

ACCEPTED

DEPARTMENT OF GRADUATE STUDIES MEASURING ATTENTIONAL CAPACITY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

in the Department
of
Psychology

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UNIVERSITY OF VICTORIA
JULY 1986

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ABSTRACT

Studies of attentional function in normals and attentional problems in clinical populations, particularly closed head injury cases, strongly indicate that the crucial aspect of attentional difficulty is the limited amount of information a person can attend to or process within a given time. Within this context, the terms "attentional capacity" and "information processing capacity" are used interchangeably and are also very closely related to the concept of "working memory".

Despite the reported prevalence of attentional problems among brain-impaired people, there is a dearth of appropriate clinical measures of attention. Those that do exist are limited in that they assume intact motor and/or speech response capacity which many brain-impaired people lack and they measure too narrow a range of capacity to be useful across the full clinical spectrum. The aim of the present study was to develop a measure that covers the full range of attentional capacity and accommodates the response deficits common in clinical populations.

A measure called the Attentional Capacity Test (ACT) was developed in which processing demands are gradually increased across eight succeeding levels of difficulty. It involves the person listening to a series of numbers,

mentally counting how many target numbers occur, and reporting their answer at the end of the series. The answer is always somewhere from 1 to 10, making the response one of multiple-choice format. Because the response is in multiple-choice format and given after the processing demands of the series are finished, the response mode and speed can be adjusted to patient requirements without affecting the processing demands of the task.

The primary concern of the present study was to explore the validity of the ACT as a measure of information processing or attentional capacity. Using a sample of 64 normal young adults, performance on the ACT was compared to that on a relatively well-established measure of information processing, the Paced Auditory Serial Addition Test (PASAT), and also to a simple measure of working memory, the Digits Backward Test. Positive relationships between the ACT and both these tasks confirmed that the ACT measured attentional capacity. The fact that the ACT related only moderately to the PASAT may have been because the PASAT demands adding skill and quick vocal responses which the ACT does not. This interpretation was confirmed by finding that the PASAT was highly correlated to a measure of adding speed and accuracy while the ACT was only minimally related to this task. Passive memory span, as measured by the Digits Forward task, was not meaningfully related to performance on either the ACT or the PASAT.

The construct validity of the ACT was further confirmed by comparing the ACT performance of nine brain-impaired patients to staff ratings of their attentional functioning in everyday life. A positive relation between the two measures was found for seven patients with diffuse injury but not for two patients with focal damage.

The implications of these findings are discussed with reference to the future development of the ACT.

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ACKNOWLEDGEMENTS

There are many people to whom I would like to express my appreciation for their contribution to this dissertation: Dr. Frank Spellacy for his pragmatic clinical approach; Dr. Lou Costa for help in developing the ideas on which the ACT is based; Dr. Roger Graves for help in making the stimulus tapes and taking a general interest in my work; Dr. Mike Hunter for advice about statistical analysis and stylistic presentation; Mr. Pat Konkin for computing assistance; Dr. Lorne Rosenblood for advice about statistical analysis; Drs. Leeming and Mooney for their participation as external members of my committee; Terri Buller and Francine Sarazin for help with word processing; and Dr. Don Read for getting me started again when I reached "stuck" points in writing the dissertation. I would also like to record my gratitude for the University of Victoria Fellowship which made it financially possible for me to pursue doctoral studies at this University.

Finally, but by no means least, I wish to thank the people who gave their time and effort by participating in the study itself. I am most grateful to those students who took time off from their studies and other activities to take part in the experimental phase of the study. A special thank you is due to the patients and staff of the Good Samaritan Hospital Center for Cognitive Rehabilitation: to the nine patients who participated so

pleasantly and cooperatively in their effort to help further knowledge about the attentional problems of brain-impaired people; to McKay Sohlberg, Suzanne Geyer, and Dennis Williams for finding time amidst their heavy work demands to complete the patient ratings on the Attention Questionnaire; and to Dr. Catherine Mateer for facilitating and organizing my access to the patients and staff at the Center, for completing the Attention Questionnaires, and for friendly encouragement.

DEDICATION

This dissertation is dedicated to my parents, Lu and Phyl Weber.

INTRODUCTION

The aim of this study was to take the first step in developing a measure of attention appropriate for clinically assessing brain-impaired individuals. The inspiration for this endeavour arose from noting the discrepancy between the prevalence of attentional problems among brain-impaired people as reported in the clinical research literature and the dearth of appropriate clinical measures of attention.

Attentional Problems Among Brain-Impaired People

Attentional problems are frequently cited among the sequelae of closed head injuries (for example, see the review by van Zomeren, Brouwer, & Deelman, 1984) and constitute a major consideration during rehabilitation (Adamovich, Henderson, & Auerbach, 1985; Ben-Yishay & Diller, 1983; Trexler, 1982). Attentional deficits occur in association with many brain disorders (Gummow, P. Miller, & Dustman, 1983). They are probably an important aspect of dementing illness (Cohen & Eisdorfer, 1979;

Ferris, Crook, Sathananthan, & Gershon, 1976), and have been reported in relation to Alzheimer's disease (Ober, Dronkers, Koss, Delis, & Friedland, 1986; Vitaliano, Breen, Albert, Russo, & Prinz, 1984) and Parkinson's disease (Talland & Schwab, 1964). Difficulties with attention are also related to other specific neurological groups, for example, learning difficulties (Brumback & Staton, 1982; Shallice & Warrington, 1977), frontal lesions (Fuster, 1980; Salmaso & Denes, 1982), aphasia (Cohen, Woll, & Ehrenstein, 1981), total commissurotomy (Dimond, 1979), convulsive disorders (Campanioli, 1970), cerebral vascular accident (Diller & Weinberg, 1972; Hibbard & colleagues in personal communication, July, 1984), and Korsakoff disease (Oscar-Berman & Bonner, 1985). The relevance of attentional problems has also been noted in populations where the possible neurological factor is presently unknown, namely, psychiatric patients (Byrne, 1977; Dienske, de Jonge, & Sanders-Woodstra, 1985; Mirsky, 1969; Persons & Baron, 1985; Zubin, 1975) and normal elderly people (Oscar-Berman & Bonner, 1985; Salthouse, Rogan, & Prill, 1984).

The attentional measures used in clinical studies range through those of sustained, focused, divided, and shifting attention, short-term memory, and information processing. The conception of attention that emerges as the most clinically sensitive and meaningful one for closed head

injury and dementing patients, and perhaps for others, is that of information processing capacity (see van Zomeren, Brouwer, & Deelman, 1984 for review, and also examples by Ferris, Crook, Sathananthan, & Gershon, 1976; E. Miller, 1970; E. Miller & Gruzat, 1981; Stuss, Ely, Hugenholtz, Richard, La Rochelle, Poirier, & Bell, 1985; Talland & Schwab, 1964). Not only is the concept of information processing capacity apparently the most useful approach to the study of attentional deficit, it also serves as a basis for understanding other manifestations of attention such as focussed, divided, and shifting attention, working memory, and to some extent sustained attention with respect to normal people as well as clinical populations. The information processing approach is now presented in some detail.

Information Processing Capacity and Attention

The term "information processing" is applied to theoretical models that try to describe and explain mental functions as sequences of information flow through the organism. A crucial aspect of such models is the notion of limited processing capacity, that is, the amount of information that can be processed at any one time is restricted. Human beings do not have sufficient mental

capacity to process all stimuli at one time and therefore, to function at all, must select some stimuli for processing while neglecting others. Such selection constitutes an attentional process of directing mental effort towards some stimuli rather than others. As Luria (1973) said, "the directivity and selectivity of mental processes, the basis on which they are organized, is usually termed attention in psychology" (p. 256). The use of the term "stimuli" within the information processing context is a broad one, including both input from the external environment such as sights and sounds and input from within the person such as memories, thought, hunger and other bodily sensations.

Geschwind (1982) has given a rather good description of the role of attention on everyday life. He points out that normal functioning requires that the person select a limited number of stimuli to be processed at any given instant and that the basis for this selection be maintained over sufficient time to give coherence to thought and action. Although the person should not be distracted by irrelevant stimuli, they should be monitoring a wide range of "unattended" stimuli so that possibly relevant stimuli can be detected and brought into focus. Any shifting of attention to include new or different stimuli must be made on the basis of appropriate need and relevance of those stimuli in the person's life. As James (1890, cited in Davies, 1983) said, "selection is the very keel on which

our mental ship is built" (p. 10).

Theories vary as to whether there is one central source of processing capacity (Kahneman, 1973), two sources (Friedman & Polson, 1981; Friedman, Polson, Dafoe, & Gaskill, 1982; Herdman & Friedman, 1985), or multiple sources (Navon & Gopher, 1979). The main sort of task used to illustrate these theories has been the divided attention task, that is, a task where the performer must attend to and deal with two or more inputs or activities at the same time. The assumption in such studies has been that an increased use of resources on one aspect of the task will result in a decrease in resources available for the other aspect/s of the task. There are various problems in interpreting the outcome of such measures including that of whether resource demands of two single tasks are not simply additive but interact in a way that makes the whole demand of a divided attention task more than the sum of its parts (Duncan, 1979). Interpretation of divided attention tasks is also complicated by individual differences in strategies; that is, whether the person uses simultaneous or alternating processing (Fuhrer, 1985). Individual differences in allocation of attention have also been attributed to stable personality factors such as introversion/extroversion (Daruna, Karrer, & Rosen, 1985).

As well as differing opinions concerning the nature of the limited capacity for information, there are also varied

notions as to when and how the consequent selection occurs. Broadbent (1958) argued that selection occurred just after sensory registration of stimuli and prior to perceptual analysis. Treisman (1960) provided evidence that this filtering process occurs after perceptual analysis and recognition of the stimulus identity, and that the rejected stimuli are only attenuated rather than completely blocked out. Deutsch and Deutsch (1963) and Norman (1968) also argued for the selection being done at a much later stage in the processing of stimuli. Broadbent (1971) subsequently modified his model to permit three stages of selection, one at the sensory stage ("filtering"), one at the level of stimulus meaning ("categorizing"), and one at the stage of response selection ("pigeon holing"). Dark, Johnston, Myles-Worsley, & Farah (1985) also proposed that limited capacity and selectivity occur at three somewhat similar stages: physical, semantic, and controlled. By the latter term they mean processing of conscious internal representatives of the stimulus. Most of the studies concerned with addressing the issue of selectivity, have used focused attention tasks: That is, tasks in which the performers have to attend to only one of two or more inputs.

It has also been pointed out that information processing may be affected by features of the data itself (e.g., audibility, visibility) as well as by resource

capacity (Norman & Bobrow, 1975; 1976) although the exact way in which this division of factors, which limit information processing, should be construed, is open to debate (Kantowitz & Knight, 1976).

Some workers (e.g., Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; Banks & Zender, 1984) have proposed that performance on divided attention tasks may be attributable to skill and practice in such division rather than to resource capacity per se. However, the more common approach has been to argue that some mental operations require the use of limited resources whereas others do not (e.g., Kerr, 1973). This argument has been formalized into the now prevalent concepts of automatic and controlled processing by Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977). Automatic processing involves well-learned processes that are in long-term store and that do not require attention even though they may attract it if attention is the learned automatic response. Controlled processing, on the other hand, requires attention, uses up short-term processing capacity, is limited and, therefore, tends to be serial in nature. It is controlled processing that makes demands on resources and is the subject of most focused or divided attention tasks. However, it should be noted that repetition of a controlled processing task may eventually result in such processing becoming automatic. Schneider and Shiffrin's division of processing into

"automatic" and "controlled" is consistent with similar concepts suggested by other workers (e.g., La Berge, 1973, 1975; Neisser, 1967; Posner & Snyder, 1975). Much research focuses on the differences between automatic and controlled processing but Logan (1980) points out that often these processes occur together, and that automatic processing may interfere with controlled processing as on the Stroop Test (Perret, 1974). In this test the subject is required to state the colour of the ink that words are written in. The words themselves are colour names that are often different to the ink colour in which they are written (e.g., the word "blue" written in red ink). The automatic response of reading the actual word tends to override the controlled response of naming the ink colour.

Schneider and Shiffrin's concepts of controlled and automatic processing also relate attentional concepts to those of memory. Well-learned stimulus response associations require no attentional effort from the limited resource capacity whereas the more effortful controlled processes do demand attention and "short-term" capacity. This leads to the notion of "working memory" introduced by Baddeley & Hitch (1974). This term signifies a dynamic concept of immediate or short-term memory, one that includes not only the number of information bits that can be stored in awareness at one time but also the processes that are currently being applied to that information.

There is thought to be a trade-off between the amount of storage required and the rate at which other processes can be carried out (Baddeley & Hitch, 1974; Daneman & Carpenter, 1983). Hasher & Zacks (1979) suggest that it is memory skills involving controlled processing that are most adversely affected in the elderly and depressed patients.

If Luria's (1973) concept of sustained attention being one outcome of voluntary attentional capacity is accepted, then it would seem that sustained attention could probably be subsumed within the framework of controlled attention concepts. That is, Schneider and Shiffrin's notion of controlled processing seems similar to Luria's voluntary attention, the only apparent difference being that Schneider and Shiffrin make allowance for performance of a given task to gradually shift (with practice) from controlled or effortful processing to automatic processing whereas Luria makes no such provision or even discusses the possibility. Vigilance tasks form a subset of sustained attention tasks in which the observer has to detect specified stimuli that occur infrequently in a background of other noncritical events or nontargets. Vigilance studies originated from practical concern with the accuracy of radar operators during World War II and have subsequently tended to focus on questions concerning vigilance decrement such as the effects of sleep deprivation on accuracy (e.g., Wilkinson, 1960), ways of

offsetting these effects (e.g., Horne & Pettitt, 1985), explanations of vigilance decrement in terms of reduced arousal, loss of perceptual sensitivity in discriminating targets from nontargets, and cautiousness in reporting occurrences of targets (see Parasuraman, 1983, for review).

No literature was found that specifically dealt with the attentional shift aspect of information processing. However, lack of inappropriate shifting would appear to be intrinsic to effective focused attention and many models of focused attention acknowledge that stimuli outside the main focus are monitored to some degree (e.g., Broadbent, 1971; Deutsch & Deutsch, 1963; Treisman, 1960). Presumably, part of the processing capacity is devoted to monitoring peripheral stimuli and evaluating their appropriateness for being shifted into attentional focus. Appropriateness is probably decided with reference to both long-term stored goals and concerns as well as those in short-term store pertaining to the task at hand. It is also probable that well practiced patterns of monitoring become automatic and thus do not use up the limited resources of controlled processing. The studies that come closest to investigating attentional shift are those concerned with the positive relationship between working memory capacity and ability to draw inferences from text (Masson & J.A. Miller, 1983), and the positive relationship between working memory and ability to resolve inconsistencies or ambiguities in the

text (e.g., Daneman & Carpenter, 1983). In clinical populations, failure to shift attention appropriately typically manifests as perseveration.

The information-processing approach to understanding attention is derived from observation of task performance and, at the present time, can only be linked to any underlying neuroanatomical bases in a loose and somewhat speculative fashion.

Possible Neuroanatomical Basis to Attentional Capacity

Attentional capacity is related to a number of different brain areas. Accounts vary somewhat in detail and emphasis (for example, compare Luria, 1973; Mesulam, 1981; and Trexler, 1982, and personal communication, 1985) but are more or less in agreement that the brain stem reticular formation is important for general arousal level or alertness, the thalamic and limbic areas (especially the hippocampus) are important for selective focus of attention on some stimuli rather than others, and the frontal lobes play a significant role in the voluntary direction and control of attention. According to Luria's (1973) model, the dorsolateral area of the frontal lobes is involved in formulation of the intention to attend and attentional strategies whereas the orbital area is concerned with

inhibition of inappropriate attentional responses. There is a complex interaction of excitatory and inhibitory effects between these three key areas and also between these areas and the cortical areas generally.

Optimal attentional functioning presumably requires appropriate functioning of all these structures plus whatever additional structures are involved in a given task. For example, Mesulam (1981) claimed that four cerebral regions modulate directed attention within extrapersonal space: The posterior parietal region provides an internal sensory map; the limbic area (particularly the cingulate gyrus) regulates spatial distribution of motivational valence; the frontal area coordinates motor programs for exploring, scanning, reading, and fixating; and the reticular system provides underlying arousal and vigilance. From a neuroanatomical point of view, it is meaningful to talk of one source of attentional capacity that is derived from the integrated working of all neuroanatomical components. However, it is also meaningful to think of each neurological unit as a separate source of capacity. The question of where to draw the line with respect to number of resources is therefore somewhat unreal in that there are probably no absolute physical bases for preferring one answer rather than another. Luria's (1973) division of attentional function into voluntary attention associated with the frontal lobes

and involuntary orienting responses to external stimuli associated with limbic structures is analagous to Schneider and Shiffrin's (1977) notion of controlled and automatic processing. At first glance, this parallel might seem to suggest that the limited capacity of controlled processing is somehow linked to functioning of the specified frontal areas. However, it must be kept in mind that such controlled or voluntary attention with its limited capacity is not the result of frontal function alone but of an integrated network of brain areas of which the frontal areas form only a part.

Limitations of processing capacity may, of course, be related to neurochemical factors as well as structural factors. For example, Dunne and Hartley (1985) found that scopolamine impaired recall of the attended words in a dichotically presented shadowing task, while simultaneously facilitating recall of unattended words. This drug, which interferes with cholinergic functioning, thus appears to disturb capacity for focused attention. Perhaps the most integrated overview of factors affecting attentional processes is that of Luria (1973). His model allows such capacity to be influenced by three categories of factors: (a) Metabolic processes that input particularly via the reticular formation and hypothalamus; (b) External stimuli that input particularly via the thalamus, caudate, and hippocampus; and (c) Speech (external instruction or inner

thought) involving particularly the frontal areas.

Perhaps the most consistently supported division of processing resources to emerge so far is that of left and right hemisphere resources. Performance by normal people on divided attention tasks (Friedman & Polson, 1981; Friedman, Polson, Dafoe, & Gaskill, 1982; Herdman & Friedman, 1985) has suggested that the left and right hemispheres form two mutually independent and finite pools of resources. There is also support for this notion from the clinical literature. The right hemisphere seems responsible for attentional function on visuospatial tasks (e.g., Diller & Weinberg, 1972; Geschwind, 1982; Mesulam, 1981), and continuity of attention generally (Dimond, 1979). It is also commonly observed that patients with right hemisphere damage are more likely to show unilateral neglect of the contralateral sensory field than are those with left hemisphere damage. The left hemisphere resource seems responsible for attentional capacity with respect to auditory verbal tasks and those where some sort of verbal encoding may form part of the task such as identifying the stimulus to which response should be made in choice reaction time tasks (Dee & VanAllen, 1973) or those requiring short-term memory (Diller & Weinberg, 1972).

In summary, neuroanatomical accounts of attention can only be very loosely linked to information processing capacity accounts. Neuroanatomical considerations suggest

that capacity to attend to and process information is the result of an integrated system of resources. Whether emphasis is given to the integrated total resource capacity or to its component constituents is a somewhat arbitrary decision which is probably best made according to the practical needs of the situation. For everyday purposes it is usually the final product of the total attentional effort that is important. However, in clinical populations it may be useful to consider the damaged component of the attentional resource system separately from the remaining intact components when planning rehabilitation strategies. It is still important in such cases to consider also the overall capacity that is the final product of the defective attentional system since this combined unitary resource capacity will determine their everyday functioning. The possibility of there being separate right and left hemisphere resources is probably meaningful but it should also be kept in mind that these two processing resources form part of a larger whole due to their linkage via callosal and other commissural connections.

As stated at the beginning of this chapter, the aim of the present study is to develop a clinically appropriate measure of attention. Research on clinical populations indicated that the information processing approach to conceptualizing attention was the most meaningful and integrative one. This approach has been described together

with its possible neurological correlates. Existing measures of attentional capacity are now considered with respect to their appropriateness for use in clinical assessment.

Measuring Attention

The terms "information processing capacity" and "attentional capacity" have so far been used interchangeably. This usage is appropriate in the sense that the amount of information that can be processed at one time is the same as the amount that can be attended to in a limited capacity system. The stimuli being processed may be internal or external. This rather broad definition of attention means that measures of this capacity have ranged from those that involve the simple detection of the presence or absence of an external stimulus through to those where the emphasis is primarily internal, such as the solving of mental arithmetic problems.

The aspect of attention to external stimuli that seems most sensitive to brain impairment is that involving more central categorizing of the stimulus rather than simply noting its presence or absence. The best example of this phenomenon is found in studies using reaction time measures. In simple reaction time measures the person

simply presses a key as soon as they detect the presence of a sound or light or other specified stimulus. In choice reaction time measures, the person either presses a different key depending on which of several possible stimuli occur or presses the key only if one of several possible stimuli occur. In the choice reaction time condition, the person has to decide what sort of stimulus has occurred and respond appropriately to that particular stimulus. It could be argued that this more discriminative or selective attention to stimuli more closely approximates the attentional demands of everyday life than does the simple reaction time measure. In any case, it is this relatively selective sort of attention that most sensitively discriminates closed head injury patients from normals (Gronwall & Sampson, 1974; MacFlinn, Montgomery, Fenton, & Rutherford, 1984; E. Miller, 1970; van Zomeren, 1981; van Zomeren & Deelman, 1978). It also distinguishes cognitively impaired elderly from normal elderly (Ferris, Crook, Sathananthan, & Gershon, 1976) and Friedreich's ataxia patients from normals (Hart, Kwentus, Leshner, & Frazier, 1985). After reviewing the literature, van Zomeren, Brouwer, and Deelman (1984) concluded that, at least for closed head injury patients, it is the speed of making such stimulus selections that is impaired rather than the ability to discriminate and select per se. They also ruled out general arousal level as a factor

contributing to the cognitive impairment of closed head injury patients and did so on the basis of studies of sustained attention and physiological measures of arousal such as heart rate.

A variety of other measures of processing speed also discriminate between brain damaged and normal groups. For example, E. Miller and Cruzut (1981) found that the time taken to sort certain target cards increased as the number of nontarget cards was increased and this increment was more marked for head injury patients than for normals. It was not that the patients were unduly distracted by the irrelevant information, but rather that they were slower in dealing with it. Brouwer and van Wolffelaar (1985) measured the ability to sustain attention over a 40-minute period during which subjects had to press a switch whenever they heard a click that was weaker than other clicks and do so against a background of white noise. They found that closed head injury patients sustained their attention appropriately but were slower at responding than were normals. Another measure of information processing speed is the Paced Auditory Serial Addition Test (PASAT) devised by Gronwall and colleagues (Gronwall, 1977; Gronwall & Sampson, 1974; Gronwall & Wrightson, 1974). The PASAT presents auditorily a sequence of numbers and the person has to add the last number to the previous one in a continuous manner. For example, after the numbers "1,9"

the answer is "10", then if the next number is "4" this is added to the previous "9" to give the answer "13", and so on. The rate of number presentation varies over four levels of difficulty from one number every 2.4 seconds (easiest level) to one every 1.2 seconds (hardest level). The PASAT thus increases processing demands by increasing speed of stimulus input. It has been found sensitive in distinguishing apparently normal functioning mildly concussed patients from normal controls and in monitoring recovery of function in such patients.

Slowed speed of processing also limits the amount of such processing that can be done at a given time. Divided attention measures of capacity to deal with more than one task at a time have also been found effective in discriminating between brain-impaired people and normals. Talland and Schwab (1964) found that Parkinson patients were less able to simultaneously perform a different activity with each hand than normals and that this deficit appeared to be due to central processing limitation rather than attributable to difficulty with movement. Stuss et al. (1985) found that interference between a short-term memory and a simple mental arithmetic activity was increased in head injury patients relative to controls even though these patients otherwise showed good recovery. Salthouse, Rogan, & Prill (1984) found that dividing attention between two short-term memory tasks was more

difficult for older adults than younger ones even though the difficulty level of the dual task was adjusted to the individual's capacity on single tasks. The problem was not that of allotting attention to two channels or of response interference, but rather it was the problem of dealing with increased complexity.

The Continuous Performance Test involves the subject pressing a key each time a specified target occurs in a sequence of visually or aurally presented stimuli. Although somewhat similar in format to the already discussed reaction-time tasks, this measure was devised by Rosvold, Mirsky, Sarason, Bransome, and Beck (1956) as a means for assessing sustained attention. Various modifications of the task have since been used in studies of attention in clinical populations, including psychiatric ones (Byrne, 1977; Mirsky, 1969). The present concern, however, is with neurological populations. Rosvold et al. (1956) found that brain damaged subjects performed more poorly on this task than normals and that this deficit increased as the complexity of targets increased. Johnson (1977) found that brain damaged children had difficulty with a version of the continuous performance test. Kramer and Jarvik (1979) reported that as well as being sensitive to brain damage, the continuous performance task was sensitive to the deficits of normal aging and that elderly people had particular difficulty if the speed of stimulus

presentation was increased. Hart et al. (1985), on the other hand reported no decrement on this task for their Friedreich's ataxia patients although these same patients showed slowing of information processing on another task. It seems likely that the sensitivity of the continuous performance test to deficits in information processing speed depends on the complexity of the targets, the rate of stimulus presentation, and the severity of the patients' neurological condition. The capacity of neurological patients to sustain attention over time has not evoked the same degree of research interest as the capacity of these patients to process information per se. Clinical observation (e.g., Luria, 1973) suggests that sustaining attention may be particularly difficult for patients with frontal lesions whose capacity for any sort of voluntary goal-directed behaviour is impaired. This difficulty in keeping to the task at hand is, however, likely to manifest itself fairly quickly and probably does not require very prolonged testing to detect its presence. Perhaps a better measure of this difficulty is the Stroop sort of task, which is sensitive to the problem of automatic processes overriding intentional controlled ones.

The tasks that have been discussed so far, although used to research deficits in clinical populations, do not constitute the sort of psychological tests that are used to assess the cognitive profiles of individual patients. That

is, these tasks are at best minimally normed and their administration and procedures are not standardized. They are therefore not useful for evaluating how an individual patient compares to other people of their age group.

Factor analysis of the Wechsler Adult Intelligence Scale and Wechsler Memory Scale scores for brain-impaired people (Clark, Crockett, Klonoff, & MacDonald, 1983; Fowler, Richards, & Boll, 1980; Larrabee, Kane, & Schuck, 1983) and of a slightly modified Halstead-Reitan Battery (Swiercinsky, 1978) indicate that attention is a relevant factor in the cognitive functioning of such persons. This attentional factor is associated with tasks such as mental arithmetic, short-term memory span for numbers, ability to count backwards and recite the alphabet. With the possible exception of the digit-span tasks, these measures involve learned skills as well as an attentional component. None of the well-known neuropsychological test batteries such as those of Luria (Christensen, 1975), Luria-Nebraska (Golden, 1981), Halstead-Reitan (Reitan & Davison, 1974), or Swiercinsky (1978), contain any attentional tasks per se.

Perhaps the most standardized group of attentional tests are those in which the person is required to cross out every instance of a particular target item occurring in a context of target and nontarget items (see test reference guides: Buros, 1978; Chum, Cobb, & French, 1975; Goldman & Saunders, 1970, 1978, 1982; Johnson, 1976; Mitchell, 1983;

Sweetland & Keyser, 1983). These paper and pencil cancellation tasks are designed to assess clerical speed and accuracy in normal people and commonly occupy a place in vocational aptitude batteries. Similar sorts of tasks have been adapted for research use with brain-impaired people, using digits, letters, words, geometric forms, and pictures as stimuli (Diller, Ben-Yishay, Gerstman, Goodkin, Gordon, & Weinberg, 1974). Some norms are available for right-hemisphere damaged patients (Gordon & colleagues, 1984) but these reflect problems of unilateral spatial neglect rather than general attentional capacity. It is the present investigator's experience when working with neglect patients, that if the number of targets is increased performance deteriorates in a manner suggestive of limited processing capacity.

At very low levels of arousal, attentional capacity is very impaired. The Glasgow Coma Scale (Jennett, 1976; Teasdale & Jennett, 1974) and the lower levels of the Rancho Los Amigos Scale (Adamovich et al., 1985) provide objective criteria for rating patients at this very low level. The attentional subscale of the Dementia Rating Scale (Mattis, 1976) comprises simple visual target selection and matching tasks, auditory digit span, and the ability to carry out simple movements in response to verbal command. Strub & Black (1977) suggested forwards digit span and getting the patient to tap the table whenever an

"A" occurs in a sequence of aurally presented numbers as bedside tests of attention.

In conclusion, the attentional measures used in clinical studies indicate the usefulness of assessing attentional or information processing capacity, but in their present form they do not constitute ready-to-use diagnostic tests that can be used as part of regular neuropsychological assessment. Eson and Bourke (1982) have started to develop a battery of information processing tasks for clinical use but this endeavour is still very embryonic. Apart from the need to develop standardized, normed, readily available versions of the existing tasks, there are some serious limitations to using those tasks with clinical populations:

1. They virtually all require intact speech and/or motor response capacity, but many brain-impaired individuals cannot speak quickly or clearly and/or have slowed or restricted motor capacity.

2. Most of these tests are restricted in the range of attentional capacity that they measure. Optimal clinical use of attentional measures requires being able to monitor a patient's progress or deterioration at both high and low levels of functioning.

From these considerations emerged the aim of the

present study, namely developing a measure of information processing that covers the range of attentional capacity, and accommodates the response deficits common in clinical populations.

Devising a Clinically Appropriate Measure of Attention

Originally the intention was to develop the new attention task on patient populations because the task is ultimately designed for clinical use. Unfortunately it was not possible to gain access to patients in sufficient numbers to develop or validate the procedures with this population. It was necessary, therefore, to find a meaningful way of evaluating the new task using university students. Before this situation became apparent, the PASAT had been chosen as a task against which to gauge the appropriate upper level for the new task. Once the possibility disappeared of validating the new task against some real-life index of patient attentional functioning, it was decided to conduct some validity exploration of the new task by comparing it to the PASAT. Given its significant role in the development of the new task, it is appropriate to discuss the PASAT in some detail.

The Paced Auditory Serial Addition Test (PASAT)

The PASAT has been demonstrated to be sensitive to very minimal degrees of brain dysfunction (Gronwall & Sampson, 1974; Gronwall & Wrightson, 1975; Levin, Handel, Goldman, Eisenberg, & Guinto, 1985), to relate to the patients' experience of symptoms and their functioning as perceived by others (Gronwall, 1976a; O'Shaughnessy, Fowler, & Reid, 1984), to reflect response to attentional training (Sohlberg & Mateer, in press), and to indicate readiness to return to work (Gronwall, 1977; Gronwall & Wrightson, 1974). The very careful and systematic work by Gronwall & Sampson (1974) established that the PASAT measured some central information processing capacity of a similar kind to that manifesting on reaction time and divided attention tasks and was not attributable to peripheral sensory registration or motor response capacity. Although it is a better predictor of subsequent memory difficulties than post traumatic amnesia (Gronwall, 1981), the PASAT is not primarily a memory task itself (Gronwall & Wrightson, 1981) nor is it associated with intelligence, at least for the average-and-over range (Gronwall, 1976b). Work by Rabbitt and colleagues (Rabbitt, 1981, 1982) also supports the notion that this task is a good measure of information processing capacity. These findings all contribute support to the construct validity and external criterion validity of the PASAT. Some idea of its intuitive appeal or face

validity can also be gleaned from its use in a wide range of other studies. Examples include studies of anaesthetic drugs (Seow, Roberts, Mather, & Cousins, 1981), mountain sickness and an antidote drug (White, 1984), lithium and physostigmine (Telford & Worrall, 1978), the effects of night duty on doctors (Leighton & Livingston, 1983), and the effects of migraine (Zeitlin & Oddy, 1984).

The strengths of the PASAT as a measure of information processing capacity are the reason for its use as a kind of model from which the new task was derived and as a sort of standard with which to compare and evaluate the new task. However, it also has some weaknesses that the present task was designed to overcome. One problem with the PASAT is its heavy demand on fast speech responses, a feature that prevents its use with dysarthric or other speech impaired patients. It is a very sensitive test of deficit in mildly injured patients and is quite a demanding and frustrating test for normal people. Thus, it is not always appropriate cognitively or emotionally for low functioning patients (Eson & Bourke, 1982). Another criticism is its mathematical content. Gronwall and Sampson (1974) state that serial addition correlates only .24 with arithmetic ability and this is probably so given the very elementary level of arithmetic skill required for the PASAT, that is, adding two single-digit numbers. However, in the present investigator's experience, individual differences occur

with respect to how quickly and accurately people can carry out even this elementary level of adding. Some people do it automatically as if they have memorized the answers and no longer need to stop and think, whereas others have to use their fingers, and many are somewhere in between these two extremes. Particularly in the group of somewhat impulsive young men who are most prone to closed head injuries, it is not safe to assume that they were competent at elementary addition prior to their injury.

The Attention Capacity Test (ACT)

The new task is called the Attention Capacity Test (ACT). Like the PASAT, it involves focused attention to auditory, sequentially presented numbers and to numerical processing. It was designed with the aim of rectifying some of the problems of the PASAT while retaining the useful component of assessing information processing capacity. There are eight levels of difficulty. For the first level, the person only has to repeat or otherwise indicate recognition of a single number. The remaining seven levels involve the person tracking and counting target numbers presented in increasingly complicated series. The upper level of the ACT was designed to be of approximately the same degree of difficulty as the PASAT. Although the person must mentally track the stimuli numbers, select out and count the specified targets at the

speed of stimuli presentation, they only give one response at the end of each trial rather than responding while they process the stimuli as in the PASAT. Thus there is no need to constrain the mode or speed of responses. How quickly or slowly a person answers in no way helps or hinders the actual task of counting targets. The answer is always in the range from 1 to 10 and thus constitutes a multiple choice format. This format allows for flexibility in the way the person communicates their answer. For example, the person can say the number that is their answer or point out their answer on a number card or even use eye-blinking or other simple motor responses to indicate "yes" when the examiner says or points to the appropriate answer. At no time is it necessary for the person to count beyond 10 and clinical experience suggests that this is a far more automatic, well-entrenched skill for most brain-impaired patients than is accurate addition.

Both the ACT and the PASAT measure information processing capacity, but whereas the PASAT increases the demands on this capacity by increasing the speed of stimulus presentation while maintaining a constant level of task complexity, the ACT increases task complexity while maintaining a constant speed. Either approach is appropriate to assess the amount of processing per unit time that a person can manage. The target complexity (rather than speed) approach to measuring attentional

capacity was chosen for the ACT because it allowed a wide range of capacity levels to be measured. In order to devise a counting task that was of similar processing demand to the PASAT, it was found appropriate (during pilot work with graduate students) to use a target stimulus of two numbers separated by another number and forming a set sequence (eg. 5, another number, 8).

Such a target allows the use of overlapping targets and use of target numbers in the wrong order, thus demanding a substantial amount of processing in order to discriminate targets from nontargets (e.g., the sequence 582558885658588558 contains four such targets). To simply slow down the presentation rate of this sort of task would not have sufficiently reduced its processing demands for low functioning patients because substantial slowing would have increased the memory factor involved in the task without significantly reducing the difficulty of discriminating targets from nontargets. The value of presenting each complexity level at two different speeds was considered but rejected because it would have made the test impractically time consuming. So target complexity alone was used as the way of manipulating information processing demands.

Because the PASAT appeared to require a minimal digit span of three, the present task was also designed to that criterion at its most difficult level. The ACT was also

designed to parallel the PASAT in other ways. Both tasks involved controlled, focused attention to aurally presented sequences of numbers, selecting the appropriate numbers to process, and dividing attention between stimulus selection and numeric processing (counting for ACT and adding for PASAT). In both tasks the two components of stimulus selection and numeric processing involve numbers and so are prone to confusion with each other. Neither task addresses the measurement of attentional shift. The PASAT trials are identical in every way except speed. Although some change of target is required across the levels of the ACT, every effort has been made to minimize these changes and to give adequate instruction and practice for the person to adjust to these changes before measurement is begun.

Having introduced the information processing approach to measuring attention, the problems with existing measures, and a task (ACT) that is intended to overcome these problems, it is now appropriate to formulate the hypotheses of the present study.

Hypotheses

Because the PASAT has acquired certain support for its validity as a clinically sensitive measure of processing capacity and because of its similar nature to the ACT, it

was hoped that the validity of the ACT could be established to some degree by demonstrating that it correlates positively with the PASAT:

Hypothesis 1. There is a positive relation between performance on the ACT and the PASAT.

However, because there are also differences between these two tasks it is not expected that this relationship will be extremely high. Differences between the two tasks are: (a) ACT target numbers are distinguished from other targets by value and sound (e.g., 8's are targets but other numbers are not) and, only at the most difficult levels by sequential position as well as value and sound. On the PASAT all number stimuli are targets at some stage, the targets at any particular time being determined by recency position in the sequence. (b) The ACT involves counting whereas the PASAT requires adding. (c) The PASAT requires more constant numeric processing of stimuli (all numbers are to be added) whereas the ACT only requires numeric processing of some of the stimuli (count the targets). (d) The ACT allows unspeeded response whereas the PASAT requires paced responding. These differences may lower the positive correlation between the two tasks but the degree

to which they may do so cannot be predicted at this stage.

In order to get some clues as to which of these factors may be important, subjects will be asked how they went about doing each level of the ACT and PASAT. After completing both tasks, they will be asked to indicate the main similarities and differences between the two tasks, which one they found more difficult, and whether they found the final (hardest) level on the ACT easier or harder than the first (easiest) level of the PASAT.

The possibility that the adding skill requirement of the PASAT could be a significant factor will be investigated. It is reasonable to assume that people who can add accurately are also able to count but not to assume the reverse necessarily applies. It is therefore possible that the higher arithmetic demands of the PASAT may constitute a component of the task that is somewhat independent of information processing capacity and thus reduce any positive correlation between this task and the ACT. To investigate this possibility, an Adding Test was devised in which the subject is asked to add two numbers together and, as soon as they have given their response, the next two numbers are presented, and so on, for one minute. The additions are of the same elementary level as those of the PASAT. If arithmetic skill is a factor in the PASAT but not in the ACT, then the Addition Test would be more likely to correlate positively with the PASAT than

with the ACT. Because some general ability factor or attentional component may be present in all three tests, even the adding test, it cannot be predicted that this latter test will have no correlation with the ACT.

Hypothesis 2. Adding Test performance is more positively related to PASAT performance than to ACT performance.

As previously stated, the minimal memory span required for both the PASAT and the most difficult level of the ACT appears to be three digits remembered in order of presentation. All normal people have at least this span. However, it was possible that the longer a person's span, the easier such tasks may be. The Digits Forward test (Wechsler, 1981) was therefore included in the present study with the expectation that it might show a moderate relationship with performance on both tasks.

Hypothesis 3. Digits Forward performance is moderately and positively related to both ACT and PASAT performance.

A more pertinent consideration with respect to memory factors on the ACT and PASAT tasks is that of working memory. To the extent that both these tasks involve mental manipulation of the presented numbers, they involve working memory rather than just passive memory span. The Digits Backward test (Wechsler, 1981) is a measure of working memory span in that it requires the person to repeat numbers in the reverse order to that in which they were presented. No study could be found that evaluated the Digits Backward test as a measure of working memory per se. Rather, the literature pertaining to both Digits Forward and Digits Backward tests seemed preoccupied with debate as to whether these two tasks are differentially linked to language and/or visuospatial skills or to general cognitive deficit (e.g., Banken, 1985; Bender, 1979; Black, 1983; Costa, 1975; Hoosain, 1979; Weinberg, Diller, Gerstman, & Schulman, 1972). There has also been some concern as to whether each measure is related to left or right hemisphere processing (e.g., Kim, 1976; Kim, Royer, Bonstelle, & Boller, 1980; Newcombe, 1969) and which part of the hemisphere is crucial (e.g., Gordon, 1983; Newcombe, 1969). Finally, there is controversy as to whether Digits Backward (Costa, 1975; Lezak, 1979) or Digits Forward (Black & Strub, 1978) is the more sensitive measure of brain dysfunction. None of these issues have been unequivocally resolved.

For present purposes, therefore, the fact that Digits Backward appears to involve more mental manipulation than Digits Forward will be accepted at face value. Digits Backward is included in the study to see whether this working memory measure is in anyway positively related to performance on the ACT or PASAT;

Hypothesis 4: Digits Backward performance is positively related to performance on the ACT and PASAT.

METHODOLOGY

General Overview

The aim of the experimental design was to facilitate comparison of the ACT with the PASAT and, secondarily, to see how adding skill, immediate and working memory measures related to performance on these two tasks. Other considerations that were incorporated in the design were possible sex, age, order, and time of day effects. Subjects were also screened for background factors that might have influenced their attentional capacity.

Overview of the Experimental Session

The tasks were given in the following order:

1. Digits Forward
 2. Digits Backward
 3. Adding Test
 4. ACT (or PASAT)
 5. PASAT (or ACT)
 6. Background Questionnaire
- } order counterbalanced across subjects

The session lasted about 1.5 hours. A five minute break was inserted between tasks 4 and 5. During this break, subjects left the testing room and were encouraged to walk around or do whatever would best mentally refresh them.

Order Effects

The PASAT is normally administered beginning with the slowest level and working towards the hardest level. The ACT has been designed to be given in the same way. Proceeding in this manner allows patients to gain some confidence in coping with the basic task requirements before being required to perform under more demanding conditions. Given that the central purpose of this study was to compare the ACT with the PASAT, it seemed appropriate to administer both tasks in order of their normal clinical use rather than varying the order to investigate or counterbalance possible within-task order effects. As Murphy and Puff (1982) point out, this approach of using the same sequence for all subjects highlights interindividual differences by eliminating error variance due to order effects. However, the order in which the two tasks, PASAT and ACT, were administered was counterbalanced to control for any possible between-task order effects and thus to facilitate comparison of the two tasks. Half the subjects were given the ACT first and the

other half were given the PASAT first.

The order of the other tasks remained constant: Digits Forward and then Digits Backward followed by the Adding Test. Because these tests were being considered primarily in relation to the ACT and PASAT rather than to each other, it did not seem necessary to counterbalance order effects among them.

Sex Effects

It was not expected that sex would influence performance on these tasks. However, it seemed advisable to check this assumption, particularly as most (if not all) the PASAT development has been done on males. Half of the people who did the ACT first were males and half were females and there was a similar sex division for those subjects who did the PASAT first.

Age

Gronwall (1977) reported that PASAT mean scores were stable across the age range of 14 to 55 years, but that the interindividual variance increased above 40 years and that there was a $-.24$ correlation between age and performance among concussion patients. In light of this finding, age was allowed to vary in the current study. Age of subject was recorded so that it would be possible to see if it correlated with performance for the present group but there

was no attempt to obtain equal numbers for each age group. It was expected that using university students as subjects would mean that the bulk of subjects would be in the 17 to 25 year range which was also the main group studied in Gronwall's work.

Time of Day

The time of day at which the subject participated in the experiment was noted to see whether this factor might affect performance.

Screening

Subjects were also asked to complete a brief questionnaire concerning recent sleep pattern, drug and food intake, and any history of brain injury or disease. The main purpose of this questionnaire was to detect any cases where performance could have been grossly affected by one of these factors.

Subjects

Subjects were 64 people aged between 17 and 45 years. All had some tertiary education and most were currently pursuing undergraduate courses at the University of Victoria. There were 32 males and 32 females. The average

age was 23 years, and 90% were aged 30 years or less. A small lottery was held at the end of the study for participants but otherwise they were unpaid volunteers. The majority were recruited via the Psychology Department's subject pool and a few had indicated to other researchers willingness to participate in further studies. Most of them had studied at least some first year psychology.

Apparatus and Conditions

Testing Situation and Conditions

The experimental session was held in a regular research office which contained two tables, a few chairs, and a waste-paper bin but otherwise no furniture, pictures, or even a window. The walls and floor were grey and the general tone of the room was rather drab. Hallway noises occasionally penetrated the room but did not affect subjects' performance.

Apparatus

In the actual testing situation, the only apparatus present were two ordinary portable audio tape-recorders, some 60 minute tapes, a digital stopwatch, the various record forms and test instruction notes used by the experimenter, and a ball-point pen.

The stimuli used in the ACT, PASAT, and two digit span tests were pre-taped. These tapes were produced via a computerized procedure that enabled each number to always be pronounced the same way, all numbers to be of similar loudness and within 500 ms duration, and speed of presentation to be accurately controlled. The task stimulus tapes actually consisted of various sequences of the numbers 1 to 10 and, in the case of the ACT, some buzzer sounds and "ee" sounds. The 10 numbers, buzzer, and "ee" sounds were tape-recorded, played through a bandpass filter (150-3800 Hz, 48 Db/octave), adjusted for equal peak amplitudes, and digitized (12 bit resolution at 10,000 samples per second) using an analog to digital converter (Data-Translation 2801-A in an IBM-PC). These digitized stimuli (within 500 msec duration) were then reproduced with a digital to analog converter (the Data-Translation 2801-A), played again through the bandpass filter and taped in accord with programmed instructions in the combinations and sequences of stimuli appropriate for the actual tasks. The buzz sound was taped from the "incorrect" signal of the Halstead Category Test.

Procedures

Information Given to Subjects About the Study

When initially contacted about participating in the study, potential subjects were told that the study was about concentration and that there would be tasks involving repeating numbers they had just heard, counting certain things they would be told to listen for, and doing some very basic addition such as $2+4$ or $6+7$. It was stressed that although the tasks themselves would be fairly simple, the real challenge would be in staying mentally focused and keeping track of what was happening. Subjects were also told that there would be a short questionnaire asking about factors that might affect concentration such as whether they had eaten and slept normally in the last 24 hours, drug intake over the last 4 weeks, and any history of head injuries, loss of consciousness and so on. Any questions they asked about the purpose of the study were answered factually at the end.

General Approach to the Experimental Session

Subjects were tested individually. At the beginning of the session they were warned that they would probably find some parts of the testing very easy, almost too easy, whereas other parts would be a lot more challenging. It

was stressed that the important thing was to do their best - not to give up if things got difficult and not to take the task for granted if it seemed too easy. They were free to withdraw from the study at any stage and were reminded of this at the beginning of the session. No total withdrawal occurred but one subject refused to do one of the tasks (PASAT) although she was quite willing to continue with the others. Her data were retained but not included in the 64 cases used in statistical analyses.

Because the aim of the study was ultimately to develop a clinically appropriate measure, the approach used in administering the tasks was a clinical one. That is, within the limits of standardized procedure, the experimenter tried to respond sensitively to individual needs with respect to explaining task requirements, answering questions, and supporting and encouraging the person's efforts. Any comments they offered about the tasks or their own experiences and ideas about attention were responded to as of interest to the experimenter. If they expressed a concern about doing poorly, individually adjusted reassurance was given. At the end subjects were encouraged to ask any questions about the study. If they asked about how their performance compared with that of other participants, they were answered objectively but with emphasis on the best aspects of their performance rather than on the relatively weak areas.

Digit Span (Forward & Backward)

The instructions and items for these two tests were taken from Wechsler (1981) and are detailed in Appendix 1. For the present study the items were audio-recorded to enable greater consistency of administration across subjects and the instructions were modified to direct the subject's attention to the taped voice rather than to the experimenter's "in vivo" voice.

Digits Forward. Subjects were required to listen to a series of numbers presented at the rate of one per second and, immediately after the series finished, to repeat it from memory in the correct order. There were seven different lengths of these number series, ranging from three numbers through to nine numbers. Two trials were given for each of the seven lengths. The test was discontinued if the subject failed both trials of a given length. The score was the total number of trials the subject got correct (maximum possible score = 14).

Digits Backward. Subjects were required to listen to a series of numbers presented at the rate of one per second and to repeat them back in the reverse order to that

presented. Again there were seven lengths of numbers but this time they ranged from two through eight numbers in length. Discontinuing and scoring procedures were the same as for Digits Forwards.

Adding Test

The subject was required to add two numbers to answer a sum presented aurally by the experimenter (e.g., "two plus three"). As soon as the subject answered one sum, the next one was presented. Each sum was delivered within a one-second time interval. So that this task could be paced to fit the subject's response speed, it was administered by the experimenter and not by tape recorder. The numbers constituting each sum ranged from 1 through 9 (the same range as used in the PASAT). The test itself lasted for one minute. It was introduced to subjects as a speed and accuracy task rather than one of mathematical ability. Practice was given to ensure the subject understood what was required and it was stressed that the best approach was to forget an answer as soon as it was given so as to be ready for the next sum and to only alter answers if this could be done quickly. See Appendix 2 for instructions and items. The score was the total number of correctly answered sums.

Attentional Capacity Test (ACT)

All test items of this task were presented via audio tape in order to maintain consistency and ease of administration. However, the short practice examples and instructions given prior to each section of the test were presented personally by the experimenter so as to allow flexibility in ensuring that individual subjects comprehended the task requirements.

The test consisted of eight sections or levels, the main features of which are described here but more detail is presented in Appendix 3 for instructions and Appendix 4 for test items:

Level-1. On this task the subject was asked to repeat single numbers. The numbers 1 to 10 were presented in mixed order, making a total of 10 trials. The purpose of this task was to make sure the subject could hear the numbers easily and clearly. If necessary, the volume was adjusted in accord with individual need. In a patient group this task would also serve as a test of low level attentional functioning.

Level-2. The subject was required to count the number of "ee" sounds in a series of such sounds. The number of

these "ee" sounds ranged from 1 through 10 in mixed order, making a total of 10 trials. The purpose of this task was to see if subjects had sufficient processing capacity and counting skill to be able to count a series of sounds.

Level-3. This task was identical to that of level-2 except that instead of counting ee's, the subject was required to count 8's. The purpose of this task was to see whether the subject was able to count sounds when these sounds were numbers or whether confusion resulted from both the stimulus and mental count being numerical. This task also introduced the subject to the number that constituted the target for level-4.

Level-4. Here the subject was presented with a mixture of the numbers 1 to 10 in mixed-up order and had to count the 8's. That is, the task became one of focused attention in that the subject had to differentiate targets from nontargets and the combination of this target selection activity with the counting made the task one of divided attention. The demands of the selection-of-target component were gradually increased through subsequent levels. There were six scored trials.

Level-5. This task was identical with level-4 except that the subject had to keep track of two targets, 8 and 5. They counted the combined number of 8's and 5's to yield one total.

Level-6. In this task the subject was required to monitor four target numbers, 8,5,4, and 7 and to report the combined total of these targets.

Level-7. Here the target numbers were the same as in level-6, but they only counted as targets if they occurred in the sequential pairs, 4 followed by 7, or 5 followed by 8. Each pair counted as one target. Thus target selection was made more complex by the fact that if the target numbers 4,5,7, and 8 occurred alone or in the wrong order they did not count as targets.

Level-8. This time the target was the sequence of 5, another number, then 8. Here the detection of targets was made difficult by the sequencing aspect and also by the fact that the intervening number was not constant but could

be any number from 1 through 10, including another 5 or another 8. This meant also that targets could overlap, that is, the sequence 5588 includes two targets. Subjects were told about this overlap and given practice in recognizing it prior to doing the scored trials.

Having described the way in which processing demands were increased across succeeding levels, some of the more general aspects of task format are now described.

Levels 1 to 3 each consisted of 10 trials and levels 4 to 8 of 6 trials each, making a total of 60 trials for the whole task. In levels 4 to 8, the total number of targets was 30 for each level. The stimulus sequences for each trial of levels 2 to 8 were presented at the rate of one stimulus per second. The duration of the actual stimulus was always within 500 ms. The choice of the one per second speed was derived during pilot work when it was noted that half-second speed made level 8 too difficult and that a 2-second speed doubled the length of the whole task making it far too long. One-second speed was chosen as the best compromise. Each trial of levels 4 through 8 consisted of 25 numbers.

At level 1, a double buzz sound preceded the stimulus number by 2 seconds and this warning signal also preceded each trial throughout the remainder of the levels. For

levels 2 through 8 there was also a single buzz sound one second after the final stimulus of the trial to let the person know that the stimuli had finished and it was time to give their answer. There was a five-second gap between this single buzz and the double buzz warning that the next trial was about to start. Usually this five-second gap was plenty of time for subjects to give their answer. However, if they did not answer within this time, the tape was stopped to allow them more time. The time taken by subjects to complete each level was recorded so as to gain some idea of the normally required time for later contrast with patient times. If the six trials were completed straight through, this time was approximately 3 minutes 23 seconds. As well as delays caused by slow answers, it was occasionally necessary to stop the tape to answer a subject's query, allow them to comment on the task, or to reassure subjects having difficulty with the task. However, in only one instance did the delays cause the total time to go beyond 4 minutes. Subjects were told they could request the tape to be stopped between trials. This instruction was given to allow subjects some sense of control so that they would not feel unduly stressed or steam-rollered by the task. Although the ACT was designed to permit various response modalities, the subjects of the present study were all able to use speech to communicate their answers. The ACT typically took about 45 minutes

from start to finish.

Subjects were instructed to count mentally, that is, not aloud and not by moving their fingers as a means of keeping a tally. They were required to keep their hands on the table so that the experimenter could check that they were not finger counting. The reason for this condition was to make the task as "mental" as possible so as to maximize the information processing load and the divided attention component of the task. At no time did the person ever have to count beyond 10. Subjects were informed that the answer would always be between 1 and 10 inclusive. When occasionally a response was given outside this range, the subject was reminded to stay within the specified range. The forcing of responses was necessary to maintain the same multiple-choice format that would occur if the responses were made by pointing to a number card or some other procedure. Subjects were advised that should they lose track in their mental count, they should not start thinking about whether they had made a mistake but rather should continue their count with the next target and if they were unsure of the exact answer then they should give their best estimate. Subjects were required to answer all items. In only one instance was it necessary to repeat a trial because the subject claimed he had been thinking about something else and had not even a vague idea of the answer.

After completing each of levels 4 through 8, subjects were asked to describe how they went about doing the task. Their descriptions were recorded. Any spontaneous comments they made with reference to trials 1 to 3 were also noted.

Before starting each level (from 2 to 8), short practice examples were given. That is, the practice examples were similar to but much shorter than the actual trials. The aim of such practice was to ensure that subjects comprehended the task requirements. Three practice examples were used at each level. These were presented twice or until the subject got two consecutive examples correct, whichever occurred first. All subjects in the present study succeeded in getting two consecutive trials correct within the six practice trials. The first time a subject made a mistake on the practice trials of a given level, the experimenter told them that their answer was not quite right and encouraged them to listen more carefully and the example was repeated. This prompting was done only once at each level and a correct response to such a prompt was not counted as one of the two consecutive correct responses. At level 8, an extra set of practice examples was used to give the subject familiarity with target overlaps. Here the prompting for the first mistake involved visual as well as auditory cuing. One subject only got one example of this sort correct but did so twice and all others got two consecutive examples correct within

six trials.

Although there were only six scored trials at each of levels 4 through 8, eight full-length trials were actually given. The first two trials were treated as "warm-up" trials in which the person acquired a familiarity with the task. The subjects were not told that these trials were unscored and from their point of view these first two trials formed part of the real task. The reason for not informing subjects fully in this respect was because during piloting it had been found that such information resulted in the person not taking the trials seriously and thus failing to benefit from the practice opportunity they afforded.

Scoring. At each level, the number of correctly answered trials was recorded, the maximum possible score for the whole test being 60.

Paced Auditory Serial Addition Test(PASAT)

This task required the subject to listen to a sequence of numbers and add each number to the previous one in a continuous number (for example, the correct responses to the sequence 1,9,6,3 would be 10,15,9). The nature of the task was explained to the subject using a written example in order to help them comprehend the concept of serial addition. They were then given unpaced practice with the auditory form of the test, then paced practice with stimuli

presented at the rate of one number every 2.4 seconds. The numbers ranged from 1 through 9, and each number lasted 500 ms or slightly less. If necessary, further explanation and written demonstration and unpaced practice were given to ensure that the subject had fully understood what was required. The procedure was based on that of Gronwall (1977; personal communication to Cindy Wilson, 14 October, 1983). Gronwall's instructions were slightly modified to give more emphasis on advising the subject how to cope with losing track on the task. This modification was necessary in order to prevent performance being lowered by anxiety rather than by limited processing capacity. Instructions and items are presented in Appendix 5.

The four test trials each involved the same 60 addition sums in the same order but at increasing speeds. The first trial presents numbers at the rate of one per 2.4 seconds, the second at 2.0 seconds, the third at 1.6 seconds, and the fourth at 1.2 seconds. The subject had to respond before the next number was presented in order to be scored correct. An interval of at least 60 seconds was inserted between trials and during this time subjects were asked how they went about doing the task and their comments were written down. Because it was difficult to score subjects accurately at the two fastest trials, these trials were taped using a second tape recorder. These tapes were erased once the scoring had been checked.

The score used in the present study was the number of correct responses (maximum possible for each trial = 60). This procedure was different to that of Gronwall (1977) who used the time per correct response (time of trial divided by number of correct responses). The number of correct responses was preferred because: (a) it was compatible with the measures used on other tasks; and (b) it did not require transformations to remove the curvilinear component that time scores produced in correlations with other data. Gronwall (1977) also discarded any trials on which the time score differed by more than 0.6 from others. In the present study, however, it was considered appropriate to retain all scores. Outlying scores appeared to reflect genuine performance variations and, given that the study concerned individual differences, there appeared to be no good reason to exclude such scores.

After both the ACT and the PASAT had been completed, subjects were asked in what way they found the two tasks similar and different, and whether they found one task more difficult than the other both generally and comparing level 8 from the ACT with the slowest (first) level of the PASAT.

Background Questionnaire

Subjects were asked to complete a brief questionnaire (see Appendix 6) asking about factors that might affect their concentration. The anonymity and confidentiality of

this questionnaire were stressed. Information requested included age, sex, educational and occupational status, usual language of numeric processing, whether the person had slept and eaten normally in the last day, drug intake over the last four weeks, and any history of loss of consciousness, brain injury, or brain disease. The drug-intake question included alcohol, illegal recreational drugs, and medical drugs. It did not include coffee, tea, tobacco, aspirin, or contraceptive pills. This question was aimed at detecting any unusual drug use that might have affected the person's performance during the experiment. The term "unconscious" was explained to subjects as including any lapse of consciousness whether caused by head injury, anaesthetic, fainting, or passing out from alcohol consumption in a fairly sudden manner (i.e., not just falling asleep because of natural fatigue in combination with alcohol). Brain injury was defined to include even mild concussion which was described to subjects in terms of disorientation, memory lapse, and difficulty concentrating following a head injury. No instance occurred in which these factors appeared to grossly affect performance. It was, therefore, not necessary to eliminate any subject on the basis of this screening device.

RESULTS

The main goals of the present analysis were to find out if the ACT related positively to the PASAT, if the Adding Test was more positively related to the PASAT than to the ACT, and whether the two digit span tasks were positively related to the ACT and PASAT. Before examining the relationship of the ACT to these other tasks, however, it was appropriate to examine the measure itself with respect to its reliability and the degree to which its multiple choice format encouraged guessing.

Reliability of the ACT

Cronbach's alpha was computed for all 60 ACT items and this measure of average inter-item correlation was 0.721. This estimate of internal consistency was based on only 36 of the 60 items because the other 24 items were perfectly performed by all subjects and so had zero variance and could not be correlated with each other. This alpha level indicates a moderately high positive interrelationship between items. The fact that it was not higher was

probably due to the nature of the task in that: (a) a number of items included in the alpha computation have very little variance; and (b) some items are meant to be harder than others both across and within levels (see Appendix 7 for an overview of subject performance). These features of the ACT, however, are actually desirable ones given the need for a wide range of difficulty levels and the fact that the present normal sample should not have been expected to show much variation on the easier items. Given these task-specific considerations, the Cronbach alpha value of 0.721 was accepted as constituting quite a strong indication of internal consistency.

Guessing on the ACT

The multiple-choice format of the ACT meant that subjects knew the answer should always be somewhere from 1 to 10. They were also obliged to give some response to each item. Allen and Yen's (1979) formula for estimating guessing in such forced and multiple-choice circumstances involves regarding the number of mistakes as evidence of the amount of guessing that is being used to perform the task. This number is divided by the number of possible choices minus one (in this case $10-1=9$). The lowest score obtained by any individual in the present sample was 45 out

of 60. That is, this person made 15 mistakes and thus may have got 1.67 items (of the 45) correct by guessing. This was a very low level of guessing and the other subjects were even lower. It did not seem that guessing played a significant role in the obtaining of correct answers. It was therefore considered unnecessary to correct answers for such a small proportion of guessing.

Having established that the ACT seemed to be a reasonably reliable measure and not significantly determined by guessing, the next step was to reduce the various task measures to a more appropriate number.

Reducing the Number of Measures

Altogether there were 15 measures: 8 ACT measures, 4 PASAT measures, 1 Adding Test measure, 1 Digits Forward, and 1 Digits Backward measure. The tasks that yielded multiple measures were the ACT and the PASAT. In order to facilitate interpretation of inter-task relationships, the original intention was to use as few measures as were meaningful. Because of the exploratory nature of the study, it was not possible to predict initially which would be the appropriate ways of reducing the number of ACT and PASAT measures. Therefore, these tasks were examined with respect to the redundancy of their measures and reductions

made on this empirical basis.

Reduction of ACT Measures

Because the ACT was designed to test a wide range of attentional capacity, it was possible that the normal subjects of the present study would only show variability at the upper one or two levels of the task. The range of scores at each ACT level is shown in Table 1.

Table 1
Percentage of Subjects Achieving Each Possible Score for Each ACT Level

	Possible scores (Levels 1 to 3)										
	0	1	2	3	4	5	6	7	8	9	10
Level 1											100
Level 2								1.6	4.7	12.5	81.3
Level 3									1.6	3.1	95.3
	Possible scores (Levels 4 to 8)										
	0	1	2	3	4	5	6				
Level 4						4.7	14.1	81.3			
Level 5						10.9	37.5	51.6			
Level 6					7.8	20.3	28.1	43.8			
Level 7		1.6	6.3	6.3	21.9	15.6	17.2	31.3			
Level 8		4.7	12.5	20.3	28.1	17.2	15.6	1.6			

Note. ACT=Attention Capacity Test

Although there was some variability at all levels except the first, it can be seen that the variance and range of scores tended to increase with the level of processing increments. The only exception to this gradually increasing range occurred at levels 2 and 3. Mistakes at these levels appeared largely due to the subject confusing the final buzz sound with the items to be counted. Usually subjects made this mistake at level 2 but had learnt to avoid it by level 3. Hence the slight reduction in variability at level 3 relative to that at level 2. As expected, it was at levels 7 and 8 that subjects showed the greatest variance. These were also the levels that showed the most tendency to correlate with other levels of the test (see Table 2). The generally moderate size of even these statistically significant correlations is probably partly attributable to low variance. Even on levels 7 and 8, the range of possible scores was only 0 to 6.

The question therefore arose as to whether only scores from the two upper levels should be used to compare performance on the ACT with performance on other tasks. This step, however, would have eliminated quite a lot of information about individual differences in ACT performance. For example, 22% of subjects (14 out of 64) showed some difficulty on levels 2 or 3. Rather than losing this information, it was considered more appropriate

to reduce the number of measures by adding all eight scores together to give one total score out of 60.

Table 2
Inter-level Correlations for the ACT

Levels	1	2	3	4	Levels 5	6	7	8
1	1.000	.000	.000	.000	.000	.000	.000	.000
2		1.000	.248	.146	-.003	.164	.100	-.001
3			1.000	.006	.048	.070	.313*	.064
4				1.000	.269*	.159	.257*	.043
5					1.000	.189	.151	.299*
6						1.000	.433*	.429*
7							1.000	.393*
8								1.000

* $\leq .05$ (2 tailed tests).

Note ACT=Attentional Capacity Test

The advantages of this measure were that it (a) allowed retention of data contributed by all levels of the task; (b) provided a wider possible range of scores than could be gained from one or two levels; and (c) reduced the number of ACT scores from eight to one. A further potential advantage of this total score (one that reaches beyond the immediate experimental aims of the present study) was that it provided normative information against which a wide

range of patient performance could be evaluated. That is, even poorly functioning patients could be considered with respect to how many items they get correct out of the possible 60, whereas if only the upper level measures were used as a standard, then some patients might not score at all.

Reduction of PASAT Measures

PASAT measurements were taken at four different levels of task demand. Subjects showed high inter-level correlations of scores (see Table 3). It therefore

Table 3
Correlations Between the Four PASAT Levels

PASAT levels	PASAT levels			
	2.4	2.0	1.6	1.2
2.4	1.000	.859*	.731*	.625*
2.0		1.000	.879*	.781*
1.6			1.000	.842*
1.2				1.000

* P<.01 (2 tailed tests)

Note. PASAT=Paced Auditory Serial Addition Test

seemed appropriate to add these four scores together to yield one combined score of the total number of correct responses (maximum possible score=240). Such a measure had

the advantage of retaining all the information of the separate level scores and at the same time it further reduced the number of measures. It also constituted an identical sort of composite measure to that used for the ACT.

Reduction of ACT and PASAT measures meant that there were five measures on which to compare subject performance, one measure for each task. The measures were conceptually compatible in that they all involved the number of correct responses. Subject scores on these measures are listed in Appendix 8.

Preliminary Analysis

Although the main purpose of the analysis was to test the four hypotheses, it was appropriate first to check the possible influence of age, time of day, sex, and order effects on task performance.

A canonical correlation was used to examine the relationship of age, time of day, and sex to the five task measures (ACT, PASAT, Adding Test, Digits Forward, & Digits Backward). None of the canonical correlations reached significance at the .05 level. Clearly, there were no effects of age, time of day, or sex on the five task measures. Note that 90% of the present sample were 30

years of age or younger, hardly a sufficiently representative range from which to draw inferences about age and these attentional measures per se. The finding of no age effect was only relevant to the present sample.

The possibility of order effects arose only with respect to the ACT and the PASAT. The ACT was administered before the PASAT for half the subjects and the reverse sequencing of tasks was administered to the other half. A MANOVA was performed for the two orders of the two tasks. No significant order effect was found ($F=0.614$, Wilks test of significance = .545).

Analysis Pertaining to Hypotheses

All hypotheses predicted positive relationships but despite this directional specificity of the hypotheses, two-tailed tests of statistical significance were used. The reason for this conservative approach was that the hypotheses were exploratory rather than tightly linked to some pre-existing theoretical structure. If the relationships had turned out to be negative and nonsupportive of the hypotheses, the investigator would still have been interested in them. The general nature of the relationships was examined using zero-order correlations and then a more precise picture was obtained

using partial correlations.

Zero-order Correlations

A summary of the results pertaining to the four hypotheses is presented in Table 4.

Table 4
Pearson Correlation Results Pertaining to the Four Hypotheses

Hypothesis number	Task Relation	r-value	2-tailed P-value	Conclusion
1.	ACT & PASAT	.4356	<.01	confirmed
2.	Adding & ACT	.1354	>.05	confirmed
	Adding & PASAT	.7020	<.01	
3.	Digits F & ACT	.2743	<.05	confirmed
	Digits F & PASAT	.2398	>.05	rejected
4.	Digits B & ACT	.4636	<.01	confirmed
	Digits B & PASAT	.3785	<.01	confirmed

Note. ACT=Attentional Capacity Test; PASAT=Paced Auditory Serial Addition Test; Adding=Adding Test; Digits F= Digits Forward; Digits B= Digits Backward.

Hypothesis 1. The prediction that there would be a positive relation between the ACT and the PASAT was confirmed. As originally suspected, (see Introduction, p.32), this relationship was not extremely high, accounting for only 18.97% of the variance.

Hypothesis 2. The prediction that Adding Test performance would be more positively related to PASAT performance than to ACT performance was supported. The relationship between the Adding Test and the PASAT accounted for 49.28% of the variance whereas that between Adding Test and ACT only accounted for 1.83%. The difference between the two correlations was statistically significant ($p < .001$).

Hypothesis 3. The prediction that performance on Digits Forward would be moderately and positively related to the ACT was confirmed, such relationship accounting for 7.52% of the variance. However, the prediction that Digits Forward would correlate similarly with the PASAT was not confirmed even though the relationship accounted for only a slightly lower amount of variance (5.75%). The difference between these two correlations was not statistically significant ($p > .40$).

Hypothesis 4. The prediction that performance on Digits Backward would be positively related to performance on both the ACT and the PASAT was confirmed. The relationship between Digits Backward and the ACT accounted

for 21.49% of the variance and that with the PASAT for 14.33% of variance. The difference between these two correlations was not statistically significant ($p > .40$).

The above findings indicated that performance on the ACT was related to performance on the PASAT, Digits Forward, and Digits Backward tests and that it differed from performance on the PASAT in not being related to Adding Test performance. However, this picture of inter-task relationships was based on zero-order correlations that may actually have overlapped with each other. Partial correlations indicate the extent of such relationships when any overlap has been partialled out.

Partial Correlations

A hierarchical multiple regression was performed to examine the way in which the PASAT, Adding, Digits Forward, and Digits Backward tests related to the ACT when their common variance was partialled out. The squared multiple regression correlation (R^2) for all four predictors combined was compared to the R^2 for the remaining three predictors when one predictor was omitted. There were four such comparisons, one for each predictor omitted (see Table 5). The difference between the two R^2 values for each comparison indicated the unique relation of the omitted predictor to the ACT when all common variance with other

predictors had been partialled out. The significance of these comparisons was evaluated by means of F tests.

Table 5
Hierarchical Multiple Regression: Four Predictors Compared to Three Predictors of the ACT by Means of F Tests

	R^2	R^2 -differences	F-value
<u>Four predictors</u>	.373		
<u>Three predictors</u>			
PASAT omitted	.219	.154	14.476*
Adding Test omitted	.295	.078	07.307*
Digits Forward omitted	.372	.002	00.144
Digits Backward omitted	.282	.091	08.592*

* $p < .01$ (2 tailed tests)

Note. ACT=Attentional Capacity Test; PASAT=Paced Auditory Serial Addition Test. The four possible predictors were the PASAT, Adding, Digits Forward, and Digits Backward tests. R^2 difference=the difference between R^2 for the four predictors and that for the three predictors.

Inspection of Table 5 showed that when partial correlations were considered, the ACT had most in common with the PASAT, a significant though smaller amount in common with the Digits Backward and Adding tests, and virtually nothing in common with Digits Forward. It should be noted that the regression coefficient for the Adding Test was negative, indicating that its relationship to the ACT was negative rather than positive.

A similar hierarchical analysis was performed with the PASAT (instead of the ACT) as the dependent or criterion measure. When overlapping variance between predictors had been partialled out, the Adding Test was found to have by far the most in common with the PASAT (R^2 difference=.380, $F=57.646$, $p<.01$) and there was considerable overlap with the ACT (R^2 difference=.154, $F=14.467$, $p<.01$). There was no significant relation between the PASAT and either of the Digit Span tests.

When the four hypotheses were considered with respect to partial correlations, the following picture emerged:

Hypothesis 1. The prediction of a positive relation between the ACT and the PASAT was confirmed, accounting for 15.4% of variance.

Hypothesis 2. The prediction that Adding Test performance would be more positively related to PASAT performance than to ACT performance was supported. The PASAT and Adding Test shared 38% of variance whereas the ACT and Adding Test only shared 7.8% of variance. Note that although the the regression coefficient for the Adding Test was negative in relation to the ACT, it was positive with respect to the PASAT.

Hypothesis 3. The prediction that performance on

Digits Forward would be moderately and positively related to that on the ACT and the PASAT was not confirmed in either instance. Although the zero-order correlation between the ACT and Digits Forward had been found significant (see Table 4), it was small and disappeared once its common variance with other predictors was partialled out.

Hypothesis 4. The prediction that performance on Digits Backward would be positively related to performance on the ACT was confirmed, accounting for 9.1% of variance. The prediction of a similar relationship with the PASAT was not confirmed. Although the zero-order correlation between the PASAT and Digits Backward had reached significance (see Table 4), it disappeared once its overlap with other predictors was partialled out.

Before discussing these findings, some patient data are presented in the next chapter.

SOME PATIENT DATA

The first step towards developing the ACT was taken with normal subjects because it was not possible to access clinical populations in sufficient numbers for this purpose. However, given that the ACT was ultimately designed for clinical use, it seemed important to get some impression of its use with patients. The Good Samaritan Hospital Center for Cognitive Rehabilitation in Puyallup, Washington State, is very concerned with the remediation of attentional problems in brain damaged patients and interested in exploring measures of attentional function. Through the help of the Clinical Director, Dr Mateer, it was possible to administer the ACT to nine brain-impaired patients and to obtain staff ratings of these patients with respect to attentional capacity. The aim of this work with patients was to get some idea of whether the current ACT administration was appropriate for patients, to see whether it discriminated between patients and normals, and to evaluate it against an external criterion of attentional capacity.

Patients

The patients were volunteers from the Good Samaritan Center for Cognitive Rehabilitation. Five were participating in an intensive cognitive retraining program, three were receiving retraining for only two hours per week on an out-patient basis, and one person had already ceased such out-patient training. They were recruited by the Clinical Director who also paid the five patients from the intensive program \$10 each for their participation. Patients were told that participation involved doing an attentional task and that they could find out how they performed on this task from the Clinical Director who would integrate these findings with other information about their general functioning.

The patients consisted of eight males and one female, were aged from 18 to 47 years, were all reported to be right handed except for one person, and varied in educational status from 11th grade to Masters degree. These general background features are detailed in Appendix 9. Six patients had sustained closed head injuries, two had suffered aneurysms, and one had sustained an intracranial hemorrhage as the consequence of being assaulted. Time post injury varied from 7 to 33 months. These injury-related details and information about the patients' rehabilitation program are specified in Appendix 10. The background information about these nine patients

was provided by the Clinical Director.

ACT Procedure

The ACT was administered in the same way as for normal subjects (see Appendix 3) and the procedure appeared to be quite appropriate and acceptable to these patients. All patients, including one fairly dysarthric patient (case 8), were able to respond vocally. The maximum possible number of correct items was 60. A deviation score was also computed for each patient. This score was the amount by which erroneous answers deviated from the correct ones and was totalled across the 60 trials. It was included to see whether it would provide a more sensitive index of patient performance than number correct, given that it had potential for a wider range of scores (maximum possible deviation score would be 353).

Attention Questionnaire

This questionnaire was devised by the investigator and is presented in Appendix 11. It allowed patients' general attentional capacity to be rated on a five-point scale ranging from "none" to "normal". Opportunity was also provided for raters to use half-way points between these five levels, making it potentially a nine-point scale. These half-way points were, in fact, often used by raters. General attentional capacity was defined as the ability to

focus and sustain attention in situations requiring selective and/or divided attention. Raters were asked to evaluate the patients' attentional functioning as it manifested in each of six rehabilitation areas: activities of daily living, cognitive activities, physiological conditioning, psychosocial activities, recreational activities, and vocational activities. These six areas were selected because they were the ones constituting the rehabilitation program. The questionnaire also provided a "no observational opportunity" category of response but this was never used. The questionnaire was presented as a seven-page booklet, the first page giving instructions and the other six pages each containing the rating scale for one of the six rehabilitation areas. The maximum possible score for any area was 5 (indicating normal functioning) and the scores were summed across the six areas to give a total score (maximum possible = 30).

All patients were rated by two staff. The Clinical Director rated all patients on the basis of their neuropsychological test performance plus her general impression of their progress in the rehabilitation programs. Each patient was also rated by a therapist who was involved with the actual retraining of that particular patient. Three therapists participated in making ratings. The questionnaire ratings were not inspected by the investigator until after the ACT was administered and

scored. Feedback about patient performance on the ACT was only communicated to the Clinical Director after she had completed her questionnaire ratings.

Results

Inter-Rater Reliability on the Questionnaire

There was a .934 correlation between the two ratings and the actual values of the scores were also similar to each other, yielding mean totals of 23.92 and 21.22 for therapists and Clinical Director respectively. The two scores were, therefore, combined into one score by adding them together. The maximum possible score for this combined measure was 60.

ACT Scores

The number-correct scores and the deviation scores were found to correlate $-.923$. This correlation did not include patient 9 because he did not complete all levels of the ACT. At the point where testing was terminated because of very poor performance at levels 6 and 7, it was unlikely that his number-correct score would have increased further. However, the deviation score would undoubtedly have increased had testing been continued and so it was not

appropriate to include his actual deviation score in any correlations.

Given the inverse relation between number of correct responses and deviation scores, it was not appropriate to combine them into one score by adding them together. Nor was it appropriate to subtract the deviation score from the total-correct score because this would have exaggerated the negative aspect of the performance disproportionately to the successful aspects. The two scores were therefore considered separately.

Relationship of ACT Performance to Attention

Questionnaire Ratings

The scores for each patient on the ACT and the questionnaire are presented in Table 6. The correlation between number of correct responses on the ACT and the questionnaire score was only .115, a clearly nonsignificant relationship. However, inspection of Table 6 indicated that it was patients 2 and 9 who deviated most from the expected positive correlation between ACT and questionnaire scores. Inspection of the background data contained in Appendices 9 and 10 indicated that neither age, education, time since injury, nor type of rehabilitation program seemed to account for patient scores on either the ACT or the questionnaire. But patients 2 and 9 could be distinguished from other patients with respect to etiology.

Table 6
ACT Scores and Attention Questionnaire Ratings for
Each Patient

Patient ID	ACT scores		Questionnaire Score
	No. correct	Deviation	
1	58	03	57.5
2	51	21	36.5
3	49	17	41.0
4	46	23	45.5
5	46	24	48.5
6	45	26	48.0
7	45	34	38.0
8	44	28	36.75
9	38	34+	54.5

Note. Patient ID numbers also indicate their ranking with respect to number of correct responses on the ACT (with deviation scores used to determine ranks of those showing tied numbers of correct responses).

Both these patients had had aneurysms: patient 2 in the right frontal area and patient 9 in the left hemisphere. Although etiological information is limited, it would seem that these two patients may have differed from the rest in that they had fairly localized brain damage whereas the other cases probably sustained more diffuse damage. When these two cases were omitted, the correlation between the questionnaire and number of correct responses on the ACT was .753 and the correlation between the questionnaire and the ACT deviation score was $-.776$. Both these correlations were significant at the .01 level (2 tailed tests).

It is, of course, inappropriate to come to any firm

conclusions on the basis of such a small number of patients and with such post-hoc elimination of two cases. However, it seems reasonable to suggest that the ACT may measure the sort of attentional deficit that arises from diffuse brain damage rather than that arising from more localized damage. The clinical literature pertaining to the information processing approach to attentional capacity mainly concerns cases of diffuse damage.

Patients 2 and 9 also differed from the other patients with respect to their behaviour during administration of the ACT. In the case of patient 9, it was clear during such administration that language problems were affecting his performance on the task. He had great difficulty retrieving target names. For example, when asked what the targets were for level 5, he had to count from 1 to 8 voicing the targets 5 and 8 more loudly than the nontarget numbers before he could say these two numbers alone. The problem was not one of memory but of retrieving the linguistic symbols. This peculiarly linguistic problem probably accounts for his ACT score being much lower than his rating on the Attention Questionnaire. That is, specific aphasic problems may lower ACT performance for reasons other than generally limited attentional capacity. However, it might be expected that in highly linguistic situations, this patient's effective attentional capacity may be more limited than suggested by his behaviour in

other situations. In the case of patient 2, the opposite pattern occurred in that this patient obtained a much better ACT score than questionnaire rating. It was noted during administration of the ACT that this patient would start making comments just as the next trial was starting and it was necessary to stop the tape and wind it back to accommodate for this tendency. It may well be that had the investigator not adjusted the testing procedure to fit patient 2's idiosyncrasy, he would have been distracted by his own comments and performed at a lower level.

Patients Compared to Normals on the ACT

The mean score for normals was 53 correct and that for patients was 47. The range of scores among normal subjects was 45 to 59, with a standard deviation of 4. Only patient 1 scored above average relative to normals; patient 2 was low-average; patient 3 scored in the bottom 25% of the normal range; four patients scored in the bottom 5%; and patients 8 and 9 scored below 45 which was the lowest score obtained by the normal sample. None of the present group of patients functioned at the level for which the lower ACT items were designed. They in fact scored perfectly or near perfectly on the first four levels (see Appendix 12).

Meaning of ACT Scores

At least for this small sample of patients, the

deviation score did not appear to be a more sensitive measure of ACT performance than the number of correct responses. The two scores were highly correlated with each other and the relationship of each score to the questionnaire score was similar to that of the other.

It is possible that two patients can achieve the same number of correct responses but for different reasons. For example, most patients showed a pattern of declining performance as the processing demands were increased but patient 6 made about the same number of errors on simple levels (e.g., levels 4 & 5) as he did on the more complex ones (see Appendix 12). His problem appeared to be that of sporadic lapses of concentration rather than limited capacity to process information within a given time.

The implications of these clinical findings are discussed in the next chapter, together with those of the experimental study on normals.

DISCUSSION

The aim of the present study was to develop a clinically appropriate measure of attention. Although the difficulty of gaining access to suitable patients meant that development of the ACT had to commence with a young adult population, it was also possible to compare ACT performance and staff ratings of attentional functioning for a small group of patients. The present discussion evaluates what has been achieved and outlines implications for further development of the ACT.

Studies of attentional function in normals and attentional problems in clinical populations, particularly closed head injury cases, strongly indicated that the crucial aspect of attentional difficulty is the amount of information a person can attend to or process within a given time. It was this aspect of attention that the ACT was designed to measure. The primary concern of the present study was to establish whether the ACT does measure information processing or attentional capacity. Performance on the ACT was compared to that on a relatively well established measure of information processing, the PASAT, and also to a simple measure of working memory, Digits Backward. The ACT was found to correlate positively with the PASAT, accounting for 18.97% of variance for

zero-order correlation and 15.4% when PASAT overlap with the other three measures was partialled out. The ACT was also found to correlate positively with Digits Backward, accounting for 21.49% of variance for zero-order correlation and 9.1% when Digits Backward overlap with the other three tests was partialled out. Although the amount of unique variance shared by the ACT and these two tests was less than for zero-order variance, it was still statistically significant ($p < .01$, 2 tailed tests). These findings confirmed the potential of the ACT as a measure of attentional capacity. The ACT was also found to be a reasonably reliable measure with no significant susceptibility to guessing.

The fact that the relation between the ACT and the PASAT was only of moderate rather than large proportion may well have been due to the PASAT measures being contaminated by extraneous factors. The PASAT was highly correlated with the Adding Test, accounting for 49.28% of variance for zero-order correlation and 38% when Adding Test overlap with other measures was partialled out. The PASAT was more highly associated with Adding than with any other test. This high association between the PASAT and the Adding Test may have been due to either or both of two factors: (a) speed and accuracy of adding skill and (b) speed of speech response. The ACT avoided both these sources of possible contamination by having nonspeeded responses and by not

using adding. The ACT thus appears to be a purer measure of attentional capacity than the PASAT. Certainly this would be so with respect to addition skill but whether the speeded response requirement should be considered a contaminant is not quite so clear. At this point it is necessary to reconsider the definition of attentional capacity. So far, this term has been used synonymously with information processing capacity or working memory and the ACT has been regarded as a measure of this capacity, differing only from other such measures in its minimization of response demands for pragmatic clinical purposes. However, there is also a theoretical consequence of this procedure. The ACT focuses measurement of processing capacity on the input end of the informational flow and relatively neglects the output end. It requires the person to listen to and mentally process the stimuli and to give only a single, unspeeded response after this processing of input is completed. Most other measures of information processing (e.g., reaction time, PASAT, Continuous Performance Test, cancellation tests, and so on) involve more equal emphasis on both ends of the processing system. They require an overt response to each target stimulus as it occurs and, in most cases, the response is a speeded one with speed comprising part of the processing measure.

Subject comments about the ACT and the PASAT generally lent support to the claim that the upper level of the ACT

was similar in processing demands to the PASAT and that the lower ACT levels required less mental processing than the PASAT (see Appendix 13). Suggestive as these comments might be, the question of the appropriateness of the ACT shift in processing emphasis toward input can only be answered empirically. From a clinical point of view, it is probably better to have this more narrowly defined measure of attentional capacity than to have none at all because speech or motor handicaps prevent patients being assessed with other measures. However, interpretation of the ACT would still depend on establishing the relation of this measure to those involving a higher response component in the processing demands of the task. It is not the purely motoric response execution that is of major concern because it has been shown to be of minor significance in the processing deficits of clinical groups (e.g., Gronwall & Sampson, 1974; van Zomeren, 1981). It is more the formulation of the response and dealing with the sensory feedback from that response that is relevant. Although these response aspects occur during the ACT, they are not speeded and thus do not make strong demands on the capacity for processing. One way of sorting out the significance of the input/output emphasis would be to administer the ACT in two different ways to the same subjects: (a) in its present form, and (b) requiring the person to count each target aloud before the next stimulus number occurs. Although

overall performance level might be expected to be lower in the second condition, if the two measures are highly correlated, it would indicate that they are measuring the same basic capacity and that the difference in input/output emphasis is not significant.

At a clinical level, if the ACT were shown to measure the same attentional capacity as other more response-oriented measures, then it would offer a more clinically flexible measure of such capacity than presently exists. If, on the other hand, it is found to measure a different (more input-oriented) aspect of capacity, it would still be of practical value. When used in comparison with more output-oriented measures, it could help delineate whether an attentional difficulty lies more toward the input or output end of processing effort.

Passive memory span (Digits Forward) was significantly (though slightly) related to ACT performance but not to PASAT performance when zero-order correlations were considered. However, once the overlap of Digits Forward with other tests (PASAT, Adding, & Digits Backward) was partialled out, it no longer correlated significantly with the ACT. Passive memory span, therefore, was not a significant factor in ACT performance for normal subjects. Nevertheless, for clinical groups in whom Digits Forward ability is reduced, passive memory span might be found to affect ACT performance.

As well as trying to validate the ACT using other information processing measures, it is also relevant to compare it to other sorts of criteria, for example, ratings of patients' attentional functioning in everyday life. Such a comparison was made for nine patients in the present study. These patients were a relatively high functioning group of brain-injured people who, nevertheless, tended to score low on the ACT compared to normal subjects. A significant correlation between ACT performance and staff ratings of patient attentional capacity was found for seven patients with diffuse damage. The appropriateness of the ACT measure for the remaining two patients, both of whom had fairly focal damage, was questionable. Further investigation of ACT performance in relation to attentional function in everyday life should, therefore, group patients according to type of damage.

It would seem that one group of patients for whom the ACT may be particularly inappropriate are those with language disorders. Their difficulty in retrieving and manipulating linguistic symbols might well hinder their performance on the ACT for reasons other than limited attentional capacity. It would be useful to make a nonverbal version of the ACT for use with such people. It should be noted that some of the diffusely damaged patients in the present study had sustained additional focal damage. Although it was not possible to consider

these minor variations in such a small group, it would become feasible to do so in larger patient populations. It may well be meaningful to consider patients as distributed along a continuum with a particular sort of focal damage at one end, diffuse damage at the other end, and varying combinations of the two in between. It would be useful to know, for example, if relatively minor degrees of focal damage to language areas combined with diffuse damage lower ACT performance more than does diffuse damage alone.

As already mentioned, the present group of patients was relatively high functioning, scoring in the upper half of the possible ACT range. It is important that lower functioning patients also be included in evaluative studies because the ACT is designed to measure their performance too. Appropriate comparison of ACT scores to measures of attention in everyday life should encompass the full range of attentional functioning from low to normal. Such correlations may well be much higher than the .75 obtained in the present study.

Consideration was also given to the possible usefulness of a deviation score for measuring ACT performance. This score did not add to the information obtained from the number-correct score for the present group of patients. Before abandoning this score, however, it might be wise to investigate its use with lower functioning patients or for monitoring progress in slowly changing people. It may well

be that, in such cases, the deviation score reflects variation in performance at a level of functioning below the floor level that can be detected using number of correct responses.

The ACT was designed to measure general processing capacity rather than certain other aspects of attentional function. One of these other aspects is that of sustained attention or lack of distractibility. Closed head injury patients are often described as being easily distracted but E. Miller and Cruzut (1981), and van Zomeren, Brouwer, and Deelman (1984) concluded that it was slowness in dealing with irrelevant stimuli that was the problem rather than proneness to distraction per se. However, Luria (1973) proposed that distracted behaviour may occur because the patient (usually with severe frontal damage) has lost the ability to voluntarily direct attention in a goal-directed fashion. Poor performance on the ACT could result both from limited or slow capacity to process information and from loss of ability to use what capacity does exist in a sustained, goal-directed manner. The latter possibility could be tested by seeing whether the patient's performance on a simple target detection task showed greater decrement over time than is normal. This procedure could be adapted to an ACT type of format where the patient counts the number of targets and is asked to report periodically on the total count without any pressure on response speed.

Brouwer and van Wolffelaar (1985) reported that the ability to sustain attention is normal in head injury patients even though they show slowed information processing. It is possible that head injury patients vary in this respect, depending on the degree and location of damage. One patient (no. 6) of the present group showed a performance profile across ACT levels that indicated that his poor score was due to sporadic lapses in attention rather than to limited information processing capacity per se. It may well be that profile analysis of the ACT could distinguish problems in sustaining attention from those of information processing capacity. This possibility requires further investigation.

The ACT was also designed not to measure the flexibility with which people can voluntarily change the focus of their attention. In the effort to maximize its value as a measure of attentional capacity, the ACT was designed so as to minimize any mental flexibility problems. The instructions, format, and target content were planned to introduce changes in a gradual, cumulative way rather than to involve abrupt or substantial changes. However, the ACT could very easily be modified to permit measurement of attentional flexibility. All that is required is to vary the target number that the person has to count from trial to trial within a given processing level. For example, if a person showed relatively normal functioning

at level 4 of the regular ACT, they could then be tested with another version of this level in which a new target was specified for each trial.

Although the ACT was designed to measure general processing or attentional capacity and not certain other aspects of attentional functioning, its basic format can be adapted so that these other attentional aspects can be measured without speeded or rigid response demands. Its applicability to measuring sustained and alternating attention has already been described. It could also be adapted to Stroop type measures of controlled versus automatic processing. For example, the target to be counted could be the word "high" said in both low and high voice tone and mixed in with other words like "low" also spoken in a variety of tones. The ACT is being offered not only as a measure of attentional capacity but also as a paradigm for assessing attentional function in patients with speech or motor problems.

The ACT and other tasks used in the present study were all aurally presented numeric sequential tasks and thus fell within the category of tasks usually deemed likely to be advantageously processed by the left hemisphere (e.g., Walsh, 1978). According to Friedman's (e.g., Friedman & Polson, 1981) notion that each hemisphere has its own resource pool, it might be argued that the ACT only measures the attentional capacity of the left hemisphere.

The most direct way of evaluating this possibility would be using glucose-uptake or regional cerebral blood flow measures of hemispheric activity during performance on the ACT.

The next most direct measure would probably be that of comparing ACT performance across left and right hemisphere lesion groups. It might be expected that patients with left hemisphere lesions would perform more poorly on the ACT than those with right hemisphere lesions. This notion received some support from the present patient data. Patient 9, who had focal left-hemisphere damage, demonstrated more difficulty with the ACT than did a patient with focal right hemisphere damage or those patients with diffuse damage. It was obvious during administration of the ACT, that dealing with linguistic symbols required more mental effort for patient 9 than was the case for the other patients. The question arises as to whether poor performance on the ACT because of specific linguistic problems constitutes limited attentional capacity. At first glance the answer seems to be no: The problem is linguistic rather than attentional. However, most measures of attentional capacity construe such capacity in terms of how much information the person can process in a given time. Within this definition, patient 9 can be said to have reduced attentional capacity, at least for verbal material. A nonverbal version of the ACT is

required to see to what extent attentional capacity is material specific.

Experimental paradigms would include those like dividing attention between the ACT and other tasks that might be expected to involve either left or right hemisphere processing. Fuhrer's (1985) point that interpretation of divided attention tasks is complicated by individual differences in strategies is also pertinent to the assumptions regarding hemispheric processing for the ACT. Subjects reported a wide range of strategies on this task including some strongly visuospatial imagery (e.g., piling up tally marks in a certain pattern, moving targets into different spatial locations than nontargets, and so on). Other subjects reported visualizing written numbers, auditory imagery (e.g., echoes), and some did not report any mental imagery or strategic devices. Subjects often used a mixture of strategies at the same time or varied them over time. Human ingenuity in devising strategies should never be underestimated.

Although it was possible to obtain some idea of the range of strategies used by subjects in the present study, it was not appropriate to analyse them in quantitative fashion. Questioning of subjects about their strategies was informal and open ended. Subjects varied with respect to the interest they showed in talking about strategies and the clarity of their descriptions. Further investigation

of strategies would probably benefit from providing subjects with forced choice alternatives for specifying their strategies. The present data suggested that such choices should include the following: (a) not aware of any strategy; (b) hearing the stimulus and/or count numbers in one's head; (c) seeing the stimulus and/or count numbers in written form; (d) seeing the stimulus and/or count numbers in some visuospatial pattern (nonverbal); and (e) combinations of these approaches.

Certain practical considerations require further development if the ACT is to be clinically useful. Normative data needs to be collected for various age groups of the normal population and clinically diagnostic cut-off points need to be ascertained by comparing normal and brain-injured people. For the ACT to be used to monitor change (recovery or deterioration) in attentional capacity, the task must be appropriate for repeated application. The first step would be to see the extent to which practice effects operate in normal and stable brain-impaired people. If necessary, parallel forms of the task could easily be devised by using the same targets as in the present version, but altering the order of stimuli and target total within a trial. They could also be devised by using a different set of numbers for the targets. In certain clinical situations, it might be convenient if only one or two levels needed to be readministered at a time rather

than having to go through the whole procedure each time. First, order effects among the ACT levels need to be clarified. Second, the effect of repeated use of single levels has to be assessed for practice effects. The use of different response modes (speech, pointing) should also be checked to see whether they alter performance in any way.

In conclusion, the ACT shows promise as a measure of attentional capacity. Possible limitations that require further exploration are that it only measures left-hemisphere processing capacity or that it measures an input-oriented processing capacity that is somehow different to the processing measured by other tasks involving both input and output emphasis. Although the ACT does not, in its present form, measure certain aspects of attention such as sustained, alternating, or automatic versus controlled attention, it does provide a paradigm for measuring these aspects of attention in patients whose speech or motor impairments make other attentional measures unusable or inappropriate. Differential diagnosis of problems in sustaining attention and those of attentional capacity might be feasible using ACT profiles but this possibility requires further investigation. To be fully developed for clinical use, the ACT requires norming and adaptation for repeated administration.

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APPENDIX 1

Digits Forwards - Instructions and Items

Instructions

You will hear some numbers on this tape. When they stop, and you'll know they've stopped because you'll hear the pause button click like this (demonstate), repeat them in exactly the same order.

ITEMS	TRIAL 1	TRIAL 2
1	5-8-2	6-9-4
2	6-4-3-9	7-2-8-6
3	4-2-7-3-1	7-5-8-3-6
4	6-1-9-4-7-3	3-9-2-4-8-7
5	5-9-1-7-4-2-8	4-1-7-9-3-8-6
6	5-8-1-9-2-6-4-7	3-8-2-9-5-1-7-4
7	2-7-5-8-6-2-5-8-4	7-1-3-9-4-2-5-6-8

Digits Backwards - Instructions and Items

Instructions

Now you will hear some more numbers, but this time when they stop, I want you to say them backwards. For example if you hear 7-1-9, what would you say?

If the subject responds correctly (9-1-7) they are told "That's right" and the test is commenced.

If the subject fails the example, they are told "No, you would say 9-1-7. You heard 7-1-9, so to say it backwards you would say 9-1-7. Now try these numbers. Remember you are to say them backwards, 3-8-4". Whether the subject succeeds or fails with this second example, item 1 of the test is commenced. Practice examples are given at the same one-per-second rate as the test items.

ITEMS	TRIAL 1	TRIAL 2
1	2-4	5-8
2	6-2-9	4-1-5
3	3-2-7-9	4-9-6-8
4	1-5-2-8-6	6-1-8-4-3
5	5-3-9-4-1-8	7-2-4-8-5-6
6	8-1-2-9-3-6-5	4-7-3-9-1-2-8
7	9-4-3-7-6-2-5-8	7-2-8-1-9-6-5-3

APPENDIX 2

Adding Test - Instructions and Items

Instructions

The next task is one of simple addition. By simple I mean sums like $3+2$ (get subject to give answer), $6+1$ (get subject to give answer) and so on. Only two numbers to be added each time and these numbers are always between 1 and 9. The idea is to see how many you can answer correctly within the timespan of one minute, so as soon as you give me your answer to one sum, I'll give you the next sum to do. Just to help you get the feel of it, we'll do a short practice run:

$8+1$ (9), $3+2$ (5), $6+4$ (10), $1+2$ (3)

(The time taken to present each sum is 1 second. Repeat these examples if necessary until subject gets the idea, then continue).

Good, that's the idea. It is not really testing mathematical ability - rather, it is a speed and accuracy task. If you give an answer and then alter it quickly, I'll take the second answer as being the one you mean. But if you give an answer and then have vague doubts about it, it's better not to waste time trying to figure it out. Forget it so that your mind is free to concentrate on the next sum and get that one right. Any questions? --- ready?

Items

1. $6+5=$	(11)	21. $2+4=$	(6)	41. $8+4=$	(12)
2. $1+3=$	(4)	22. $9+5=$	(14)	42. $4+9=$	(13)
3. $1+8=$	(9)	23. $8+7=$	(15)	43. $3+8=$	(11)
4. $2+9=$	(11)	24. $2+3=$	(5)	44. $5+7=$	(12)
5. $6+7=$	(13)	25. $4+6=$	(10)	45. $3+6=$	(9)
6. $5+4=$	(9)	26. $3+1=$	(4)	46. $6+3=$	(9)
7. $7+9=$	(16)	27. $9+6=$	(15)	47. $2+1=$	(3)
8. $3+2=$	(5)	28. $5+1=$	(6)	48. $4+1=$	(5)
9. $9+5=$	(14)	29. $8+4=$	(12)	49. $3+7=$	(10)
10. $7+2=$	(9)	30. $4+9=$	(13)	50. $6+7=$	(13)
11. $6+8=$	(14)	31. $5+2=$	(7)	51. $9+2=$	(11)
12. $4+1=$	(5)	32. $9+1=$	(10)	52. $2+5=$	(7)
13. $9+3=$	(12)	33. $3+1=$	(4)	53. $2+9=$	(11)
14. $8+5=$	(13)	34. $8+6=$	(14)	54. $5+8=$	(13)
15. $7+3=$	(10)	35. $7+5=$	(12)	55. $7+2=$	(9)
16. $6+2=$	(8)	36. $4+7=$	(11)	56. $3+4=$	(7)
17. $1+4=$	(5)	37. $9+3=$	(12)	57. $6+3=$	(9)
18. $1+8=$	(9)	38. $2+9=$	(11)	58. $1+9=$	(10)
19. $5+6=$	(11)	39. $5+8=$	(13)	59. $6+5=$	(11)
20. $7+9=$	(16)	40. $2+6=$	(8)	60. $1+8=$	(9)

APPENDIX 3

Attentional Capacity Test (ACT) - Instructions

Level 1

- You'll hear a voice on this tape say some numbers. After you hear each number, please repeat it aloud. The purpose of this task is to make sure you can hear the voice on the tape. Just before each number, you'll hear two buzzing sounds 'buzz buzz' - that's the signal to pay attention because the number is about to occur.

- For example: 'buzz buzz 4' then a short time for you to repeat the number, then another 'buzz buzz' to warn you that the next number is about to occur.

(Play tape. Score number correctly repeated. If there are any mistakes, check appropriateness of volume and repeat all trials at a louder volume. If the subject continues to make mistakes despite optimization of volume, abandon ACT.)

Level 2 (ee's)

- The voice on the tape will say 'ee ee ee' and you are to count the number of times it says 'ee'.

- Just as before, there will be two buzzing sounds 'buzz buzz' to warn you when the ee's are about to start. When you hear 'buzz buzz' it means you should start listening carefully.

- There will be a different number of ee's each time, varying between 1 and 10. So that you know when the series of ee's has finished, there will be one buzz, then a pause for you to give your answer. When you hear that one buzz coming straight after the ee's, say how any ee's you counted. Give your answer as quickly as possible.

- Count the ee's mentally, not aloud, and not using your fingers. Please put your hands on the table so I can see them.

- For example: 'buzz buzz ee ee ee buzz' is the sort of thing you will hear. How many ee's did you count just then? (Get subject to answer and repeat if necessary)

- Note that in this and in all subsequent practice examples, there are 2 seconds between commencement of the double buzz warning signal and the first item to be counted, the items are presented at 1 per second, and the single buzz follows 1 second after the last item.

Practice Examples:

buzz buzz ee ee ee ee ee buzz (5)

buzz buzz ee ee buzz (2)

buzz buzz ee ee ee ee ee ee buzz (6)

Repeat these examples until subject gets two consecutive ones correct, or until each example has been repeated once, then proceed to the taped trials. The first time the subject makes a mistake, the examiner says: 'That answer was not quite right. I'm going to give you that example again, listen carefully and try to get it right this time'. This is only done once and a correct response does not count as one of the two consecutive correct responses. After that, if there is a further mistake the examiner stresses the importance of careful listening for the next example but makes no comment on the incorrectness of previous example. If the subject were given maximum practice, this would include twice through the three examples plus one immediate repetition, a total of seven practice trials.

Level 3 (8's)

- This time, the voice on the tape will say '8 8 8' instead of 'ee ee ee', and you are to count the number of times it says '8'. Again the numbers of 8's to be counted will vary between 1 and 10.

- There will be the same 'buzz buzz' to warn you when the 8's are about to start and the same single 'buzz' to tell you that the 8's have finished and it is time to give your answer.

- Once again, give your answer as quickly as you can, count mentally, and keep your hands on the table.

Practice Examples:

buzz buzz 8-8 buzz (2)

buzz buzz 8-8-8-8 buzz (4)

buzz buzz 8-8-8-8-8-8-8 buzz (7)

Practice procedure is the same as for Level 2 above.

From here on, reminders about warning signals, answering promptly, counting mentally, and keeping hands on the table can be given if the subject seems to need such reminding but otherwise these instructions may be partially or wholly omitted. How much help is needed can usually be gauged from how the subject handles the practice examples.

After each level is completed, the examiner will ask subjects how they went about the task, noting down these

comments.

Level-4 (8's)

- This time instead of hearing a voice saying 8's, it will say a mixture of numbers - any numbers from 1 to 10 in mixed up order. But your task is still to count the number of times it says '8'. The number of 8's to be counted will vary between 1 and 10.

Practice Examples:

buzz buzz 8-4-8-3 buzz (2)

buzz buzz 7-8-8-8-2-8 buzz (4)

buzz buzz 1-8-2-9 buzz (1)

Practice procedure is the same as for level 2.

-The number series you'll hear on this tape will be longer than the examples you've had so far. To give you a feel for the length, I'll give you a practice example now:

buzz buzz

2-8-4-3-1-6-9-8-8-8-2-1-6-8-1-10-9-4-8-8-2-10-4-9-8

buzz (8)

(If subject exclaims re the length of this example, reassure them that this is often how people feel at first but that they usually get used to it and do better than they think.)

- At the moment you are counting 8's. Later I'll ask you to count some other things. But throughout all the counting, the length of the number will be the same as what you had just now, and the speed will always be the same. The other thing that will always be the same is that the answer will always be somewhere from 1 to 10.

- If you do happen to lose track of your counting, don't start thinking about whether you missed one or counted one you shouldn't have. Just try to pick up the next target number, that is the next 8, and go on from there. If at the end you are not sure of the exact answer, give your best estimate.

- If you feel the need to stop for any reason, wait till the end of the series, give your answer, then ask me to stop the tape.

- Now before we begin, what is the special target number that you are going count? (get subject to say '8' and remind them and ask the question again if they show any uncertainty). Good. I may stop the tape occasionally just to ask if you still have that special number in mind. It

does not mean that you've made a mistake; it's just a routine check. (The subject is asked again for the special number after trial 3 and trial 6 of the scored trials.)

Level-5 (8's & 5's)

Give whatever general reminders seem necessary.

- This time you'll hear the same sort of number series, but your task is to count how many 8's and 5's you hear altogether. You still only have one answer. For example if you heard 'buzz buzz 4-5-2-8-5 buzz' your answer would be '3' because that is the combined total of 5's and 8's that you heard. Do you understand? If subject requires further explanation, say "You heard two 5's and one 8 so altogether that makes a total of three special numbers" and repeat the example, getting subject to count again.

Practice Examples:

buzz buzz 8-5-2-5 buzz (3)

buzz buzz 6-9-5-10 buzz (1)

buzz buzz 5-6-8-2 buzz (2)

Practice procedure is the same as for level 2.

- Now before we begin, what are the special numbers? (This question is repeated after trials 3 and 6 of the scored trials.)

Level-6 (8's, 5's, 4's, & 7's)

Reminders are given as appropriate.

- This time, as well as 8's and 5's, you are going to count 4's and 7's, that is, there are four special numbers to listen for: 4, 5, 7, and 8. (The subject is asked to repeat these numbers aloud). At the end of each series you say how many 4's, 5's, 7's, and 8's you counted altogether. Just give one answer.

Practice Examples:

buzz buzz 1-4-8-7-5 buzz (4)

buzz buzz 3-4-8-8-2 buzz (3)

buzz buzz 7-5-5-9-4-8 buzz (5)

Practice procedure is the same as for level 2.

- Now, before we begin, what are you counting? (This question is repeated after trials 3 and 6 of the scored trials.)

Level-7 (5-8 & 4-7)

Reminders given as appropriate

- This time you listen for 4,5,7, and 8 again BUT you only count them if you hear '5 followed immediately by 8' in that order or '4 followed immediately by 7' in that order. That is, 5-8 or 4-7. They must always be in the right order. If you heard 7-4 or 8-5 the numbers are in the wrong order so they don't count. One way of remembering the order within each pair is that the lower number always comes first: 4 before 7 and 5 before 8. Each time you hear one of these pairs of numbers given in the right order, it counts as one special number.

Practice Examples

buzz buzz 6-5-8-2-4-7 buzz (2)

buzz buzz 8-5-8-3-7-4 buzz (1)

buzz buzz 5-8-4-7-4-7-5-8 buzz (4)

Practice procedures are the same as for level 2.

- Now before we begin, what are the special numbers? (This question is repeated after trials 3 and 6 of the scored trials.)

Level-8 (5, another number, 8)

Reminders given as appropriate.

- This time you only listen for 5's and 8's BUT they must be in the order '5, another number, then 8'. For example, 5-6-8 is correct but 8-6-5 is not. Can you tell me why 5-6-8 is correct but 8-6-5 is not? If subject answers correctly, continue immediately but if not explain again.

- The number between 5 and 8 may be any number between 1 and 10. So it may be a different number to 5 and 8, for example 5-9-8 or 5-10-8. Can you give another example? Repeat this explanation till subject gives an appropriate example.

OR, it may be another 5 or 8, for example, 5-5-8. Can you give another example? Repeat explanation till subject gives 5-8-8.

Practice Examples:

buzz buzz 5-3-8-2-5-8-8-7 buzz (2)

buzz buzz 5-5-8-3-8-8-5-6 buzz (1)

buzz buzz 5-5-8-5-4-8-5-8-8 buzz (3)

Practice procedures the same as for level 2.

- Sometimes the number groups can overlap, that is, you could hear 5588.

Demonstrate by showing subject these numbers written down and giving the following explanation with appropriate pointing: "The first five relates to the first eight with the second five in between them. The second five relates to the second eight with the first eight in between them".

Practice Examples:

buzz buzz 3-5-5-8-8-4 buzz (1)

buzz buzz 5-10-8-5-5-8-8-2 buzz (3)

buzz buzz 5-5-8-8-5-8-5-1 buzz (2)

Practice procedure is the same as for level 2 with the modification that the first time the subject makes a mistake, they are shown the sequence written down while the examiner says it in the usual way. The series is then repeated again without the visual aid.

- Now before we begin, what are the special numbers? (This question is repeated after trials 3 and 6 of the scored trials.)

APPENDIX 4

Attentional Capacity Test (ACT) - Items

Level 1

3, 10, 4, 1, 6, 9, 7, 5, 2, 8

Level 2 (ee's)

10, 2, 5, 4, 6, 9, 3, 8, 1, 7

Level 3 (8's)

5, 9, 7, 10, 1, 4, 2, 8, 3, 6

Level-4 (8's)

Unscored Trials:

8-1-9-4-8-7-8-5-8-2-1-9-4-10-7-3-8-4-6-3-8-9-2-10-8 (7)

4-8-6-2-8-9-1-7-3-6-8-8-4-10-2-6-10-10-4-5-9-8-6-3-7(5)

Scored Trials:

1-3-6-10-5-9-4-1-6-8-7-4-3-3-5-2-4-7-10-9-6-2-8-7-8 (3)

5-8-6-8-2-4-7-8-1-8-8-7-3-8-4-10-8-9-8-10-1-3-8-8-2(10)

8-9-1-4-7-6-9-3-2-10-5-6-7-7-7-4-9-8-1-3-6-4-2-3-5 (2)

5-3-5-8-9-2-6-8-8-8-2-8-3-3-7-4-8-1-9-7-8-10-4-6-2 (7)

7-9-7-6-6-4-9-2-1-3-1-4-7-8-10-4-8-7-9-1-3-5-4-10-7 (2)

8-4-2-1-7-10-4-4-7-6-4-8-2-8-3-1-8-8-1-7-4-9-10-8-4 (6)

Level 5 (8's & 5's)

Unscored Trials:

8-4-1-9-2-7-5-3-4-8-6-8-9-4-2-7-1-5-1-10-4-7-3-6-1 (5)

1-6-2-3-5-8-3-5-4-2-1-6-5-9-8-8-3-7-4-1-10-2-5-2-8 (8)

Scored Trials:

2-1-3-5-6-7-8-1-4-3-8-9-2-7-6-1-10-3-5-4-7-2-10-6-9 (4)

1-8-2-3-5-7-6-9-9-4-5-5-7-10-1-4-8-2-8-8-6-7-5-4-3 (8)

8-9-4-7-2-10-4-3-7-6-1-9-10-5-6-8-4-7-2-3-3-6-4-9-2 (3)

4-7-6-5-2-10-1-9-6-7-8-3-2-10-6-7-3-3-4-5-10-1-7-2-6(3)

6-4-10-1-2-5-6-2-10-4-7-9-6-6-4-9-6-8-1-4-10-9-2-7-6(2)

5-6-7-1-9-8-8-5-4-3-8-1-7-6-10-5-5-2-8-4-6-8-2-5-4 (10)

Level 6 (8's, 5's, 4's, & 7's)

Unscored Trials:

2-3-10-4-6-1-3-8-9-2-6-1-3-10-9-6-5-1-3-7-10-2-1-3-6(4)

9-1-8-6-2-3-5-1-6-8-9-2-10-1-4-7-3-6-9-3-1-10-2-4-1 (6)

Scored Trials:

4-6-7-2-3-10-8-8-2-5-6-10-3-1-7-2-4-10-9-2-6-5-8-9-3(9)

6-2-1-7-8-9-1-6-3-3-2-1-10-4-6-3-5-1-2-9-7-6-10-3-9 (5)

10-6-3-1-4-9-2-6-1-10-9-6-6-6-3-2-10-1-9-6-2-2-9-10-9(1)

3-9-2-8-9-10-6-2-6-10-1-3-6-5-9-9-2-1-6-10-7-6-3-2-10(3)

1-7-6-8-10-3-9-4-6-5-2-10-10-6-9-7-6-5-4-3-1-9-6-8-2(8)

6-3-10-4-6-6-3-9-8-3-10-6-10-1-2-5-6-3-6-10-3-1-9-6-7(4)

Level 7 (5-8 & 4-7)

Unscored Trials:

5-6-4-9-5-8-2-7-4-7-4-5-7-8-2-4-7-6-5-2-8-5-8-6-4 (4)
 8-5-4-7-5-8-7-2-4-8-5-8-4-7-5-8-5-8-8-5-8-4-7-4-7 (9)

Scored Trials:

4-7-7-4-4-8-5-5-7-4-5-5-8-9-4-2-7-8-5-8-8-5-6-7-4 (3)
 6-4-7-5-8-8-5-8-7-4-7-4-7-5-8-5-8-8-5-8-7-4-7-4-7 (10)
 5-2-8-9-7-4-7-7-7-4-5-7-8-5-5-3-9-5-8-8-7-7-4-5-7 (2)
 5-5-7-4-10-4-7-7-4-7-7-8-5-8-6-4-7-7-5-8-8-3-5-8-4 (6)
 8-4-7-7-1-6-4-8-8-5-4-6-3-8-7-5-8-4-8-7-9-8-2-1-7 (2)
 3-4-8-5-9-4-7-5-8-6-5-8-4-8-8-6-4-7-4-7-5-8-8-4-7 (7)

Level 8 (5, another number, 8)

Unscored Trials:

8-2-4-6-5-3-8-8-2-10-1-5-5-4-8-9-6-8-5-5-2-6-5-7-8 (3)
 4-5-5-8-8-6-5-8-5-5-1-8-5-2-8-8-5-5-8-5-5-8-8-3-8 (7)

Scored Trials:

7-2-5-8-5-6-1-8-5-5-8-5-6-5-8-4-5-6-5-8-5-8-6-5-8 (1)
 5-5-6-8-4-5-7-5-5-8-8-3-5-9-8-4-6-5-8-3-5-10-5-5-8 (5)
 6-5-5-8-8-3-5-5-8-8-4-5-2-8-9-5-5-8-8-5-4-8-5-5-8 (9)
 8-5-5-8-5-5-5-8-8-6-5-7-8-5-8-5-5-8-8-5-5-6-8-8-5 (7)
 7-5-8-3-8-2-5-5-8-8-10-5-6-8-5-2-8-9-5-4-8-5-5-8-2 (6)
 5-8-5-5-6-10-5-8-5-5-8-5-4-5-8-10-5-1-8-8-5-8-5-2-5(2)

APPENDIX 5

Paced Auditory Serial Addition Test (PASAT)

Instructions and Items

Instructions

- The next task involves doing the same very simple sort of addition that you did earlier but the task itself is different. You will hear one number, then another number, and you add them together and say the answer. Then when you hear a third number, you have to add it to the number that occurred just before your answer. You keep adding the number before the answer to the number after it.

- Let me show you what I mean (show numbers written down):

5
3
7
4
2
9

You see, you add the 5 and the 3 together and say 8. Then you have to forget the 8 and remember the 3. When the 7 comes along you add it to the 3 and say 10, and you have to remember the 7. Alright, what do you say after the 4? (Continue until subject understands what to do).

- Unpaced Practice:

Now we'll do some practice listening to the numbers without seeing them written down. The main thing to remember is that if you forget the last number, you can always pick up and get going again with any two consecutive numbers (demonstrate with reference to the written example).

The experimenter then repeats the following number sequence, waiting till the subject has either answered, or indicated inability to do so, before saying the next number:

7-2-4-1-6-9-3-5-8-2-4

The written demonstration is repeated if the subject is still unsure what to do. The unpaced practice is repeated until the subject gets at least 3 consecutive answers correct. If the subject is unable to meet this criterion within 3 attempts, the task is discontinued. If subjects

do poorly on their first attempt, they are asked what the difficulty is and encouraged to think of a way to overcome it.

- Paced Practice:

That's good. Now try it on the tape. The difference between doing it with the tape and doing it with me is that although the tape gives you a fair amount of time to answer, it does not stop and wait for you. If you don't manage to give your answer before the tape says the next number, just forget about that answer and concentrate on the next one. Don't try to fill in back answers because it won't work. Just wait for two consecutive numbers and get going again. Ready?

(Play Practice List recorded at the rate of one number per 2.4 seconds):

3-4-1-7-2-4-9-6-3-7

-Test Trials:

Good. We'll do the task itself now. It will be at the same speed as what you did just now but it is 6 times longer, that is, it runs for about two and a half minutes. The main thing to keep in mind is that if you lose track for any reason, you can always pick up and get going again. Everybody loses track sometimes. When this happens to you, don't panic, just stay calm, wait for another two consecutive numbers and pick up from there. If you lose track again, just pick up again. Whenever you lose track, just try to pick up again - that's the secret of doing this test. Ready?

(During a trial, if the subject does not answer for several consecutive items, they should be prompted to "pick up". If the subject expresses concern about being able to cope with the next trial, especially the last and fastest one, tell them to focus on what they can do and not worry about items they cannot do.)

(An interval of at least 60 seconds is allowed between each trial. During this time the subject is asked to describe how they went about doing the task.)

Items

Paced Test Trials:

The same items are used for all four trials. Each trial presents items at a different speed, starting at one item per 2.4 seconds for the first trial, then 2.0 seconds for the second trial, 1.6 seconds for the third trial, and 1.2 seconds for the fourth trial.

2-7-3-4-8-1-5-6-9-1-3-6-4-3-2-7-8-5-9-4-2-
9-7-6-5-8-1-4-1-2-6-3-7-5-8-3-9-1-4-8-6-
2-7-5-9-2-3-9-7-4-5-7-6-8-1-3-1-9-2-5-6.

APPENDIX 6

Concentration Background Questionnaire

ID Number Age Sex Education
Occupation

1. When counting or calculating do you normally do so in English? Yes/No (circle appropriate answer)
2. Did you have your normal amount of sleep last night?
less - normal - more (circle appropriate answer)
3. Have you eaten your usual amount of food today for this time of day?
less - normal - more (circle appropriate answer)
4. In the last four weeks have you consumed any of the following drugs:

Drug	Yes/No	Last Use	Frequency per Week
Alcohol			
Marijuana			
Cocaine			
LSD			
Other Recreational Drugs			
Specify			
Prescribed Drugs			
Specify			

5. Have you ever been unconscious? Yes/No (circle answer).
If so, when _____, how long _____, Cause _____
and do you feel fully recovered now? Yes/No
If not fully recovered, what effects remain? _____

6. Have you had any other brain injury or disease? Yes/No
If so, what kind _____

When _____ How long _____

Do you feel fully recovered now? Yes/No

If not fully recovered, what effects remain? _____

APPENDIX 7

Number of Subjects Scoring Correctly on Each Item of the ACT

Item	Correct answer	No.subjects correct	Item	Correct answer	No.subjects correct
1-1	3	64	4-1	3	64
1-2	10	64	4-2	10	61
1-3	4	64	4-3	2	64
1-4	1	64	4-4	7	60
1-5	6	64	4-5	2	63
1-6	9	64	4-6	6	57
1-7	7	64	5-1	4	60
1-8	5	64	5-2	8	52
1-9	2	64	5-3	3	60
1-10	8	64	5-4	3	59
2-1	10	63	5-5	2	64
2-2	2	64	5-6	10	51
2-3	5	56	6-1	9	41
2-4	4	62	6-2	5	52
2-5	6	60	6-3	1	63
2-6	9	64	6-4	3	62
2-7	3	64	6-5	8	46
2-8	8	63	6-6	4	61
2-9	1	64	7-1	3	55
2-10	7	63	7-2	10	38
3-1	5	62	7-3	2	50
3-2	9	64	7-4	6	39
3-3	7	64	7-5	2	54
3-4	10	64	7-6	7	33
3-5	1	64	8-1	1	20
3-6	4	63	8-2	5	35
3-7	2	64	8-3	9	29
3-8	8	63	8-4	7	26
3-9	3	64	8-5	6	40
3-10	6	64	8-6	2	38

Note. The first number of the item indicates the task level and the second number indicates the item within that level.

APPENDIX 8

Number of Correct Responses for Subjects on the Five Tasks:
ACT, PASAT, Adding Test, Digits Forward, and Digits
Backward.

Subjects	Tasks					Subjects	Tasks				
	A	P	D	F	B		A	P	D	F	B
01	56	137	24	12	09	33	47	104	21	07	06
02	55	164	29	11	12	34	56	194	33	10	13
03	51	115	27	06	04	35	48	127	27	09	08
04	49	071	21	11	05	36	55	205	33	11	09
05	58	208	36	14	12	37	46	153	30	12	12
06	50	140	34	11	06	38	56	128	30	10	07
07	50	098	32	06	05	39	58	190	25	12	07
08	53	185	28	10	05	40	48	163	29	08	08
09	49	094	26	09	07	41	46	147	31	08	09
10	54	168	34	09	08	42	54	163	27	10	08
11	52	176	27	08	07	43	49	098	27	14	08
12	55	074	19	06	10	44	54	123	31	13	11
13	56	153	30	09	09	45	52	181	31	09	08
14	57	068	21	09	08	46	55	138	28	07	10
15	57	187	33	10	09	47	59	202	34	11	12
16	48	111	29	11	08	48	45	102	29	10	04
17	48	141	33	08	06	49	58	218	37	12	12
18	54	161	32	07	09	50	50	081	24	11	05
19	52	146	32	13	12	51	59	207	37	09	13
20	55	185	27	10	05	52	53	137	28	06	06
21	51	139	35	07	08	53	48	210	36	07	07
22	53	116	26	09	06	54	48	086	22	07	08
23	53	112	21	06	06	55	48	153	30	06	05
24	58	149	21	10	08	56	52	127	30	09	11
25	56	173	32	12	11	57	59	176	32	10	11
26	51	173	33	09	06	58	54	158	29	13	11
27	52	085	27	07	05	59	49	122	28	08	06
28	58	113	20	11	12	60	55	184	32	06	09
29	58	194	38	14	14	61	59	155	28	08	07
30	51	160	27	10	07	62	53	190	32	09	03
31	55	148	28	08	07	63	56	184	32	10	09
32	56	111	27	10	06	64	56	169	30	09	06

Note. A=ACT(Attentional Capacity Test); P=PASAT(Paced Auditory Serial Addition); D=Adding Test; F=Digits Forward; B=Digits Backward.

Subject ID numbers: even=female; odd=male; first two=ACT first; next two=PASAT first, and so on.

APPENDIX 9

Patient Background: General

Patient ID	Rating Rank	Sex	Age	Hand Preference	Education
1	1	M	26	R	high school
2	9	M	47	R	technical school electronics
3	6	M	28	R	1 year college
4	5	M	20	R	high school 1 semester community college
5	3	M	19	R	high school completed post injury
6	4	M	36	L	2 years college Associate degree police science
7	7	M	18	R	11th grade
8	8	F	24	R	B.S. engineering
9	2	M	34	R	M.S. education

Note. M=male; F=female; R=right handed; L=left handed
Patient ID indicates rank of performance on the ACT with respect to number of correct responses (with deviation scores used to determine ranks of those showing tied numbers of correct responses). Rating rank refers to the rank of patient ratings on the Attention Questionnaire.

APPENDIX 10

Patient Background: Injury

Patient ID	Rating Rank	Etiology	Months Post Injury	Rehabilitation
1	1	assault: intracranial hemorrhage	19	CCR 5 months
2	9	right frontal aneurysm	7	OP only
3	6	CHI	28	CCR 4 months
4	5	CHI more left than right hemisphere involvement	15	CCR 3 months
5	3	CHI left CVA	33	OP only not current
6	4	CHI	26	CCR 5 months
7	7	CHI	11	OP only
8	8	CHI	8	OP only
9	2	aneurysm bleed left CVA	24	CCR 3 months

Note. CHI=closed head injury; CVA=cerebrovascular accident; CCR=Center for Cognitive Rehabilitation which involves intensive cognitive retraining; OP=out patient sessions twice per week; Patient ID=rank of performance on the ACT with respect to number of correct responses (with deviation scores used to determine ranks of those showing tied numbers of correct responses); Rating Rank=rank of patients rating on the Attention Questionnaire.

APPENDIX 11

Attention Questionnaire

PATIENT ID RATER ID DATE

INSTRUCTIONS:

There are six pages in this questionnaire, one page for each of the six areas of the rehabilitation program. The area is specified at the top of each page.

You are asked to rate the above patient's general attentional capacity for each of these areas and to base such rating on your own observations. 'General attentional capacity' refers to the ability to focus and sustain attention in situations requiring selective and/or divided attention.

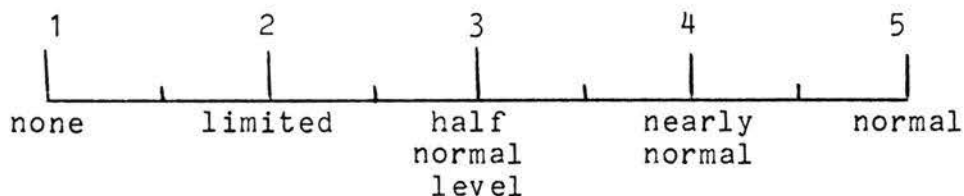
Circle the number on the five-point-scale that most closely represents your evaluation of the patient, or, if you consider that the patient's attentional capacity falls between these numbers, you can circle the 'half-way mark'.

If you have not had the opportunity to observe the patient in a particular program area, then please circle "no observational opportunity" (located below the scale).

There is also a space on each page for you to add any comments you may wish to make about your rating.

RECREATIONAL ACTIVITIES

Please rate patient's capacity for appropriate attentional behavior.

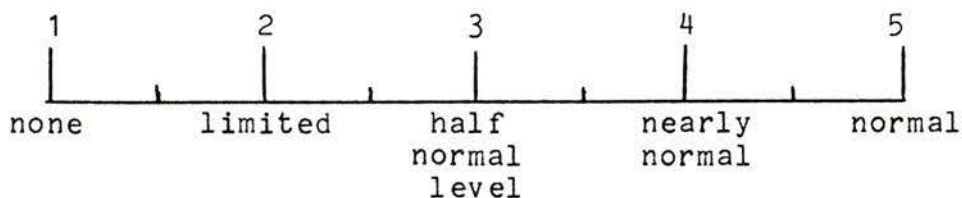


*no observational opportunity

Comments

PHYSIOLOGICAL CONDITIONING

Please rate patient's capacity for appropriate attentional behavior

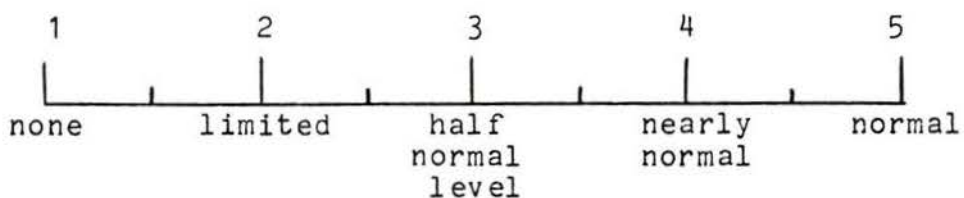


* no observational opportunity

Comments

ACTIVITIES of DAILY LIVING

Please rate patient's capacity for appropriate attentional behavior

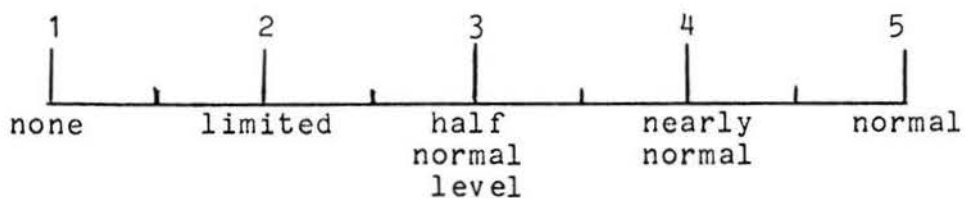


*no observational opportunity

Comments

COGNITIVE ACTIVITIES

Please rate patient's capacity for appropriate attentional behavior

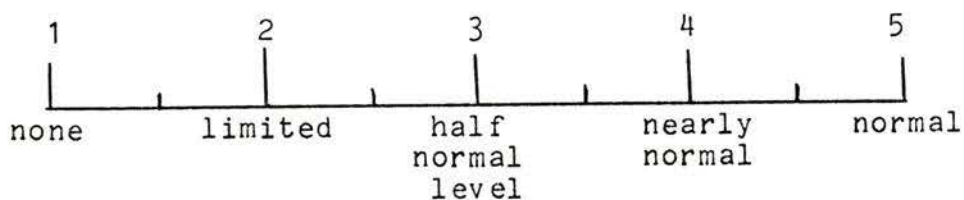


* no observational opportunity

Comments

PSYCHO-SOCIAL ACTIVITIES

Please rate patient's capacity for appropriate attentional behavior

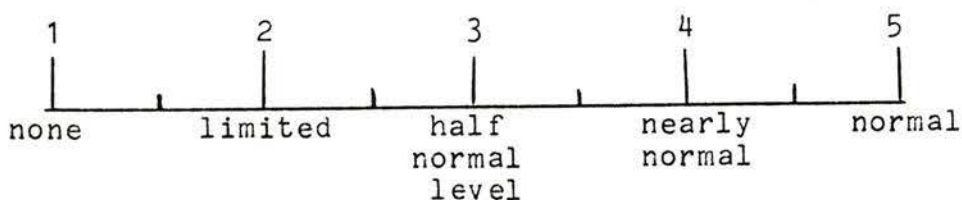


* no observational opportunity

Comments

VOCATIONAL ACTIVITIES

Please rate patient's capacity for appropriate attentional behavior



no observation opportunity

Comments

APPENDIX 12

Patient Scores (number of correct responses)
at Each Level of the ACT

Patient ID	Score on ACT levels							
	1	2	3	4	5	6	7	8
1	10	10	10	5	6	6	6	5
2	10	10	10	6	5	5	2	3
3	10	10	10	6	5	6	1	1
4	10	10	10	5	5	2	3	1
5	10	10	9	6	4	4	1	2
6	10	10	9	4	3	3	3	3
7	10	10	10	6	2	3	2	2
8	10	10	10	5	1	2	4	2
9	10	10	10	5	3	0	0	-

Note. Patient ID=rank of performance on ACT with respect to number of correct responses (with deviation scores used to determine ranks of those showing tied numbers of correct responses). The maximum possible scores at levels 1 to 3 was 10, and the maximum possible score at levels 4 to 8 was 6.

APPENDIX 13

Subject Comments about Processing Demands
of the ACT and PASAT.

The majority of subjects reported that the ACT was an easier and less stressful task than the PASAT. However, they regarded level 8 of the ACT as equally difficult or more so than the lowest level of the PASAT. In describing similarities between the two tasks, they referred to more similarities between the PASAT and level 8 of the ACT than with other levels of the ACT. One subject, on completing level 8 spontaneously associated it with his experience of having done the PASAT two years earlier as part of a battery of entrance tests for admission to the airforce. He made this comment before having been given any indication that the PASAT would be used in the present study.

In reporting why they found the PASAT more difficult than the ACT levels, many subjects mentioned the mathematic content of the PASAT and also that it seemed to require more mental effort than the ACT. They referred to aspects such as that the PASAT required every stimulus to be processed whereas only the targets had to be processed on the ACT and they could mentally rest inbetween targets; that adding was a higher level process than counting; that they had to do more things on the PASAT - keeping track, operating, and responding whereas on the ACT there was only keeping track of what was heard.

The few people who reported finding the PASAT easier than the ACT emphasized the automatic nature of their ability to add, so that all they had to do was keep track of the stimulus numbers. That is, they felt there was less effortful processing required of them on the PASAT.

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MEASURING ATTENTIONAL CAPACITY

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