem lesions. The staggered spondaic word test (SSW) has also been found to predict brain stem lesions (Jerger and Jerger, 1976; Katz and Pack, 1975; Katz, 1975). Auditory discrimination abilities have ranged from fair to normal in several cases of patients with acoustic neuromas (Hendershot et al., 1981; Musiak, 1982).

With regard to the second two hypotheses, the data is far less clear. The second hypothesis --that memory alone is affected-- could not adequately be tested. Although it

appears that those measures that were significantly impaired were measures of memory, it is difficult to separate the attentional from the memory components necessary for performing these tasks. It is clear, however, that tests related to both attention and memory processes are affected.

Therefore, the third hypothesis --that both attention and memory are affected by brain stem compression from large posterior fossa tumors-- is most clearly supported.

Although the pure attentional task, the CPT, did not show an impairment, this may be explained by the fact that the task was too easy, and that there was a floor effect. Moreover, the high correlation between the CPT measure of reaction time and tumor size suggests that the ability to sustain attention may be a function of the size of the tumor and therefore, of compression.

More clearly substantiated is the effect of compression on tests that tap both attention and memory within the auditory modality, such as Digit Span and the Selective Reminding Test. Further, it is those tasks in which a span of information is presented auditorally or sequentially over time rather than spatially that showed an impairment --Digit Span and the Selective Reminding Test. In contrast, tasks in which information is presented visually and spatially, such as Benton Memory, did not show an impairment.

Performance on pure attentional measures --Digit Symbol, the CPT, and the serial sevens measure of the

Mini-Mental State Examination-- was not impaired. Rather, measures of short-term working memory that require attention in order for the subject to hold the information in short-term working memory, such as Arithmetic, were affected. Memory tests that do not place as much of a demand on attention, such as the Mini Mental-State three word memory test and Benton Memory, did not show an impairment, possibly because the span of information is not as great.

One question that arises from the results is the reason for the discrepancy between the impairment observed in the LTG vs. the STG and control Ss on the number of trials to criterion and the lack of impairment on the other measures of the Selective Reminding Test such as consistent long-term retrieval, short-term retrieval and long-term storage. This might have occurred because the trials to criterion measure is more sensitive to fluctuations in conscious effort which disrupt retrieval processes. In addition to memory, this measure reflects concentration and attentional factors. The other measures --especially long-term storage and consistent long-term retrieval reflect encoding and consolidation processes. Although short-term retrieval was also unimpaired, it does not reflect retrieval of the entire span of information and therefore, it may not require as much conscious effort.

In summary, tasks requiring vigilance and sustained

attention were not affected while tasks requiring the maintenance of information in active rehearsal were. Performance on tasks that require long-term retrieval, such as verbal fluency, the Information subtest of the WAIS-R and the three word memory test, also was not impaired. It, therefore, appears that brain stem compression affects those tasks requiring attention for rehearsal and short-term working memory.

Although the tests administered in the current research proved successful in tapping attention and memory deficits, future research may incorporate other tests. For example, the immediate reproduction administration of Benton Memory, which was used in this study, is not particularly sensitive to memory processes but rather to visual-perceptive and motor processes, according to a recent study (Larrabee, Kane, Schuck and Francis, 1985). The delayed reproduction administration was found to be a more valid measure of visual memory (Larrabee, et al., 1985).

To delineate attention from memory further and to measure visual memory specifically, future research on brain stem compression should use the delayed administration of the Benton Memory test. The Paired Associate Learning subtest of the Wechsler Memory Scale which does not appear to be highly correlated with linguistic or attentional factors (Larrabee et al., 1985) could be used as a valid measure of relatively pure verbal memory in the auditory

modality.

The effect of span of information on attentional capacity could be further assessed by devising a CPT task so as to vary the number of items presented at one time. This would help assess the relationship of performance as a function of span length to tumor size.

Models of Processing

The nature of the deficits evidenced in this study may be explained with respect to the model of "controlled versus automatic" processing, which purports that conscious effort is necessary for processing information and storing it in memory. The findings do not appear to address the "levels of processing" model, which postulates that memory deficits result from the inability to process information on a semantic level. Because performance on the Arithmetic subtest does call for some linguistic processing it could be argued that the lack of improvement in Arithmetic results from deficits in semantic processing, thereby supporting the levels of processing model. However, the data more strongly support the model of controlled versus automatic processing because most of the tasks that were impaired and improved following the removal of the tumor were tasks requiring conscious "controlled" effort for memory.

The reason those tasks presented to the auditory modality were affected while tasks presented to the visual

modality were not, may be that the auditory modality places a greater demand on attentional processes --that is, it may be the sequential nature of those tasks presented to the auditory modality that is sensitive to the impairment. Those tasks presented to the visual modality require the processing of a lesser span of information and they require the encoding of information presented spatially at one time; the tasks presented to the auditory modality, on the other hand, require the encoding of information presented sequentially over time. Although a deficit in linguistic processing would be an alternative hypothesis, it does not appear that such a hypothesis would explain the findings. Instead, it appears that the capacity for attention is limited by brain stem compression and the tasks presented to the auditory modality are more sensitive to such a limitation.

In contrast to the small tumor patients, the patients with large tumors have some type of deficit in their ability to take in and consciously process information, especially when the span of information is great. When information must be processed with maximum conscious effort, as in the Arithmetic and Digit Span subtests and the Selective Reminding Test, the large tumor group evidenced impaired performance.

Thus, it is the controlled aspect of processing, whereby voluntary effort is required, that is deficient in

patients with brain stem compression from large posterior fossa tumors. The distinction between controlled and automatic processing is based on the presence or absence of conscious effort: while controlled processing requires deliberate attention to a task in order for the information to be encoded in memory, automatic processing requires no voluntary attention for encoding to occur.

Specifically, tasks that are affected by brain stem compression (e.g., Digit Span, Arithmetic and the Selective Reminding Test) require both attention and short-term working memory which utilize controlled processing, in that subjects must voluntarily attend to the task in order to retain the information in memory. Those measures that are not affected require pure attentional processing without a memory component (e.g., the CPT) and may be described as automatic-processing tasks.

There appears to be two forms of attention. One form is required for vigilance tasks; it is a sustained, more passive form of attention that is best described as fitting the requirements for automatic processing. The other form is required for span-like memory tasks; it is a more active form of attention that is best described as fitting the requirements for controlled processing. It is this latter form of attention that is affected by tumors that compress against the brain stem. Digit Span and the Selective Reminding Test, both of which showed an impairment, may

require a voluntary, effortful form of attention. The Continuous Performance Test, which did not show an impairment may represent a less voluntary and effortful and a more automatic form of attention.

Capacity Theories

The capacity theories of attention and memory (Kahneman, 1973) are supported by the current research. These theories purport that there is a limited amount of attentional resources available at any one time. In fact, the controlled versus automatic processing model is a derivative of the capacity theories. It appears that the amount of attention necessary for a task increases in relation to the amount of material to be processed. Therefore, tasks that entail a greater span of information will place more of a demand on the system. The data shows that performance on these tasks is impaired, suggesting a deficiency in attention. In contrast, tasks requiring a minimal load of processing, such as Benton Memory, do not evidence an impairment, suggesting that only minimal attention is required. Similarly, performance on tasks that do not require recall, such as Digit Symbol, and tasks that require sustained attention or vigilance, such as the CPT, are also not impaired. The CPT, like Benton Memory, requires the processing of only a limited span of information; in the case of the CPT, only one item must be attended to at a

given time.

Span of information may be related to theories of selective attention: when there is competing stimuli, the information to be processed must be more salient or relevant in order for the subject to process that information. Accordingly, the theories of Deutsch and Deutsch (1963) on the interaction between alertness and saliency of the stimulus input may be applied to the current findings. As stated in the selective attention theories, the less salient the stimuli are, the more alert the subject must be in order to process the information. According to the current findings, there is also an interaction between stimulus input and attentional processes; the amount of stimulus input, as defined by the span of information, is directly related to the demand on attention.

In a like manner, the hypothesis that a greater span of information places a greater demand on attention may be addressed by the controlled versus automatic processing model. Automatic processing requires less effort than controlled processing (Hasher and Zacks, 1984). It has been demonstrated that controlled processes are dependent on load and are capacity limited (Shiffrin and Schneider, 1977). Thus, information that places a demand on controlled processes, such as the span-like tasks, were impaired. Information which places a greater demand on automatic processes were unimpaired.

In summary, span-like tasks place a greater demand on attention and require more of the limited capacity available for attention (Kahneman, 1973). It is these tasks that require controlled processing and that show an impairment when large tumors compress against the brain stem in man.

Conclusion

The brain stem auditory evoked response did not significantly differ from pre- to post-operative testing. This is in contrast with the finding that the neuropsychological and psychometric tests that were impaired pre-operatively improved after the surgical removal of the tumor. A viable explanation for this is that the reticular activating system is located medial to the brain stem auditory pathway. Since the tumor first compresses against the lateral brain stem, the auditory pathway would be the earliest structure compressed with the more medial RAS involved only with increasing compression. Consequently, the brain stem auditory pathway would be the most susceptible to compressive effects and may be the least likely to recover. Therefore, the decrease in compressive effects from medial to lateral in the brain stem may explain the recovery of attention and memory (medial brain stem) and the non-recovery of BAER's (lateral brain stem) post-operatively.

Although the brain stem has previously been associated

with attentional processes, and specifically with arousal (Bloch, 1970), it appears that it also plays a role in the attentional capacity for retrieval of a span of information from memory. Overall, the patients with large posterior fossa tumors were impaired in their performance on measures requiring both attention and memory. Removal of the tumor led to improved performance on impaired tasks. Thus, the study of patients with large posterior fossa tumors is an excellent vehicle for understanding the effects of brain stem compression on cognitive functioning in human beings.

Table 1

Demographic Characteristics
of Tumor Patients
and Controls on Psychometric Tests
at First Testing.

	N	AGE			EDUCATION			TUMOR SIZE	
		Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
control	10	50.7	13.7	24-66	14.3	2.5	10-17	-	-
Large Tumor 2.5-5.0	15	42.3	16.6	16-66	13.2	2.4	9-17	3.5	.95
Small Tumor 1.0-2.0	11	46.6	11.4	27-61	14.5	3.2	8-19	1.5	.41

Table 2

Demographic Characteristics
of Tumor Patients
and Controls on Psychometric Tests
at Second Testing.

SIZE	AGE			EDUCATION			TUMOR		
	N	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
control	9	50.9	14.0	26-67	14.6	2.5	10-17	-	-
Large Tumor 2.5-5.0	12	42.0	16.8	16-66	13.2	2.5	9-17.5	3.4	1.3
Small Tumor 1.0-2.0	6	50.3	7.9	40-61	13.3	3.3	8-16	1.5	.5

Table 3

Number of Subjects in First
and Second Testing Groups.

	FIRST TESTING		SECOND TESTING	
	Neuropsych	CPT	Neuropsych	CPT
small	11	6	6	7
large	15	4	12	12
normal	10	10	9	19

• 5 of these were previously tested on the neuropsych measures. The remaining 5 were new controls

Table 4

Demographic Characteristics
of Tumor Patients
and Controls on the CPT
at Second Testing.

	N	AGE			EDUCATION			TUMOR SIZE	
		Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
control	19	44.3	15.3	16-67	14.4	2.8	7-17.5	-	
Large Tumor 2.5-5.0	12	42.0	16.8	16-66	13.2	2.4	9-17.5	3.4	1.3
Small Tumor 1.0-2.0	7	50.9	7.4	40-61	14.1	3.7	8-19	1.6	.5
Large and Small Tumor 1.0-5.0	19	45.3	14.5	16-66	13.5	2.9	8-19	2.9	1.3

Table 5

Tumor size with Psychometric and
Neuropsychological Tests
Pearson Correlation Coefficients

Tests	r	n	
Verbal I.Q.	-0.42	24	p<.05
digit span	-0.41	26	p<.05
forward digit span	-0.47	26	p<.01
vocabulary	-0.41	25	p<.05
arithmetic	-0.48	24	p<.01
Benton memory	0.41	26	p<.05
Selective Reminding Test	0.34	26	p<.05
Long Term Storage	0.14	26	N.S.
Consistent Long-Term Retrieval	-0.01	26	N.S.
Short-Term Retrieval	0.05	26	N.S.
Performance I.Q.	-0.20	24	N.S.
Full Scale I.Q.	-0.29	24	N.S.
Comprehension	-0.15	24	N.S.
Similarities	-0.04	25	N.S.
Backward Digit Span	-0.18	26	N.S.
Digit Symbol	-0.26	26	N.S.
Benton Copy	-0.15	25	N.S.
Wepman Test of Auditory Discrimination	0.14	25	N.S.
Sound Blending	-0.02	22	N.S.
Mini-Mental serial 7s	-0.08	24	N.S.
Mini-Mental 3 wd mem	0.10	24	N.S.
Verbal Fluency			
C	-0.13	14	N.S.
F	0.01	11	N.S.
L	-0.38	10	N.S.
Animals	-0.02	13	N.S.
Supermarket	-0.31	13	N.S.

Table 6

The III-V Interpeak Latency with
Psychometric and Neuropsychological Tests
Pearson Correlation Coefficients

Tests	r	n	
Vowel errors on the Wepman Test of Auditory Discrim.	0.56	20	p<.005
Full Scale I.Q.	-0.40	19	p<.05
Verbal I.Q.	-0.39	19	p<.05
Backward Digit Span	-0.40	20	p<.05
Performance I.Q.	-0.43	19	p<.05
Digit Symbol	-0.42	20	p<.01
Benton Memory	0.56	20	p<.01
Digit Span	-0.37	20	p=0.056
Vocabulary	-0.37	20	p=0.057
Benton Copy	-0.12	19	N.S.
Selective Reminding	0.12	20	N.S.
Long Term Storage	0.30	20	N.S.
Consistent Long-Term Retrieval	-0.03	20	N.S.
Short-Term Retrieval	0.21	20	N.S.
Forward Digit Span	-0.24	20	N.S.
Information	-0.05	20	N.S.
Arithmetic	-0.15	19	N.S.
Comprehension	-0.19	19	N.S.
Similarities	-0.31	19	N.S.
Wepman test of Auditory Discrim.	0.28	19	N.S.
Sound Blending	0.11	16	N.S.
Mini-Mental Serial 7s	0.04	18	N.S.
Mini-Mental 3 wd mem	0.12	18	N.S.
Verbal Fluency			
C	0.35	13	N.S.
F	-0.02	10	N.S.
L	-0.14	9	N.S.
Animals	0.23	12	N.S.
Supermarket	0.01	12	N.S.

Table 7

**Tumor Size with CPT Measures
Pearson Correlation Coefficients
on Pre-Operative Testing**

	r	n	
Mean RT	0.82	10	p<.01
Log of RT	0.80	10	p<.01
Errors of Omission	-0.13	10	N.S.
Errors of Commission	-0.15	10	N.S.
Overall Standard Deviation of RT	0.19	10	N.S.

Table 8

**The III-V IPL with CPT Measures
Pearson Correlation Coefficients
on Pre-Operative Testing**

	r	n	
Mean RT	0.18	9	N.S.
Log RT	0.19	9	N.S.
Errors of omission	0.02	9	N.S.
Errors of Commission	0.17	9	N.S.
Overall Standard Deviation of RT	0.29	9	N.S.

Table 9

T-Test between Large Tumor Patients and Control
on Psychometric and Neuropsychological Tests
Pre-Operative Measures

Tests	Means		t	df	p< (1-tail)
	large	control			
Verbal I.Q.	98.6	104.6	-1.26	22	N.S.
Digit Span	8.1	9.0	-1.13	23	N.S.
Forward Digit Span	7.4	7.5	-0.14	23	N.S.
Arithmetic	8.4	10.8	-2.04	22	.05
Vocabulary	10.4	11.0	-0.69	23	N.S.
Selective Reminding	8.1	5.1	2.67	23	.01
Consistent Long-Term Retrieval	7.5	5.2	0.94	22	N.S.
Short Term Retrieval	3.1	1.3	1.30	22	N.S.
Long Term Storage	2.6	2.6	0.03	22	N.S.
Benton Memory	4.5	3.6	0.77	23	N.S.
Benton Copy	0.9	0.4	1.15	22	N.S.
Backward Digit Span	5.6	6.8	-1.51	23	N.S.
Digit Symbol	8.1	8.5	-0.47	23	N.S.
Information	10.2	11.1	-1.41	24	N.S.
Comprehension	10.6	10.8	-0.16	22	N.S.
Similarities	9.4	8.0	1.13	22	N.S.
Mini Mental					
serial sevens	1.6	1.0	0.79	20	N.S.
3 word memory	.9	.8	0.44	20	N.S.
Verbal Fluency					
C	13.6	14.0	-0.26	15	N.S.
F	14.2	13.8	0.20	13	N.S.
L	12.0	13.7	-0.84	12	N.S.
Animals	18.2	19.1	-0.34	14	N.S.
Supermarket					
Items	22.7	24.6	-0.50	14	N.S.
N.S.					

Table 10

T-Test between Small Tumor Patients and Control
on Psychometric and Neuropsychological Tests
Pre-Operative Measures

Tests	Means		t	df	p< (1-tail)
	small	control			
Verbal I.Q.	108.8	104.6	0.70	18	N.S.
Digit Span	10.1	9.0	-1.06	19	N.S.
Forward Digit Span	9.4	7.5	1.99	19	N.S.
Arithmetic	10.9	10.8	0.07	18	N.S.
Vocabulary	12.4	11.0	1.14	18	N.S.
Selective Reminding	5.0	5.1	-0.07	19	N.S.
Consistent Long-Term Retrieval	4.9	5.2	-0.11	18	N.S.
Short Term Retrieval	2.6	1.3	0.76	18	N.S.
Long Term Storage	2.3	2.6	-0.14	18	N.S.
Benton Memory	3.2	3.6	0.28	19	N.S.
Benton Copy	1.6	0.4	1.88	19	N.S.
Backward Digit Span	6.7	6.8	-0.07	19	N.S.
Digit Symbol	9.6	8.5	0.87	19	N.S.
Comprehension	11.8	10.8	0.94	18	N.S.
Similarities	10.2	8.0	1.72	19	N.S.
Mini Mental serial sevens	1.0	1.0	0.00	16	N.S.
3 word memory	1.0	.8	0.50	16	N.S.
Verbal Fluency C	16.3	14.0	0.98	15	N.S.
F	15.7	13.8	0.84	14	N.S.
L	15.7	13.7	0.94	14	N.S.
Animals	20.1	19.1	0.35	15	N.S.
Supermarket Items	27.6	24.6	0.78	15	N.S.

Table 11

T-Test between Large and Small Tumor Patients
on Psychometric and Neuropsychological Tests
Pre-Operative Measures

Tests	Means		t	df	p< (2-tail)
	large	small			
Verbal I.Q.	98.6	108.8	-2.82	22	.01
Digit Span	8.1	10.1	-2.54	24	.05
Forward Digit Span	7.4	9.4	-2.52	24	.05
Arithmetic	8.4	10.9	-2.69	22	.05
Vocabulary	10.4	12.4	-2.42	23	.05
Full Scale I.Q.	97.6	107.2	-2.09	22	.05
Selective Reminding	8.1	5.0	2.21	24	.05
Consistent Long-Term Retrieval	7.5	4.9	1.11	24	N.S.
Short Term Retrieval	3.1	2.6	0.25	24	N.S.
Long Term Storage	2.6	2.3	0.22	24	N.S.
Benton Memory	4.5	3.2	1.02	24	N.S.
Benton Copy	0.9	1.6	-1.07	23	N.S.
Backward Digit Span	5.6	6.7	-1.56	24	N.S.
Digit Symbol	8.1	9.6	-1.46	24	N.S.
Information	10.2	11.6	-1.41	24	N.S.
Comprehension	10.6	11.8	-1.28	22	N.S.
Similarities	9.4	10.2	-0.92	23	N.S.
Wepman Test Auditory Discrimination	1.7	1.7	.07	23	N.S.
Sound Blending	26.5	27.9	-1.33	20	N.S.
Mini Mental serial sevens	1.6	1.0	.93	22	N.S.
3 word memory	.9	1.0	-0.19	22	N.S.
Verbal Fluency C	13.6	16.3	-0.89	12	N.S.
F	14.2	15.7	-0.59	9	N.S.
L	12.0	15.7	-1.70	8	N.S.
Animals	18.2	20.1	-0.83	11	N.S.
Supermarket Items	22.7	27.6	-1.15	11	N.S.

Table 12

T-Tests between Large and Small Tumor Patients
and Controls on CPT Measures
Pre-Operative Testing

	Means			t	df	p< 1-tail
	large	small	controls			
Errors of omission						
large vs small	0.25	0.67		-0.64	8	N.S.
large vs control	0.25		0.50	0.45	6	N.S.
small vs control		0.67	0.00	-1.35	10	N.S.
Errors of commission						
large vs small	1.50	4.50		-0.79	8	N.S.
large vs control	1.50		4.50	0.85	6	N.S.
small vs control		4.50	1.70	-0.92	10	N.S.
Mean Reaction Time						
large vs small	199.1	168.4		1.78	8	N.S.
large vs control	199.1		184.2	-0.52	6	N.S.
small vs control		168.4	172.0	0.31	10	N.S.

*msec.

Table 13

T-Tests between Patient and Control Groups
on CPT Measures
Pre-Operative Testing

	Means		t	df	p<	1-tail
	Patients	Controls				
Errors of omission	0.50	0.20	-0.82	18	N.S.	
Errors of commission	3.30	2.80	-0.22	18	N.S.	
Mean Reaction Time	180.8	176.9	-0.28	18	N.S.	
Overall Standard Deviation	27.33	26.60	-0.19	18	N.S.	

*msec.

Table 14

T-Test between Patients
Pre- and Post-Operative Performance
on Psychometric Tests

Tests	Means		t	df	p< (1-tail)
	Pre-	Post-			
Verbal I.Q.	101.2	105.7	3.28	17	.01
Digit Span	9.1	10.0	1.76	17	.05
Arithmetic	8.9	9.8	1.86	17	.05
Digit Symbol	8.2	9.1	2.60	17	.01
Selective Reminding Test	7.3	4.4	-3.81	17	.01
Performance I.Q.	99.2	106.3	4.59	17	.001
Full Scale I.Q.	100.4	106.3	5.35	17	.001

Table 15

T-Test between Large Tumor
Patients' Pre-Operative
and Post-Operative Scores on
Psychometric and Neuropsychological
Tests

Tests	Mean pre-op	Mean post-op	t	df	p< (1-tail)
Verbal I.Q.	98.2	103.2	3.15	11	.01
Forward Digit Span	7.3	8.6	2.32	11	.05
Digit Span	8.2	9.7	2.84	11	.01
Performance I.Q.	96.2	104.6	4.93	11	.001
Digit Symbol	7.8	8.9	3.03	11	.01
Full Scale I.Q.	97.4	103.7	4.54	11	.001
Selective Reminding Test	8.5	4.2	-5.29	11	.001
Backward Digit Span	5.8	6.3	1.07	11	N.S.
Benton Copy	1.1	0.9	-0.48	10	N.S.
Benton Memory	4.6	5.3	0.58	11	N.S.
Information	9.9	10.3	0.77	11	N.S.
Vocabulary	10.2	10.9	1.47	11	N.S.
Arithmetic	8.3	9.1	1.48	11	N.S.
Comprehension	10.6	11.1	0.94	11	N.S.
Similarities	9.1	9.7	0.82	11	N.S.

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