Paced Auditory Serial Addition Task:

AN EXPERIMENTAL INVESTIGATION

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Abstract

This study investigated the effects of seven independent variables upon a Paced Auditory Serial Addition Task (PASAT; Gronwall & Sampson, 1974).

The main effects found were that arithmetic ability and a short-term memory measure were related to performance on this task. Interactive effects were found for measures of anxiety, sex and the strategy used in performing the PASAT.

Theories considered included those of Broadbent (1977), Neisser (1976), Kerr (1973), Kahneman (1973) and Broadbent (1971) with emphasis on the latter two. The findings are most easily interpreted in terms of Kahneman's (1973) theory. Broadbent's (1971) model could not account for the effects of environmental and task conditions upon information-processing capacity.

Further research is needed to examine the effects of individual abilities and biases in selective attention. Also it is suggested that perception and the allocation of effort policy (Kahneman, 1973) be studied further from Broadbent's (1977) perspective of global and local analysis of information.

Clinical implications for the interpretation of the PASAT are discussed. It is suggested that this test could be used more widely as a measure of selective attention. More specifically it is suggested that the administration instructions could be simplified where necessary; and error scores considered together with rate of performance. These measures give an indication of performance effectiveness.

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Chapter 1 - Introduction

From their series of experiments on the psychological effects of concussion-producing injury Gronwall & Sampson (1974) concluded that concussion results in reduced information-processing capacity due to lowered physiological arousal. But, the ability to maintain and make efficient use of instructions was not impaired by concussion.

Their findings were derived mainly from investigations of the Paced Auditory Serial Addition Task (PASAT), and their view of the concept of information processing capacity was strongly influenced by empirical evidence derived from this test. Their main conclusions were about capacity, arousal and learning/performance set.

Based upon Broadbent's (1971) model of information transmission, processing capacity referred to the rate at which the nervous system transmits information. It was assumed to be limited by the structure of the organism and dependent upon integrity of brain tissue. It was also assumed to be constant, independent of environmental or task conditions. Limits to capacity could be demonstrated by requiring simultaneous performance of two tasks or increasing processing steps in a single task.

Based upon Moray's (1969, 1970) use of the term, arousal referred to a position on the conscious-unconscious continuum. Gronwall & Sampson (1974) viewed this as a physiological rather than a psychological construct. It was argued that arousal affected decision processes by determining that portion of the physiological processing capacity which can be used. In this way arousal was affected by both internal and external conditions, such as task requirements, extraneous noise and brain-stem reticular formation (BSRF) activity (Jasper, 1958, in Gronwall & Sampson, 1974). Levels of arousal were assumed to be operationally defined and empirically assessed by measures such as galvanic skin responses and EEG activity (MacNeilage, 1966, in Gronwall & Sampson). Thus it was assumed that physiological arousal probably formed the basis of psychological arousal, as Broadbent (1971) used the term.

The role of instructions in controlling allocation of processing space, and so making optimal use of that space was defined as set. In this way, set could be taken to refer to the ability of 'higher-level arousal' to monitor and modify changes in 'lower-level' arousal. Set it was argued determines the family of operations that will be carried out and selects these stimuli appropriate to the task. Gronwall & Sampson (1974) did not attempt to specify the mechanisms involved in set.

The current clinical use of the PASAT is chiefly as an objective measure of severity of closed head injury and progress during the recovery period (Gronwall, 1977). With adjustment for a possible practice effect the scores reliably measure recovery rate for any individual relative to mean scores for non-concussed controls (Gronwall, 1980). Also, in practice, it has been found to be a valid measure of capacity to go back to work (Gronwall, 1980). As PASAT scores improve there is generally a consistent reduction in reports of the non-specific post-concussion symptoms, and also improved performance on most cognitive tasks (Gronwall, 1980).

Overview of the Aims of the Present Investigation

The present study aimed to look at a broader range of factors which might conceivably affect information processing capacity as measured by the PASAT. If other factors are important, this would have implications for the continued use of the test in clinical practice. Alternative models of the processes involved in PASAT performance will also be considered.

Specific factors which concerned the researcher were whether arithmetic ability, short-term memory capacity and anxiety would affect PASAT performance and of lesser interest, whether type of instruction, and, sex would affect performance. These independent variables will now be considered in more detail, some of which will be expanded upon in the body of this thesis.

Since the PASAT involves addition sums (see Appendix A), arithmetic ability of the subject/patient would intuitively appear to be an important factor which might affect PASAT performance. While Sampson (1954), (reported by Sampson & Gronwall, 1974), found a correlation of only .24 (N = 207) between serial addition performance and arithmetic ability it is not clear what measures of arithmetic ability were used. While acknowledging that arithmetic ability defined in some general way may not be a unitary construct, it does appear that some common transformation processes (Kerr, 1975) exist in the PASAT. For the present study arithmetic ability was operationalized as performance on the Wechsler Adult Intelligence Scale (WAIS: Wechsler, 1955), arithmetic subtest. This test covers such skills as addition, subtraction, multiplication, division and manipulation of numbers.

General intellectual ability was found not be be correlated with PASAT performance (Gronwall, 1976). But there is evidence that people are differentially motivated to perform tasks such as mental arithmetic (Golden, Hemmeke, & Purisch, 1980). This is consistent with the view that the "policy of allocation of effort to a task reflects the permanent dispositions and temporary intentions of an individual" (Kahneman, 1973). After using mental arithmetic performance as a dependent variable (Lacey, Kagan, Lacey & Moss, 1964) reported, "involvement in motivationally relevant tasks - tasks that interest and engage a subject because they correspond with his own achievement needs - were accompanied by high autonomic reactivity". This implies, in line with the aim of the present study, that computational ability would modify and influence PASAT performance.

Because the PASAT requires tracking both the current sum and the digit heard prior to it, short-term memory (STM) capacity could also be an important determinant of PASAT performance. Gronwall & Sampson (1974) have argued that from their experiments (see Chapter 4) STM was not a factor affecting PASAT performance. However theoretical aspects of this conclusion are not particularly clear because of the vagueness inherent in the term STM (see page 21 and discussion below). For this reason the issue of STM was re-examined here.

The digit span subtest of the WAIS has often been used in psychological assessment to give an operational definition or measure of STM, attention and concentration. This test appears to involve both tracking and scanning (e.g see discussion in Lezak, 1976). An alternative view is that it assesses multiple-input processing, with a transformation process rule required for digits backward. (e.g. see discussion by Kerr, 1973).

Gronwall (1980) found that when the Wechsler Memory Scale (WMS: Wechsler & Stone, 1973), and PASAT were given to subjects, and the results factor analysed, then the mental control subtest score of the WMS loaded on the PASAT, whereas the digit span subtest did not. This finding is at odds with the results obtained by Kear-Colwell & Heller (1978). These authors, using a normal sample, found that factor analysis of their WMS results revealed that mental control and digit span loaded on one factor (Factor 2). They concluded this factor was a "measure of attention and concentration or distractability" in normal populations. With this inconsistence present in the literature, it was decided in the present study to examine the effects of both digit span and Factor 2 to determine which ability (or both) might have an influence on, or relate to PASAT performance.

Various sources of evidence suggest that learning and memory may be influenced by levels of anxiety (Eysenck, 1979; Mueller, 1979; Gross

& Mastenbrook, 1980; Broadbent, 1977). Since the PASAT would appear to involve both learning and memory, it was considered that performance on this task might similarly be influenced by anxiety levels.

Apart from the evidence that arithmetic tests in psychological assessment may contribute to anxiety; since the PASAT requires responding to rapidly paced stimuli which probably increases arousal and produces stress (Welford, 1968), these components of PASAT performance could contribute to anxiety too and thus feedback to affect PASAT performance.

So while recognising that arousal and anxiety are related, it is necessary to distinguish these concepts. For the present study, anxiety is considered to have both a congnitive or 'worry' component and an emotionality or arousal component (Eysenck, 1979).

Posner & Boies (1971) and Posner, Klein, Summers & Buggie (1973) concluded from their series of experiments that 'high anticipatory arousal' (similar to the above definition of anxiety) improves perceptual analysis, but does not facilitate other mechanisms that determine choice of response. In terms of performance, this means that the percentage of errors increases in subjects that are highly aroused. It is equally possible, as Eysenck (1979) argued that while anxiety will always reduce processing effectiveness, performance efficiency will not be impaired if there is sufficient effort expenditure. Therefore it was expected that high state anxiety would lead to, at least, increased errors on the PASAT.

Anxiety was assessed by the State-Trait Anxiety Inventory (STAI: Speilberger, Gorsuch & Lushene, 1970). It is an inventory which gives indices of the cognitive or 'worry' component of anxiety, and is discussed in more detail in Chapter 3.

It had been observed that performance on the PASAT may be optimized by adopting an efficient as possible processing strategy (Gronwall & Sampson, 1974). However, the effects of strategy have not been systematically investigated. This will be examined in the present study by suggesting to some subjects a helpful alternative strategy if such is not being used. An additional point, and one inherent in Kahneman's (1973) theory of increased effort according to demand, is that it may well be the case that strategy and state anxiety interact to produce subtle change in error rates on the PASAT.

Sex differences may exist in the performance of this test and this has not been examined previously (see review by Fairweather 1976). Cronwall & Sampson (1974) used only male subjects, so whether or not males and females may perform differently on this test is unknown. Furthermore, some interaction effects may also be present. For example, Feinberg & Halperin (1978) found that sex and arithmetic ability interacted to affect performance on a statistics course. Kear-Colwell & Heller (1978) found a significant sex difference on their Factor 2. Thus sex and STM factors may well interact to affect PASAT performance.

Chapter 2 - Cognitive Process

The foregoing chapter supplied a brief introduction to the aim of this Thesis and related theoretical issues. The present chapter will supply more detail about the theory which is most pertinent to understanding the underlying mechanisms of PASAT performance.

Broadbent (1971) postulated the existence of a limited-capacity central processor, along with internal mechanisms for attention and short-term memory. He distinguished two types of conscious selective attention. Firstly, filtering, which is the selection of a stimulus for attention because it possesses some one feature that is absent from irrelevant events. Secondly, in pigeon-holing, however, the relevant, and irrelevant stimuli do not differ by a single feature. Rather, there is a set of responses or pigeon-holes which are distinguished from each other by various combinations of sensory features, and into which any event in the environment will be forced if possible, or rejected if it fails to fit any of them. Pigeon-holing therefore requires more processing of information than filtering does, although it still saves a certain amount of processing because there is no need to discriminate between irrelevant events.

The pattern of errors for the two processes is different. A filtering process error results in a decision about an irrelevant event, whereas probability errors occur with pigeon-holing. In terms of PASAT performance filtering involves perception of digits and pigeon-holing involves categorizing that number for a certain type of processing. So filtering errors would be the result of processing the wrong information, whereas pigeon-holing errors would be the result of processing information the wrong way.

Since the selective filter passes only a relatively small amount of information to the limited-capacity channel, which in turn is relatively slow, information continually queues up behind the filter. Hence, the system needs some temporary memory capacity. According to Chase (1978) the best experimental demonstration of this system came from the temporal ordering of output data when subjects were presented with simultaneous sequences of inputs. This implied that the mechanism underlying the immediate memory span was a rehearsal loop. Thus as pacing on the PASAT increases, STM is reduced, and so is the rate of responding. If errors are made this reduces the rate of responding on PASAT further. Rabbitt & Rogers (1977) argued that this was not necessarily evidence for a temporal model of information processing since their study showed that rate of responding (on a CRT task) after an error was not slowed if the subject was required to make an error correction response.

So various issues surrounding the use of the temporary memory systems remain unresolved. For example, Kahneman (1973) pointed out that pre-perceptual memory needs to be distinguished from post-perceptual short-term memory. Also it is not clear whether or not filtering is a valid concept. For example Treisman (1971), (reported in Kahneman, 1973), hypothesised that divided attention and parallel processing are possible for two simultaneous inputs if they do not require the same analysers. And further, it is not clear whether or not information is filtered out of the system before it is ever processed or attended to. For example, the 'Deutsch-Norman Theory' (Kahneman, 1973) said that "a message will reach the same perceptual and discriminatory mechanisms whether attention is paid to it or not".

Consequently, filter theory is practically devoid of mechanisms specified well enough to make quantitative predictions (Chase, 1978). Thus the selective attention mechanisms involved in PASAT are similarly difficult to specify. So while filter theory remains a useful approximation to what people usually do (Kahneman, 1973), its limitations necessitate the hypothesis that PASAT performance depends upon a limited-capacity central processor. Not only does such a concept imply a passive vessel into which things are put, obviating personality and environmental variables. It also appears mathematical theory of channel capacity, upon which it was based, has dubious relevance to psychology, since it cannot be demonstrated that selective attention has any relation to the brain's real capacity (Neisser, 1976).

Broadbent's (1977) current position recognises that personality and environmental variables may influence normal processing capacity. However his approach remains empirical. Adopting Neisser's (1967) term he postulated that filtering and pigeon-holing are used consciously and deliberately, but both are constrained in different ways by hidden 'pre-attentive processes'.

Experiments such as those conducted with hearing (Frankish, 1975) and vision (Kahneman & Hanik, 1976) supported the view that the perceptual system operates in a hierarchical fashion, with the more detailed and local features nested within the more global and general ones. An important part of the preattentive processes therefore, is the segregation of detailed stimuli into bundles or segments that can be attended to or rejected as a whole. This would imply that those with greater digit span, would be better at the PASAT.

The pigeon-holing mechanism, rather than the filtering one is where individual motive and meaning biases affect how one construes a given perception. Thus Broadbent (1977) said that "if a person approaches each new situation with certain interpretations 'at the ready' then he will produce one of them whenever the situation contains, somewhere a roughly appropriate stimulus". Thus it is possible that similar biases affect numerical processing as in the PASAT.

After considering evidence from experiments on word perception, visual masking (see review by Broadbent, 1977) and in the light of Becker & Killion's (1976; reported in Broadbent, 1977) verification hypothesis Broadbent synthesised a more complex approach which allowed that pre-attentive processes could determine how much space is allocated to channel capacity. They do this through two stages of perceptual selection.

The early global or low-frequency, stage packages information from the environment into different segments, each of which can then be attended or rejected; but it also acts, largely passively, to suggest percepts biased according to probability. Thus at this stage PASAT digits are perceived in terms of the task parameters such as pacing and instructions given. A later enquiry, or verification, stage works with more detailed information from the original segments and is perhaps more affected by context and the co-ocurrence probability of detailed features. This is the active stage of processing and transformation of the PASAT digits. If these stages could be distinguished, it is possible in terms of the present study that PASAT performance will be related to tasks which reflect this distinction, such as digit span and arithmetic ability.

Broadbent's (1977) approach is similar to Kahneman's (1973) perceptual hypotheses. In perception, Kahneman argued, there appears to be, firstly, unit formation. This is an initial grouping stage where attention is focused by selecting among available perceptual units (objects or events) those units to which most capacity should be allocated. Secondly, if selective attention results in attenuation, the figural emphasis given depends on the ease with which relevant stimuli can be segregated at the stage of unit formation, and that the effectiveness of rejection of irrelevant stimuli depends on the amount of capacity demanded by the primary task.

Where Kahneman differs from Broadbent, is that he specified that effort is invested in perception. The allocation of effort or attention to a particular perceptual object is manifested in figural emphasis.

The effect of this allocation is to enhance the quality of the information which eventually reaches the recognition units. The number of activated recognition units and their degree of activation are affected by the amount of attention that was paid to the stimulus object. However, the activation of recognition units and the achievement of perceptual interpretations do not require more attention than was already allocated at the stage of figural emphasis. Thus PASAT performance may be viewed as a function of attention paid to task stimuli and effort supplied to figural emphasis.

Kahneman (1973) argues that perceptual and response readiness may be viewed as altered states of the specific units which are activated in the processes of perceptual interpretation and response selection. It is maintained that performance units are roughly equivalent to perceptual units and that each unit is characterized by a certain level of demands i.e. need for attention or effort. Performance falters if the amount of attention allocated to a performance unit is less than the amount demanded. Furthermore, the amount of attention or effort supplied to a unit rises with demand, until a task is made too complex, then performance slows down and errors increase in spite of augmented effort. Thus it is expected that the attention or effort supplied to the PASAT will be limited, and this will be reflected by a drop in PASAT performance as task demands increase.

Kahneman postulated that there are two types of interference possible. Capacity interference which is due to attentional demands rather than a constant limit on capacity per se, and structural interference. Structural interference suggests antagonistic interactions among neural structures. He applies structural interference for situations of strong interaction between similar tasks, and labels capacity interference situations where task difficulty is the main determinant. While task difficulty and modal specificity are tenuous concepts a sufficient explanation of interference is based on the assumption that the supply of attention generally fails to meet increased demands, which in turn explains why increased effort fails to compensate fully for increased difficulty in both single-task and dual-task situations.

These two theoretical approaches may be seen to complement each other. Broadbent's (1977) view of perception in terms of a hierarchical process involving high frequency (detail) systems nested within low-frequency (global) systems, is similar to Kahneman's process involving unit formation and figural emphasis. If Kahneman's 'activation of recognition units' and 'allocation of effort policy' processes are similar to Broadbent's processes of active verification, then both would allow that individual bias in relationship to environmental or task conditions would affect the attention given to a task and hence processing capacity. Both approaches also allow that there are probably structural limitations to these processes which could also limit processing capacity.

Kerr (1973) put forward the view that while theorists differ on the nature and therefore mechanisms involved in information processing, any hypothesis allows that different mental operations will require varying degrees of processing. Mental operations that can be distinguished experimentally include the following.

Encoding, or the operations required as one stimulus item is received and contacts its representative in memory. Multiple input, or series of operations associated with group stimuli. Rehearsal, or operations that 'maintain' an item or list of items. The specific processing demands for rehearsal have yet to be demonstrated experimentally. During multiple item tasks, rehearsal may be confounded with encoding, transformations and responding, since subjects must retain all items while operating on individual items. Transformations, or operations requiring some type of mental manipulation of stimulus information. And, responding, or operations associated with 'producing' answers.

Kerr, concluded from evidence to date, that responding, at least in recall requires more processing capacity than multiple input, which in turn requires more processing than rehearsal. Finally she made the point that some questions, including the effect of learning on processing demands remain unanswered. Neisser's (1976) approach suggested one answer.

Neisser (1976) rejected the linear model of information processing in favour of a 'perceptual cycle' which allows that experience on learning modifies perception and vice versa. In other words perception is guided by expectancies that in turn are altered by consequences. To describe the kind of information a perceiver gets from the environment he used the term schema:

> ... a schema is that portion of the entire perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified (p. 54).

Thus it is possible that PASAT performance will be a function of the schema available for, or ability at, the mental operations required for this task.

For the purpose of the present thesis information processing capacity is most usefully considered from the attentional mechanism model rather than the structural or physiological correlates of behaviour model. This is because PASAT performance is cognitive. That is, information is processed hierarchically, within a capacity where space is allocated according to demand. How much space is allocated is determined by effort expended which in turn is constrained by pre-attentive processes and schema or abilities. Accordingly, arousal is considered to be a psychological construct and will be discussed in relation to this perspective in Chapter 3. Finally, it is recognised that the operations involved in tasks used to measure information processing define what is being measured by their structure or parameters.

Gronwall & Sampson's (1974) theoretical stance is somewhat different. They used aspects of Broadbent's (1971) model of information transmission which involved the use of the following assumptions. Firstly, that the organism is considered to be an information-processing system operating within a single channel of limited capacity. Hence,

> ... a stimulus is seen as giving rise to certain states of evidence, not necessarily corresponding exactly to the stimulus because of random errors in transmission through the nervous system. A selective filter operates to pass some but not other states of evidence for analysis by a limited capacity processing stage. A system Broadbent terms categorizing then allots certain responses to certain states of evidence. In addition, he describes a pigeon-holing mechanism which may alter the probability of some responses, given the same states of evidence (p. 16).

Although their series of experiments were not designed to evaluate this model or to extend it in any way. Since, as the authors noted, " the bridge used will determine the theoretical outcome". These assumptions need to be considered further. Particularly in relation to how information processes involved in PASAT performance are concerned.

Broadbent (1958) argued that the 'single channel' processor analysed selected information and it could only process one piece of information at a time and therefore incoming information was analysed sequentially.

Broadbent's (1971) modifications to this theory did not generally change the model, however it did allow for changing 'states' in the input (filter), processing and output mechanisms. As mentioned earlier, incoming information is held up at the filter mechanism, so that there is a time limited rehearsal loop from short-term memory to the selective filter. From this perspective PASAT performance was considered to be a measure of the rate at which the nervous system could transmit information. It was structurally limited only, that is, what was being measured was assumed to be constant, independent of environmental or task conditions (Gronwall & Sampson, 1974).

Thus one aspect of this thesis is to show that Kahneman's (1973) perspective has more potential to supply an understanding of the underlying mechanisms of PASAT performance, than Broadbent's (1971) approach.

Chapter 3 - The Independent Variables: Theory and Measurement

While Chapter 2 presented the background theory which leads to the experiments done in this study, the present chapter will discuss the perspective used and tests selected to measure the independent variables outlined in the introduction. They were (1) arithmetic ability, (2) short-term memory, (3) anxiety, (4) strategy, (5) sex differences. Each of these will now be examined in turn.

Arithmentic Ability

Brush (1980) has documented that from her experience arithmetic performance may result from poor early school attitudes or experiences. Likewise, Golden, Hemmeke & Purisch (1980), who developed the Luria-Nebraska Neuropsychological Battery, found that in their experience any arithmetic test is extremely sensitive to educational deficits. Furthermore, even "individuals with normal educational backgrounds can score either very well or very poorly..... This appears to have something to do with an individual's reaction to mathematical items. People see them and immediately decide they are impossible although the items within the subtest are, in fact, very simple" (p. 61).

The current educational research into mathematical performance while not yet specifying, cause and effect of relative abilities, has found some correlation between short-term memory, modality of encoding, verbal ability, and attitude toward quantitative concepts and arithmetic ability. For example, Webster (1979) found that mathematically able students recalled significantly more items from serial lists of digits or nonrhyming consonants presented either visually or aurally. The mathematically disabled students recalled more information with the visual presentation. So Webster concluded that his result supported the hypothesis of inefficient use of memory encoding strategies during information processing by mathematically disabled students. There is some evidence from other fields of research in psychology to support the idea of modality specific memories.

For instance, Metcalfe, Glavanov & Murdock (1981) found an interaction between input modality and type of recall, specifically, visual superiority was found on a spatial task and auditory superiority on a temporal task. Similarly, high correlations are found between verbal and arithmetic ability on the WAIS. They range from .71 to .75 for the various age groups (Wechsler, 1955). Also, Aiken (1972) found correlations ranging from .4 to .86 between reading and mathematical ability, with intelligence covaried.

So, since arithmetic ability appears to be correlated with auditory STM and verbal ability, and if auditory superiority is found on temporal tasks, then PASAT performance could well be expected to be influenced by arithmetic ability.

For this thesis, a mental arithmetic test was used as a general measure of this ability, while recognising that task modality would confound a true estimate of ability (Lezak, 1976).

Similarly it has been found that attitudes affect mathematical ability. For example, Feinberg & Halperin (1978) found that attitudes toward quantitative concepts, state anxiety, expected grade outcome and basic mathematics achievement were related to course achievement in introductory statistics. Their study showed that affective and cognitive variables are correlated with achievement in mathematics-related subjects. Although Feinberg & Halperin used university students as subjects, Lacey, Kagan, Lacey & Moss (1964) findings were similar but based on a longitudinal study of normatively selected subjects. That is, these latter researchers, found that cognitive and affective variables affect performance on arithmetic. However they added the proviso, they would affect performance only on motivationally relevant tasks. Thus it appeared that the type of problems included in an arithmetic task might affect performance. So it was concluded that the type of test needed to measure arithmetic ability in the present study needed to include calculation problems which were relevant to as wide a range of people as possible, whilst including samples of most arithmetic operations.

The skills which apply to all types of arithmetic computations could be generalised from Cohn's (1961) delineation of the skills and abilities required for successful multiplication. These skills are (a) the recognition of the meaning of the indicated symbol for the operation; (b) a static memory for the appropriate tables involved; (c) a dynamic memory for operations which involve the carrying of numbers; (d) the ability to order the numerical results correctly; and (e) a final addition employing dynamic memory for carrying of numbers to achieve a solution to the problem. In Kerr's (1973) terms the mental operation is a transformation one where the processing demands are such that subjects cannot select responses by retrieving the correct answer from memory, but must combine and rearrange stimuli while applying the appropriate mathematical operation in order to answer correctly.

The currently available mathematics tests that included the above operations without undue relative emphasis upon reasoning included those used in intelligence, aptitude or neuropsychological test batteries. The latter tests were usually presented in a visual form and were specialized with norms given for specific population subgroups only. However, the WAIS arithmetic subtest is standardized for a wider range and for this and the above reasons, it was selected.

It was recognized that the arithmetic subtest score may not be a pure measure, but also reflect other factors such as 'ideational discipline' (Saunders, 1960), concentration, conceptual tracking, immediate memory and response rate (Lezak, 1976). However, while it is always difficult to obtain a conceptually pure measure, this subtest was accepted as a sufficient estimate of arithmetic ability for the present purpose.

Also, a further problem in the use of one subtest from a test where the overall reliability is built up from the integration of all subtests is that a bias in estimates relative to the scaled scores could occur. However this bias is not expected to cause serious problems in the present study because raw scores would be used.

Another problem of concern is that for some populations, for example, university students, the number of discriminating items may not be sufficient. One way of overcoming this problem is to add some items which are more difficult and hence aid discrimination at higher ability levels (Walsh, 1978; Lezak, 1976). Similarly some populations may have a prior knowledge of the test, for example, university students. As Bromley (1974) pointed out the WAIS arithmetic subtest requires little mathematical reasoning or problem solving as the problems are already formulated and conceptually familiar. So an equivalent form was needed to ensure that possible computational practice efforts did not occur. Thus rather than the more common WAIS, the arithmetic subtest of the Naylor-Harwood Adult Intelligence Scale (NHAIS), 1972, could be used. The correlation between the WAIS-NHAIS arithmetic subtests is .77. So overall, the use of either form where it appeared appropriate was considered justified to obtain an estimate of general arithmetic ability, in the present study.

Short-Term Memory

As mentioned earlier (p. 16) one component considered important in arithmetic ability is short-term memory (STM).

STM is usually taken to mean a temporary storage mechanism which serves to hold either newly acquired information until it is processed for long-term storage or to hold previously acquired information retrieved from long-term memory store for use in the present. (Webster, 1979).

According to the information processing perspective of Miller (1956) the span of short-term memory is limited by the number of items it can hold. While the amount of information contained in an item may vary, the span of STM is usually seven, plus or minus two, items. Nevertheless, recent research has shown that both developmental and individual differences in STM are large, with span for digits (the most frequent stimuli) exhibiting roughly a threefold increase from the age of 2 to young adulthood and a ratio of approximately 2:1 within age (see Dempster, 1981 for a review of the sources of individual and developmental differences).

Current educational research indicates that STM capacity and processing efficiency seem to be important parameters which constrain rapidity of new learning (Bjork, 1972; Miller, 1956), the ability to generate new ideas, and the capacity to integrate and conceptualize newly learned information with previously acquired knowledge (Baddeley, 1976). Dempster reported correlations of digit span with scholastic tests of achievement and aptitude ranging from $r = .74$ to .81. These findings may reflect the relative ease with which STM tasks may be administered and the assumption of reliability of repeated measurements. It cannot be assumed however that STM capacity determines intelligence. For instance the digit span subtest of the WAIS correlates less well with general intellectual ability (.3-.53) than any other Wechsler subtest (Lezak, 1976). Interestingly, because of the use of PASAT, she also points out it is the most sensitive test to brain damage (as reflected in lowered scores and forward-backward disparity of three or more points).

Some researchers, for example, Dempster (1981) have attempted to separate the types of factors in a task which may influence STM capacity. Accordingly, Dempster separated strategic variables from non-strategic variables. The necessity for this assumption of a distinction between functional and structural variables is not entirely clear and for the present study all variables are considered to be cognitive constructs. However it is recognized that the debate is complex. For instance, Hinrichs, Yurks and Jing-Mei (1981) concluded from their study that there are two modes of representation of numerical information: a psychophysical form that represents quantity and that can be used for rapid comparison on approximation, and a symbolic representation that is rule governed and used for exact computation. But, from Dantzig's (1954) historical and cross-cultural analysis the evidence is strong that people have little innate sense of number passed a concept of up to three, so that it appears numeracy in all its aspects is learned.

Dempster concluded that the most important factor underlying STM span differences was the speed with which incoming items could be identified. Thus, "an individual who has difficulty identifying items will have relatively less capacity left over for storing items and so will have a shorter memory span than someone who identifies items with relative ease" (p. 79).

This perspective differs from Broadbent's (1977) filter hypothesis and Kahneman's (1973) figural emphasis stages where assumptions of 'pre-attentive processes' or effort are argued to determine efficiency of item identification, although the end result in terms of STM capacity may be similar.

An alternative approach is to assume that any test of STM involves the processing demands of multiple inputs as identified by Kerr (1973; and see previous discussion, p. 12). That is, it encompasses the operations associated with encoding, retaining and comprehending a series of items as they are being presented, and the capacity available for this operation will vary according to one's skill. This is because multiple input operations involve encoding a stimulus item while simultaneously remembering previously presented items. In conclusion, for the present study, it is accepted that STM capacity is a cognitive process.

Yet another issue in relation to STM is anxiety level. Eysenck (1979) in his review of the effects of anxiety on working memory capacity defined this capacity as involving an 'articulatory loop and a modality-free central processor'. He found that most research used digit-span measures of this capacity. In his review of current research he found that 11 out of 12 studies reported a significant effect of high anxiety on working memory capacity. That is high anxiety reduced its capacity. While it is recognised that Eysenck has combined the concepts of STM and available central processing, findings such as these indicate measures of STM may also reflect affective variables. This is of importance to the present study because it is hypothesised that personality variables affect available processing capacity.

For this study the digit span subtest of the WAIS was selected to give an estimate of short-term memory capacity. Because it is presented aurally this test measures immediate auditory memory span (as defined above). There are two aspects to this test, digits forward which involves a multiple-input processing operation and digits backward which involves some transformation processing (see Walsh, 1978). That is, reversing a sequence requires that both the memory and the reversing operations proceed simultaneously. Thus both mental arithmetic and digit span performance involve a form of conceptual tracking (Lezak, 1976). But the mental operations required for mental arithmetic are qualitatively different, than those required for digit span (Kerr, 1973).

In psychological assessment digit span has been considered an evaluation of concentration and tracking, a specific aspect of the more global construct of attention. Other tests which are traditionally used to assess attention, particularly in the neuropsychological field, include serial subtraction or addition and retrieval of automatisms such as the alphabet or counting (Lezak, 1976). An example of the use of such concepts comes from the identification of a Factor 2 in the Wechsler Memory Scale (WMS; Wechsler, 1973) by Kear-Colwell, 1973, Kear-Colwell & Heller, 1978, 1980. By factor analysing the seven subtests of the WMS Kear-Colwell (1973) isolated three factors which accounted for about 76% of the variance. These factors were identified as (1) the learning and immediate recall of new information (Logical Memory, Visual Reproduction and Associate Learning); (2) attention and concentration or distractability (Mental Control and Digit Span); and (3) orientation in time and place and the recall of long established information (Information and Orientation). Then using a general population sample of n = 116, collected on a stratified quota sample basis, Kear-Colwell & Heller (1978) replicated these findings except for Factor 3. This they explained was due to a lack of variance in the data. However these findings indicated that a sufficient range of scores could be found on a normal sample to differentiate ability on Factor 2. Thus, while the WMS manual claimed the seven subtests had no differentiating value for normal subjects, the evidence from Kear-Colwell & Heller (1978) would indicate that it is appropriate to use Factor 2 with normal subjects.

Gronwall (1980) found from a group of head-injured patients given both the PASAT and WMS that the factor analysed test results gave three main factors: (1) loaded highly on PASAT and Mental control and .... "seems to be the attention/concentration/information processing rate aspect" .... (2) appeared to be a learning/memory factory loading highly on Associate learning and also on Visual recall; (3) was a general factor which loaded on Information plus Orientation scores and Digit Span. This failure by Gronwall to replicate Kear-Colwell's findings is perplexing and represents an experimental consequence requiring further investigation. It is recognized as Lezak has pointed out that the reliability of the WMS is questionable because of the disparate internal consistency of the subtests and disparate difficulty levels between the subtests and so factors such as, subtest difficulty, may account for the different factor structures. To see if the concepts used in other studies were applicable to the concepts used in the present study, Factor 2 from the WMS was included as an independent variable by combining mental control with digit span according to the method used by Kear-Colwell and Heller (1978).

Anxiety

It has been demonstrated in psychological research that high state anxiety interferes with short-term memory and problem-solving, (Mueller, 1979). The concept of anxiety is viewed in different ways by different authors. Thus Welford (1962) hypothesised that arousal affected the discriminability of stimuli and argued that mild degrees of emotions (such as anger and fear), "could bring the system to an optimum state while stronger ones would impair its ability to deal with tasks requiring a high capacity" (p. 366).

Thus it is necessary when discussing a concept such as anxiety which refers to the emotional 'state' of an individual to distinguish a cognitive component and the motivational component with its associated state of physical arousal (Eysenck, 1979).

Eysenck distinguished a cognitive component of anxiety which is called worry. This involves concern about one's level of performance, negative task expectations and negative self-evaluations; whereas emotionality involves changes in the level of physiological functioning and concomitant feeling states of uneasiness, tension and nervousness.

As Schachter & Singer (1962) pointed out, highly similar states of physiological arousal can be involved in different emotions and that it is cognitive activity which determines the emotion expressed. Also they hypothesised that anxiety is a function of arousal and cognitive appraisal. This view is accepted in the present study. So where other authors discuss the effects of arousal on task performance it can be read as anxiety. For instance, Posner's (1971, 1973) series of studies demonstrated how errors in cognitive task performance are related to what he terms ' high-anticipatory arousal'.

However the emphasis taken in the present study is similar to that of Eysenck's, that is, that worry is a task-irrelevant cognitive activity and competes with task-relevant information for space in a processing system of undifferentiated capacity. The decrements in performance due to anxiey depend therefore on the capacity demands of the task-relevant information.

Kahneman's (1973) theoretical analysis of effort suggested that a way in which highly anxious subjects would attempt to compensate for impaired task performance would be by increased effort expediture. Kahneman argued that subjective evaluation of task demands determined the amount of effort expended. The effective task demands for anxious subjects are greater than for non-anxious subjects because the former must process both task-relevant and task-irrelevant information. Kahneman also made the point that the discrepancy between task demands and the supply of effort was likely to grow as the processing demands increased. This means that the increased effort of highly anxious subjects would typically compensate partially but not entirely for the reduction in available information processing capacity caused by task-irrelevant processing.

Since worry pre-empts some available capacity and arousal increases attentional capacity, Eysenck distinguished performance effectiveness and performance efficiency to describe how this worked. He said that efficiency is a measure of the quality of performance, whereas effectiveness refered to the relationship between the quality of performance and the effort invested in it. Anxiety reduces processing effectiveness and therefore efficiency unless highly anxious subjects can compensate for reduced effectiveness by enhanced effort.

It would be generally expected therefore that high-anxiety subjects will be more likely to demand more processing space than low-anxiety subjects, and will thus exert more effort. An exception to this has been pointed out by Revelle & Micheals (1976). They suggested that effort could be affected by the subjective probability of success. "Since high-anxiety subjects tend to set hard goals that have a lower probability of success than those set by low-anxiety subjects it follows that high-anxiety subjects will be more susceptible to the lowered motivation that occurs when the chances of success appear minimal" (Eysenck p. 366).

Either way it should be possible to distinguish performance effectiveness and efficiency (in terms of the types of measures obtained from the PASAT: see below and; for example, Eysenck, 1979 for a review of the empirical evidence).

At this point of the discussion two main predictions are forthcoming in relation to PASAT performance. Namely (1) anxiety would reduce rate of responding to the task, provided the amount of effort that an individual exerted did not compensate for task-irrelevant information processing and (2) that high anxiety would reduce performance effectiveness as reflected in increased errors.

To maintain the distinction between arousal and anxiety, the latter needs to be measured by a test which highlights the 'cognitive appraisal' or state aspects of the anxiety concept. A suitable test instrument and one selected for this study was the STAI. As Katkin

(1978) said this test "is an easy-to-administer, easy-to-score and reliable index of at least individual differences in transitory experience (cognitive/affective) of anxiety". The STAI is based on the assumption that there is a valid distinction between trait anxiety (a semi-permanent predisposition to experience anxiety) and state anxiety (a transient emotional mood or condition). Since state anxiety is determined interactively by trait anxiety and by situational threat or stress and is thus responsive to situational factors whereas trait anxiety is not, the basic expectation is that state anxiety should be more predictive than trait anxiety of PASAT performance. Much evaluative research has been conducted on the validity of the STAI. For example, Naylor (1978) found evidence that the A-State is not a unitary concept, so that the summed score is possibly an artifact of situation (reversed items) by dimension (non-reversed items). It appears that the STAI may measure personality variables apart from anxiety, for example defensiveness. Redfering & Jones (1978) found that as the level of experienced stress and defensiveness increased, the magnitude of reported anxiety decreased without respect to A-State or A-Trait. Thus as Dreger (1978) pointed out, not only is there evidence that the A-Trait is measuring considerable state-anxiety, the STM is open to faking and "therefore the user needs to ascertain independently to what degree examiners would be likely to bias their responses and in which direction".

Also, there is an equal amount of research indicating that the STAI is a reliable measure. For example, Metzger (1976) examined the STAI in stress and no-stress situations and found the inventory a "highly reliable discriminating measure and therefore a useful research tool".

In line with earlier comments (p. 24) the A-State was possibly measuring the 'worry' (Eysenck, 1979) or 'self-reference effects' (Mueller, 1979) of anxiety rather than arousal or emotion. This is a strong argument in support of its use in the present study where a measure of the former is sought.

A final point is that it is possible to check on bias in the selection of a sample and the possibility that 'demand characteristics' (Orne, 1962) would be affecting the results in the present study. For example some indication of the group bias can be obtained by reference to the available norms supplied by Spielberger, Gorsuch & Lushene, 1970. If discrepancies were observed suitable modification to the interpretation of the results may prove necessary.

Strategy

As Gronwall & Sampson (1974) observed every subject's task performance was extremely efficient within limits imposed by reduction in information-processing capacity. In their terms, "behaviour was adaptive in the sense that a trade between arousal level and instructions ('set') apparently enabled operations required by a task to be carried out as efficiently as the system's available capacity allowed" (p. 89). As mentioned earlier, (p. 2) these authors did not attempt to explain the mechanisms involved in 'set', but recommended that "different types of emphasizing intructions" be investigated.

Kahneman's (1973) theory offers an explanation of set as a determinant of effort demands. He said that instructions allow anticipation of task requirements and therefore reduce the effort required for task performance and ensure that the supply of effort will meet the demands. Demand effort can mean either a necessary condition (demand 1) or further action to meet a need (demand 2). In the second sense it is the feedback loop from task performance which continues that type of mobilization demand. If task instructions determine the continuous allocation of some capacity, then it is reasonable to assume that the type of task determines attention and effort demands. For instance, the rate of mental processing is a primary determinant of success of effort. This arises because with an imposed rate, the rate of rehearsal must compensate for the rate of decay of stored information. Clearly a concept of rate becomes meaningful only when the units of activity are specified such as in a continuous stimuli situation. So in Kahneman's terms 'set' is an adjustment of effort where the anticipation of future stimuli and responses facilitate task performance by permitting response integration. This has clear links/ implications for PASAT performance and the results from this present study will permit some evaluation of this model. If, as Kerr (1973) argued, the processing demands of a task vary according to the mental operations involved then a task involving multiple input rather than transformation could be less demanding (see earlier discussion p. 12). So if the instructions for a task enabled it to be carried out using one of these alternative mental operations and individuals exert effort to optimize their performance, then it is possible, depending on available spare capacity, either multiple-input or transformation processes will be used. Furthermore, if anxiety pre-empts cue utilization (Gross & Masterbrook, 1980) then it is possible that the strategy used will interact with this variable to affect information processing capacity. The present study, by examining two processing strategies will enable some evaluation of Kerr's (1973) model. It differs from Kahneman's (1973) view in that if Kerr is correct, the strategy which requires more complex mental operations will be more difficult, so task performance will depend on strategy used. If Kahneman is correct task difficulty (strategy) will interact with spare capacity available and hence effort allocated to the task.

Sex Differences

Fairweather (1976) has pointed out one cannot "pretend to test a theory of sex differences since at present none can exist". Theoretical candidates such as cerebral lateralization fail on the grounds that specific sex/hemisphere interactions as have been found contradict the theory's predictions (Marshall, 1973). Similarly, Fairweather (1976) argues that the hypotheses of spatial ability being carried on an X-linked recessive gene, is complicated by the failure to find a (highly circumscribed) sex difference until puberty. In his review Fairweather (1976) concluded that legitmate studies of sex differences can only grow from observations of clear individual differences in salient psychological processes; and second, from the observation that the groups of individuals thus differentiated have clearly biased compositions when divided by sex. Despite these arguments and evidence to the contrary, researchers such as Kear-Colwell & Heller (1978) continue to use sex as an independent variable in normative studies of various psychological measures. These authors found, for example, a significant difference in favour of males on Factor 2 of the WMS. Further investigation of the Factor 2 subtests revealed a non-significant difference between the sexes on mental control, but there was a significant difference in favour of males on the digit span subtest ($t = 2.8$, $p < .01$). Thus they concluded from their sample of 56 males and 60 females that males are significantly more free from distractability than are females on this test. Aside from questioning what theoretical bases there is for this 'distractability' sex difference, the result could be due to the nature of the sample (e.g. Factor 2 also interacted with social class). That the results were due to some individual differences per se is contensious, since they also found a significant relationship between social class and all other scores.

Gronwall (1977) found that sex of respondents had an insignificant effect upon PASAT performance. But, Gronwall and Sampson's use of male subjects in their 1974 studies, while highlighting the cultural phenomena of the likelihood of concussion producing injury occuring in males, gave no detail as to why only males were used, or if sex differences could be expected on some theoretical/empirical grounds. However, educational research (e.g. Brush, 1980) findings could be construed to form a theory for sex differences. For example, if males have reduced anxiety by believing they are better able than females to learn and perform specific cognitive tasks, then this may be the source of observed sex differences. For instance, Feinberg and Halperin (1978) found that regardless of previous ability, females experienced higher state anxiety, perceived themselves as having less ability, expected a lower grade, and consequently performed significantly worse on a statistics course. Thus, in the context of the present study, sex differences may arise as a consequence of an interaction with other factors such as anxiety, rather than arithmetic ability for example. For this reason this study makes a preliminary examination of the effects that sex (alone and in conjunction with other factors) may have on PASAT performance.

Table 1 summarises how the independent variables discussed in Chapter 3 may be expected to effect information processing capacity as measured by the PASAT, according to the theoretical perspectives discussed in Chapter 2.

Table 1: Expected effects of the independent variables on PASAT performance according to theoretical perspective

	Arith	DS	F2	state	trait	strat
Sampson and Gronwall	NE	NE	NE	NE	NE	NE
Broadbent, 1977	NP	ME	ME	IE (DS)	NE	IE (state
Kahneman, 1973	ME	ME	ME	IE (Arith (DS (F2 (strat (sex	IE (state	IE (state (sex
Kerr, 1973	ME	ME	ME	NE	NE	ME
Neisser, 1976	ME	ME	ME	NP	NP	ME

Key: NP = theory makes no clear prediction in the context of this thesis

NE = no effect

ME = main effect

IE = interactive effect with other independent measures (as shown)

Arith = arithmetic ability

DS = digit span

F2 = factor 2

state = state anxiety

trait = trait anxiety

strat = strategy

N.B.: Sex is not included in the table, but is included as an independent variable for explanatory purposes.

Chapter 4 - PASAT

The effects of pacing on performance of serial addition

In the 1950's Sampson investigated vigilance decrement. The question was, why did a decrement in number of responses typically occur when subjects were required to respond rapidly to a homogenous series of stimuli, over a period of time.

To answer such questions Sampson (1956) developed a serial addition task and looked at parameters of performance on it. He used a visual presentation of the task, and found that the level of performance depended not only on frequency of stimulus presentation (pacing) but also upon the time-on-time-off ratio. A 50:50 on-off ration resulted in the poorest performance whereas the largest on to off ratio yielded the highest scores. Furthermore, Sampson also observed a disproportionate increase in omissions ("blocking") with increase in pacing, as compared with increase in errors. He concluded that it was not sufficient to conceptualize the effects of timing on behaviour in terms of the frequency of presentation alone, other factors were involved.

Temporal Integration

Using previous research and their own data Sampson and MacNeilage (1960) put forward an explanation of performance on serial addition from a theoretical paradigm of temporal integration. They hypothesised that under the appropriate pacing conditions subjects could achieve 100 per cent correct responses on the task. Deviations from a continuous flow of responses occurred "because a 'directive' (a neurological organization necessary to fulfill task demands) regresses towards randomness with respect to the demands of the particular task as a function of task duration with rate of regression a function of pacing rate" (p.86). Sampson and MacNeilage argued that a variable background of non-specific stimulation was required to sustain temporally integrated behaviour. The three sets of relevant stimuli were: (1) those that supply the critical content (the digit forms and the instructions) of the directive; (2) sensory stimuli associated with pacing rate and pacing change, and (3) a group of general environmental stimuli.

Thus three conditions were proposed to effect a change in the direction of behaviour on the paced serial addition task. Firstly, as mentioned earlier, a regression of the directive; secondly, errors which were followed by omissions (i.e. recognised 'errors') could refocus the directive; thirdly, decrease of background stimulation would disrupt performance, particularly in later stages of the task.

They concluded that the value of increased stimulus duration was that it allowed rescanning, that is, the integrative process was facilitated by the opportunity to rescan. Their observation that subjects were significantly less accurate on an auditory form than the visual task they explained was a function of rescanning difficulty.

The temporal integration paradigm could now be criticised because of its behaviouristic perspective. That is, Sampson and MacNeilage argued an individual's behaviour was determined by external stimulus control. However, they also allowed that a more complex temporal process integrated perceptual information and this perspective is similar to current hypotheses, for example, Broadbent (1971).

Practice Effects

Theorists such as Osgood, Harlow and Cook (reported in Sampson, 1961) supply some of the earlier attempts to conceptualize what role practice played in learning and transfer. A key issue in the debate was whether or not practice effects were mediated by central or peripheral mechanisms. Following such debate Sampson (1961) saw the necessity for treating practice as an isolable psychological process to be taken into account in the performance of any task. Thus he examined the role of practice on a paced serial addition task.

In order to isolate practice effects he used visually presented conventional and unconventional digits. Subjects were matched on sex, anxiety levels and pre-test performance. Anxiety was measured by the IPAT anxiety scale (Cattell, 1957). Sampson acknowledged that "there were preliminary indications that level of anxiety was related to initial performance level on the experimental task". The first two experimental sessions were five months apart, and one week separated the second and third session.

The results showed an inter-session improvement in performance dependent on the use of conventional digits. This improvement he attributed to practice and argued that it would have an effect at the central rather than peripheral level. Thus, rather than improved 'technique' he explained this result may be due to a central mechanism particularly involving memory. The data showed that when stimuli were "on" longer than .4 sec. performance was a function of digit type and test-session. Whereas when stimuli were "on" just .4 sec. then level of performance was a function of test session. "The central integrating mechanism involved are able to handle task-relevant information projected briefly more adequately with practice", (p.194), because practice makes use of memory.

As Sampson and MacNeilage had observed, Sampson's (1961) data also showed an intra-trial decrement in performance and they found a 13% decrement in percent correct responses between the first 31 digits and second 30 digits of a serial addition task. This was explained in terms of the "directive" regressing toward randomness, as a function of task duration, which seemed not to depend on practice.

So, while the distinction between technique and central mechanisms did not clearly explain the results, Sampson's (1961) study had four interesting aspects. Firstly, the consideration of anxiety as a variable that may affect performance. Secondly, that practice or learning improved performance on paced serial addition. Thirdly, the consideration of a 'central' integrating mechanism rather than a 'sensory channel' for processes of task performance (cf. Sampson and MacNeilage, 1960). And, fourthly, the evidence that a "directive" or similar concept was needed to explain performance decrement on the task.

Development of the PASAT

Following the above research Gronwall and Sampson (1974) developed the Paced Auditory Serial Addition Task (PASAT) in response to a need for an objective measure of severity of closed head injury and progress during the recovery period. The auditory version was used as it was simpler to administer and circumscribed any problems of photosensitivity in patients.

PASAT

This test consists of a taped series of 61 single digits (1 - 9 in random order). The subject is instructed to add each number he hears to the one just before it, and to give his answer aloud. To be correct a response must be made before presentation of the next stimulus. While percentage correct or mean seconds per correct response are usually the measures scored for each administration of the test, error scores may be taken into account too. Errors are usually expressed as a percentage of the total correct. They may be classified as either late responses, response adding, retrieval or miscellaneous (such as arithmetic faults). Ommissions may also be taken into account. These scores will be discussed further at the end of this chapter. Trials are usually given at four different speeds, starting with one digit every 2.4 secs and increasing by .4 sec. steps each trial, until at the fastest, one digit is heard every 1.2 secs. In their 1974 series of experiments the PASAT included a fifth pacing trial of .8 secs and the inter-stimulus intervals were reversed for half their subjects.

Gronwall & Sampson argued that "PASAT thus yields an estimate of the subject's ability to register sensory input, respond verbally and retain and use a complex set of instructions. He must also hold each item after processing, retrieve the held item for addition to the next digit, and perform at an externally determined pace" (p.26).

Apart from the experiments using serial addition that have already been discussed, Gronwall & Sampson (1974) mentioned several other known parameters of this test. They cited Corballis (1962) who showed the task to have a large recent memory component. They also cited Sampson's (1954) finding of low correlations between serial addition performance and arithmetic ability (.24), and with general intelligence (.28). These results were the main reason for the conclusion that cognitive abilities had no significant effect upon PASAT performance. The previous discussion has indicated that the situation may not be so straight forward and requires further study.

<u>Gronwall and Sampson's 1974 experiments</u>

The most relevant of Gronwall & Sampson's other 1974 experiments and findings may be summarised as follows:

The first experiment of their series of studies showed that recently concussed patients' performance on the PASAT was significantly poorer than that of the controls. Both concussed groups (mildly concussed, MC, and severely concussed, SC) understood the unpaced practice instructions and both experimental and control groups were equally likely to revert to an incorrect set as measured by response-adding and retrieval errors. This, they argued, indicated that neither comprehension of instructions or reduced STM capacity explained the results because all groups were likely to revert to an incorrect set and could retain the practice digits.

However, both experimental groups showed an excess of late-response errors. Four possible explanations were put forward for this result. Firstly, that paced presentation may have a more deleterious effect than normal on STM span. Mackworth (1962) had shown that pacing and STM span interact to effect speed of responding in normal subjects. Secondly, response-production time may be prolonged compared to controls. Gronwall and Sampson reported that Briggs and Swanson (1970) had demonstrated in normal subjects that central processing time was short compared with the time taken to produce a response. Thirdly, reception difficulties may introduce a delay in information reaching the processing stage. Finally, it was considered that since rapidly paced stimuli normally increase arousal (Welford (1968), and it was known that BSRF was important in maintaining arousal level, and furthermore this system was implicated in the production of concussion, it was possible that concussion could have reduced the effective capacity of a single-channel decision-making process. This fits with Broadbent's (1971) theory (see discussion page 14). In terms of Kahneman's (1973) model it would be explained by arguing that the variable capacity available for information processing was reduced (see discussion page 11). Kerr's (1978) model would give a similar interpretation. Thus, while the end result from these various views may be similar it remained to be demonstrated how this might occur.

Further investigation was then made of the contribution of pacing and STM reduction to performance decrement following concussion. Also input, decision and output processes were to be considered separately.

This led Gronwall and Sampson to conduct a second experiment which compared MC patients with normal controls (NC) on a choice reaction time (RT) task. A pinball machine was used. On the non-symbolic aspect of the task, the subject was required to press the key at the base of the alley the ball had entered. On the symbolic trials the key with the same number as the alley the ball had entered was to be pressed.

The results showed that concussed patients had significantly slower RTs on this discrete trial, choice RT, task. This result eliminated pacing as a necessary condition for response decrement. It also appeared to eliminate defective STM span since the stimulus was available until and during the response, and retention of only one item was necessary for any one trial. Although MC patients did not differ significantly from NC on the non-symbolic form of the task, they did on the symbolic form. However, the results showed a non-significant difference between intercepts of rates of information transmission within both types of task. Also the slopes of the group functions were similar within both types of task. Thus it appeared there was no support for a delayed response production or movement explanation of concussion. Contrary to the predictions of Briggs and Swanson's (1970) model this result concurred with Broadbent's (1971) theory of reduced channel capacity. However it may also in Kahneman's (1973) terms indicate that the amount of attention allocated to a performance unit was less than the amount demanded.

Two hypotheses were suggested to fit the significant difference in RT on the symbolic task. Firstly, the experimental group could have adopted a more stringent response criterion. Or in Broadbent's (1971) terms concussion might result in an inefficient use of a pigeon-holing mechanism. Secondly, concussed patients may not have been able to use redundant information inherent in the keyboard layout. Again due to reduced channel capacity.

Experiment three examined the differential effects of input analysis in concussed and non-concussed subjects. The task involved repitition of 1st$^-$, 2nd$^-$ and 4th$^-$ order approximations to syntactical english (Miller & Selfridge, 1950). Conditions of high, medium and no masking noise were added to the messages.

There was no significant difference between groups for lists of words under any of the masking conditions. This was taken to imply that STM storage was not disturbed. Equally plausible is the explanation that both groups of subjects could supply the effort demanded by this task (Kahneman, 1973).

However there was a significant difference between groups for meaningful messages. Analysis of types of error and proportion of correct first words of each message indicated that neither inefficient use of 'pigeon-holing' (see discussion p.7) or ability to perform a recycle/modify stage after the complete message was received, explained this result. Gronwall and Sampson concluded that a differential ability to simultaneously process evidence and modify earlier responses produced meaningful message differences. In Kahneman's (1973) terms a differential ability in selective attention or allocation of effort to selected perceptual units could explain this result. Gronwall and Sampson questioned whether the task in experiment three was a model of actual processes. So a further experiment (four) using normal subjects attempted to show that performance on the speech-processing task was a function of channel capacity, (Broadbent, 1971), rather than a function of reduced attention.

The primary task was as in experiment three, and a concurrent or distraction task of letter sorting was used. The result showed that "when performing a concurrent distracting task normal subjects do not make efficient use of redundancy in the message and repitition of 4th-order approximations to english is no better than repetition of 1st-order messages" (p.67). Since this performance was like the concussed patients', it was seen to provide some support for the reduced channel capacity hypothesis. However the pattern of errors for the distraction condition revealed that these subjects' performance was poorer than the concussed subjects of experiment three.

So it was questioned whether a discrete distraction task models the effects of concussion. As the authors pointed out, premature termination of the distraction task could have confounded the results.

A further experiment (five) was conducted to determine whether concussed patients' performance on a choice RT and speech-processing tasks was influenced by the same factors that influenced PASAT performance. So a continuous RT distraction task was given with the PASAT to normal subjects. The results showed that PASAT performance was significantly poorer with distraction than without. The results paralleled the MC patients' performance of experiment one, and provided further support for the "limited single channel" model. Again, however, the results could also be explained in terms of Kahneman's variable capacity model. That is, while total capacity increased as a function of demand, this increase was at a slower rate than the increase in capacity flowing to the primary task. So the outcome was a decrease in spare capacity with increasing capacity demanded.

However Gronwall and Sampson argued that since there was no interaction of primary task difficulty (ISI) with distraction condition, the results suggested that processing rate was affected by distraction. Furthermore, the late-response errors differed significantly in the two distraction groups.

Consequently it could now be implied that concussion increased distractability. Distractability was defined as inability to focus attention on relevant stimuli only or inefficient 'filtering' (see discussion p.8). Experiment six attempted to differentiate operationalized measures of selective attention versus reduced total capacity. MC and NC subjects were given a dichotic listening task. They were asked to repeat the message (list or 1st-order text) given to the left ear only.

The results showed that the MC group was significantly less efficient in repeating the relevant message. While there was also a significant groups and test-occasions interaction, error analysis gave no indication of group differences. However since the controls showed more effect from switching (greater omissions) messages this result could have been due to too few subjects (Miller & Cruzat, 1981).

The authors concluded however that there was no evidence that selective attention was impaired after concussion. They viewed selective attention as the filtering of relevant from irrelevant events, rather than as a function of the quality of figural emphasis due to the allocation of effort (Kahneman, 1973). In this way Gronwall and Sampson argued that since patients were able to ignore one source of stimulation and respond only to an equal-intensity source designated as relevant by instructions that patients must be using a central processor of limited capacity.

These results lead to the conclusions given in the introduction of the present study. That is, that concussion reduces a fixed amount of space which is available for information processing. So, the PASAT measures "channel capacity" - the amount of information that can be handled at one time, a quantity with definite limits. The processing of information will be inadequate either if the number of items requiring simultaneous attention is too great, or if the rate of function is inadequate.

Gronwall and Sampson's argument centred around demonstrating that processing rate was not affected by STM capacity; inability to follow instructions; pacing; input difficulty (pigeon-holing); response production or selective attention (filtering). They sought to explain that capacity was reduced by the relative inefficiency of physiological structures. These structures were those involved in the process of active interaction between the BSRF and cortical (particularly the frontal lobes) systems. The end result of this process was conceptualized as arousal (Moray, 1969). To substantiate a synthesis between the latter and Broadbent's (1971) cognitive concepts, pathological evidence was cited, such as EEG and other physiological measures of cortical activity during PASAT performance.

Thus Gronwall and Sampson relied heavily on the models of Broadbent (1971) and Moray (1969, 1970), both in interpreting and designing the experimental investigations. As discussed, more recent evidence and theory suggests there may be better alternative models to explain the results. Further, more recent theory and evidence raises some doubts about the effects of STM, strategy, anxiety and arithmetic ability being as insignificant as Gronwall and Sampson argued. Since these concepts were key to the development of the PASAT, they require a re-examination in light of recent developments.

Gronwall (1980) admits the earlier synthesis did not explain behaviour on all cognitive tasks after concussion, particularly memory tasks. Consequently two further investigations were made to examine STM in more detail.

Further PASAT Investigations

Gronwall (1976) looked at the effects of pre-injury intelligence on recovery from concussion. When university students were matched on accident and demographic variables with non/students it was found that their recovery times were not significantly different (as measured by normal PASAT scores). During recovery word fluency, Quick-test IQ (Ammons & Ammons, 1962) and Wechsler Memory Scale scores were not significantly different between the groups. When PASAT scores were normal, however, the student groups scored significantly better on all these, largely verbal, tests. Gronwall concluded that intellectual level did not appear to be a factor influencing recovery time and in fact patients with higher IQs were more handicapped during this period. This result could indicate that during the recovery time either of the two information processing models (Broadbent & Kahneman) fitted the data. Whereas after recovery, the students' increased performance on these largely verbal tests is better explained in terms of effort supplied to task demands (Kahneman, 1973) than arousal and channel capacity.

In a sample of head-injured patients Gronwall (1980) found that PASAT scores significantly correlated with all subtests of the WMS except for associate learning and Quick-test. Factor analysis of this result gave a factor which loaded highly on PASAT and mental control, which Gronwall called an attention/concentration/information processing rate factor. The second factor loaded highly on associate learning and visual recall and appeared to be a learning/memory factor. The third factor appeared to be a general one and also included digit span and Quick-test IQ score. Similar results were obtained when the results were analysed for minor head injury cases only. The conclusion with regard to STM was that a consequence of relatively minor head injury appeared to be a specific learning deficit, which was not related to information processing capacity.

To investigate the memory factor further another sample of head injury patients and controls were given the PASAT, the Bushke Selective Reminding Task (SRT; Bushke, 1974), a verbal learning task which allows separate analysis of storage and retrieval mechanisms, the the Visual Sequential Memory (VSM) subtest from the ITPA (Kirk, McCarthy & Kirk, 1968).

While the VSM correlated with PASAT scores, there was no significant correlation between PASAT and SRT. The SRT storage scores correlated with post-traumatic amnesia duration, whereas SRT retrieval scores did not. While not explaining the mechanisms involved these findings reflected Gronwall's original observation that memory and information processing capacities recover differentially, memory usually taking longer.

As the earlier discussion suggested it is not possible to make a sharp distinction between perception and memory. Information processing depends on memory. In Neisser's (1976) terms what is remembered depends upon the information picked up and the schematic modification that took place. That is, schema become modified by anticipation of an object or event (such as task demands) in a particular context.

Again the evidence suggests that a more complex model of cognitive processes is required to explain information-processing capacity. Kahneman's (1973) theory allows for more complexity than Broadbent's (1971) theory in that it can take account of, for example, task demands, which are ignored in earlier models.

PASAT dependent variables

Quantitative and qualitative aspects of performance on any task are estimated by using both correct and error scores. On the PASAT, as already mentioned on p.36 quantitative aspects of performance are gained from the percentage correct or proportion correct scores and/or the mean seconds per correct response. Both scores reflect the rate of performance for each correct answer as a function of the total number of stimuli. Usually scores are obtained for the test as a whole. Gronwall (1977) pointed out there is usually no more than 0.6 secs difference between the pacing speeds (trials). The average time score allows direct comparison of tests where different numbers of trials are given, thus this is usually used clinically. Whereas the percentage correct was used for research purposes.

The errors on the PASAT are calculated as a proportion of the responses and they usually account for less than ten percent of the total responses (Gronwall 1977).

Gronwall & Sampson (1974) classified the types of errors which can occur as follows. Late responses: a correct response to the n^{th} digit, but delayed until n+1 or n+2 has been played, providing no other response is made between the late response and the n^{th} digit. Retrieval errors: on a response where digit n-2 instead of n-1 is added to the n^{th} digit. Response adding (errors of 'set' - Gronwall 1977) where the n^{th} digit is added to the previous answer instead of to digit n-1. And, miscellaneous errors, which are errors not falling in the above categories, and includes errors of arithmetic.

The discrepancy between the percent correct and percent errors equals the percent ommissions.

It has been shown that it is pacing rate that is associated with a disturbance of performance which is characterized by significantly fewer correct answers accompanied by increased blocking (stimulus omissions) rather than wrong answers (Sampson and MacNeilage, 1960). These responses are those that indicate rate of information processing. Whereas, by taking errors into account an indication of not only 'how much', but 'how' the task is carried out may be gained. In summary; Gronwall and Sampson (1974) saw the three PASAT dependent measures as indices of channel capacity and rate of information processing. However, it is possible that other factors could influence these indices, for instance, errors may arise from sources apart from rate. Table 2 summarises the underlying dimensions of each of the PASAT measures as they could be viewed from the theoretical perspectives outlined in Chapter 2.

<u>Table 2:</u> <u>Underlying dimensions of PASAT measures according to theoretical perspective</u>.

<table>
<tr><th></th><th>percent correct</th><th>mean secs.</th><th>percent error</th></tr>
<tr><td>Sampson & Gronwall</td><td>arousal</td><td>arousal</td><td>arousal</td></tr>
<tr><td>Broadbent, 1977</td><td>preattentive</td><td colspan="2">processes x verification processes</td></tr>
<tr><td>Kahneman</td><td colspan="2">effort x figural emphasis</td><td>capacity</td></tr>
<tr><td>Kerr</td><td colspan="3">transformation processing demands</td></tr>
<tr><td>Neisser</td><td>schemata</td><td>schemata</td><td>schemata</td></tr>
</table>

Chapter 5: Synthesis

The aim of this chapter is to highlight the differences between the limited-capacity channel models and variable-allocation capacity models of information processing in relation to PASAT performance. Both Kahneman and Broadbent take a monist psychoneural perspective of cognitive activity where the evidence for this activity comes from behaviour. If it is accepted that behaviour is any performance that affects the environment, that is, has social meaning, then the environment in turn clearly modifies behaviour. Where the theories differ is in their explanation of what limits cognitive activity. ("This problem arises because we do not attend to the same information when we describe our behaviour as when we execute it", Neisser (1976).

Kantowitz (1974) proposed a useful distinction between Broadbent's (1971) and Kahneman's (1973) models based on where these models proposed that the 'locus of limitation' to information processing would occur. Broadbent's (1971) limited-channel model consisted of a central processor and a feedback monitoring system which attenuated rather than blocked signals. Although it was possible the constraints of the system would decrease with practice the bottleneck in information processing resulted from the rate at which information was transmitted through the channel.

Gronwall and Sampson (1974) eliminated the various limiting mechanisms of Broadbent's model, that is, short-term memory capacity, filtering and pigeon-holing as constraints on PASAT performance. They accepted that rate of information processing on the PASAT was limited by the channel capacity of a central processing system. However they could not escape the explanation that concussed patients 'made less use of stimulus information'.

A variable-allocation capacity model which has no locus of limitation would also explain this result. In Kahneman's (1973) model the apparent bottleneck results from the nonlinear supply of effort as more capacity is demanded. At the point where no spare capacity is available the variable-allocation model becomes a limited-capacity model, with the locus of limitation being unspecified. A key assumption of Kahneman's model is that "the mobilization of effort in a task is controlled by the demands of the task, rather than by the performer's intentions". Predictions from this model are very difficult because there is no a priori standard of distinction between task demands and the performer's intentions (Kantowitz, 1974).

However, one advantage of Kahneman's model is that it does not rely on a physiological or structural explanation for a hypothetical mechanism to the extent that Gronwall and Sampson's interpretation of Broadbent's (1971) model does. Also, Kahneman's model allows that other variables such as skills and personality factors may affect the allocation of effort.

Neisser (1976) suggested that cognitive activity would be more usefully conceived as a collection of acquired skills, than as the operation of a single fixed mechanism. That is, we acquire schema. Schema allow not only anticipation, but a smooth adjustment of effort. This operates at two levels. Firstly, Kahneman (1973) argued that preparatory adjustments such as perceptual readiness and response readiness reduce the effort required in any task and thus increase the likelihood of a particular interpretation or response. So "perceptual and response readiness may be viewed as altered states of the specific units which are activated in the process of perceptual interpretation and response selection" (p.193).

Secondly, in contrast, selective set is a characteristic of an allocation policy that controls figural emphasis and other manifestations of selective attention. Here, when a selected stimulus demands attention, more attention or effort is allocated to it than to the processing of other stimuli. This means that PASAT performance depends upon the selective attention given to auditory inputs and the allocation of capacity given to task relevant spatio-temporal perceptual units in preference to others. Likewise it is possible that irrelevant stimuli may be grouped with task relevant perceptual units. Then "spare capacity is continuously allocated to the processing of perceptual units that are not emphasised" (Kahneman, 1973).

Kahneman pointed out that the mechanisms of 'set' are not mutually exclusive and more than one mechanism may be engaged in any task. Therefore the locus of limitation is an allocation policy which could vary according to an individual's ability or experience with the environment. This means task demands vary according to an individual's skill or ability too. Thus general abilities could affect the variable capacity available; assuming that context and intent of a task is constant (experimentally). More specifically and in relation to PASAT performance, arithmetic ability could affect the capacity available for processing the incoming digits from the PASAT. These aspects of perceptual and response readiness would be reflected in the 'seconds per correct response' and 'percentage correct responses' measures gained from the PASAT. That is, it could be expected that greater arithmetic skill would decrease task demands and the effort required so a person could do more items of increased difficulty or respond longer on a continuous reaction-time task involving arithmetic sums.

Similarly, familiarity with encoding digits could decrease the task demands and effort required for multiple input or transformation processes (Kerr, 1973) in digit span and mental control STM tasks. While a concept of STM capacity is usually found within a limited-capacity model of information processing, as Chase (1978) pointed out it is the most debatable aspect of Broadbent's (1971) model. Therefore consideration of the processing required by tasks such as digit span and mental control best fits within a variable-capacity model. This is not to imply that ability on these STM tasks is necessarily related to arithmetic ability. In relation to PASAT performance this means that it is difficult to specify a priori in which way the perceptual processes and mental operations involved in this task are similar to digit span or mental arithmetic tasks.

As previously discussed, Eysenck (1979) demonstrated how anxiety might pre-empt available capacity (see pages 25-26).

Clearly, a given strategy for a task would affect the selective attention allocated that task. So it is here that the context and intent of a task could determine task demands and effort expended, more than abilities, though the two are never mutually exclusive (Kahneman, 1973). Again the variable-allocation model allows that an individual, regardless of arithmetic ability, given an additional helpful strategy for completing the PASAT, could experience less anxiety and so achieve a lower score on the "percent errors" measure on the PASAT than one who has similar arithmetic skill, but is given complex instructions only, and experiences anxiety. Testing for this interaction is one important feature of the present study.

Similarly if there is a sex bias in acquired abilities, then it could be expected that there would be at least an interactive effect of sex and ability and/or sex and anxiety on PASAT performance.

To summarize, although one of the virtues of the limited-channel model is its greater testability the more amorphous variable-capacity hypothesis allows that a subject's abilities, plans and purposes could affect performance on a cognitive task. That is, PASAT is a focused attention task best described by the emphasis given to perceptual units rather than in terms of a filter that selects among channels.

In Kahneman's terms, it is predicted that PASAT performance depends on the ease with which relevant stimuli can be segregated at the stage of unit formation, and that the effectiveness of rejection of irrelevant stimuli depends on the amount of capacity demanded by a task.

Chapter 6 - The experimental investigation

A number of clear hypotheses arise out of the foregoing (Chapter 5) discussion. These will now be briefly reiterated and this will be followed by a discussion/description of the experiment used to examine these hypotheses.

Main effects hypotheses

These may be summarised as follows:

For each of the three dependent measures (percent correct, mean seconds per correct response, and percent errors) significant differences will occur between:

high and low (a) arithmetic ability (Arith) groups (see page 17)

(b) digit span (D.S.) groups (see page 20)

(c) Factor 2 (F.2) groups (see page 24)

(d) state anxiety groups (see page 26)

(e) trait anxiety groups (see page 26).

Also differences between strategy used (strat), and between male and females will be tested (see page 30).

Two-way interaction hypotheses

These may be summarised as follows:

For each of the three PASAT measures, an interaction will occur between:

(a) arithmetic ability and state anxiety (see page 17)

(b) digit span and state anxiety (see page 22)

(c) Factor 2 and state anxiety (see page 22)

(d) strategy and state anxiety (see page 29)

(e) sex and state anxiety (see page 31)

(f) sex and arithmetic ability (see page 31)

(g) state anxiety and trait anxiety (see page 27).

These hypotheses were tested, where appropriate, with planned comparisons (unequal n, unweighted means solution), Keppel (1973).

While all these analyses were done with the normal sample subjects (see below), the results obtained and the demographic characteristics of the patient sample led to some reduction and modification of these hypotheses for that group. They will be outlined in a latter section of this thesis.

Experimental Design

The experiment consisted of a seven-way, between subject, fully-crossed factorial design. The seven independent variables were: arithmetic, digit span, Factor 2, state anxiety, trait anxiety, strategy and sex. These factors were partitioned for analysis into two levels (high and low). These levels were determined by a median split procedure (see Appendix B for data).[1] For purposes of computing correlation co-efficients, raw scores were used.

The PASAT dependant variable measures were percent correct, mean seconds per correct response and percent error (see scoring

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[1]Analyses were done with anxiety measures partitioned into high, medium and low groups to provide a check that interaction effects were not occuring because of lack of extreme scores for the normal group. The results from these supplementary analyses produced no new findings and were consistent with those referred to here based on the median split. They will not for this reason be discussed further.

procedure in Appendix A).

The design of Experiment 2 (using a patient sample) will also be given in a latter section of this thesis.

Experiment 1

Subjects Forty-eight, second-year, Psychology students participated in the experiment. There were thirteen males and thirty-five females. Their ages ranged from 19 to 31 years; the mean age was 21.3 years.

Apparatus and materials One PASAT tape, prepared by a male speaker was used. On the tape was a practice series of ten digits recorded at the rate of one digit every 2.4 secs. This was followed by a series of four trials of 61 digits (1 to 9), in the same random order for each set, recorded every 2.4, 2.0, 1.6 and 1.2 secs respectively. At each trial the appropriate series of digits was to the subject, who was instructed to add each digit he heard to the one immediately preceding it, and to give his answer aloud. (For further details, see Appendix A).

The other tests used were as follows.

The arithmetic subtest of the NHAIS. Because of possible ceiling effects, two sets of four additional multiplication problems were given in a counter-balanced order. (That is, either 99 x 2, 23 x 9, 99 x 22 and 99 x 36; or, 99 x 3, 24 x 9, 88 x 22, and 88 x 36). The NHAIS problems were administered and the raw score obtained, according to the NHAIS manual. The multiplication problems were scored either correct (1 point) or incorrect. This score was added to the NHAIS raw score and a medium split performed (see Appendix B).

The digit span subtest of the WAIS and the mental control subtest of the WMS were administered according to the respective manuals. Forms I and II of the WMS were used in a counter-balanced order. Raw scores were obtained for both measures. In addition, the results from the digit span subtest and mental control subtest were combined, (mean of digits forward, digits backward and mental control), to give a Factor 2 score (Kear-Colwell and Heller, 1978).

The State-Trait Anxiety Inventory (STAI) (see earlier discussion p.27) was used and administered as per the manual. However the additional instruction was given that the subject respond to the State items according to how one felt during the PASAT test.

There were two strategies for doing the PASAT which were investigated and these are given in the procedure section which follows.

Procedure Testing was carried out over a three week period during July-August 1981. The same experimenter was used for all testing sessions. The same room was used to administer all tests; and each subject was seen for two half hour sessions, each session separated by one week. In the first session the mental control, digit span and arithmetic tests were given. On the second occasion the strategy/PASAT and STAI were given. This was so the high and low arithmetic ability levels could be matched for the strategy/PASAT given.

In all cases the instructions recommended by the PASAT manual for the administration of this test were used (see Appendix A). This was strategy one. For strategy two the administration was the same as for strategy one with the additional instruction:

> "an alternative strategy that has been found to be useful for completing this task is to add each successive pair of numbers, so that one can complete at least half the additions, particularly on the fastest two trials".

Results

Main effects hypotheses

Table 3 summarizes the results in respect to each hypothesis (for further details also see Appendix C).

Table 3. Experiment 1 main effect F values for each of the dependent variables

	Percent correct	mean secs.	Percent error
arithmetic	16.92***	12.16***	5.73*+
digit span	3.29	1.65	5.40*
Factor 2	6.61**	5.96*	5.47*
state anxiety	.47	.40	5.96*+
trait anxiety	.00	.21	.41
strategy	.13	.47	.58
sex	3.49	2.39	.25

df (1,40);

* $p < .05$

** $p < .01$

*** $p < .001$

\+ (significant 2-way interaction also occurred see table 4)

The results showed that arithmetic ability significantly affected percentage correct, mean seconds per correct response and percentage errors on the PASAT.

The effect of a difference in digit span ability was non-significant for the percentage correct and mean seconds per correct response measures. However there was a significant average difference for percentage error between the groups (see table 3). High and low Factor 2 groups differed significantly in average percentage correct, mean seconds per correct response and, also, on average percentage error. (See table 3)

The main effects for state anxiety; trait anxiety; strategy used and sex were non-significant (see table 3 and also Appendix C for means of main effects).

Two-way interaction hypotheses

Table 4 summarises the results of these hypotheses (see also Appendix C).

Table 4: Experiment 1 two-way interaction F values for each of the dependant variables

	Percent correct	mean secs.	Percent error
State x Arith	.002	.002	5.73*
State x D.S.	.01	.08	7.66**
State x F2	.34	.30	6.7**
State x strategy	.69	.25	4.66*
State x sex	2.84	2.04	6.28*
Sex x Arith	.28	.00	.02
State x trait	8.78**	5.52*	.24

df (1,40);

* $p < .05$

** $p < .01$

*** $p < .001$

Figure 1 illustrates the significant two-way interactions between the ability measures and state anxiety which affected the percentage error measure of the PASAT. They were: arithmetic x state anxiety, digit span x state anxiety, and Factor 2 x state anxiety (see table 4).

Figure 1 shows that all three of these significant two-way interactions were due to a significant difference between the mean percentage error for high and low arithmetic, digit span and Factor 2 groups, when state anxiety was low. While state anxiety made no difference to those with higher ability, those with lower ability on these independent variables were significantly more likely to report low state anxiety.

All the other two-way interactions involving arithmetic, digit span and Factor 2 were non-significant for all measures (see table 4).

State x trait anxiety significantly effected percentage correct and mean seconds per correct response but not percentage error (see table 4). Figure 2 shows how these interactions reversed, depending upon the measure obtained. That is, high trait anxiety is likely to be equally related to low state anxiety as to high state anxiety, with a similar effect for low trait anxiety.

State anxiety x strategy effects were non-significant for percentage correct and mean seconds per correct response and significant for percentage error (see table 4). Figure 3 shows that state anxiety made no difference when subjects used strategy two. The interaction is largely explained by the difference between strategy one and strategy two when state anxiety was reported to be low.

State anxiety x sex interaction effects were non-significant for percentage correct and mean seconds per correct response, and significant for percentage error (see table 4). Figure 3 shows that percentage errors increased significantly for females as anxiety decreased, whereas males made significantly fewer errors than females when anxiety was low.

The remaining two-way interaction hypothesis, of a relationship between sex and arithmetic ability was non-significant (see table 4).

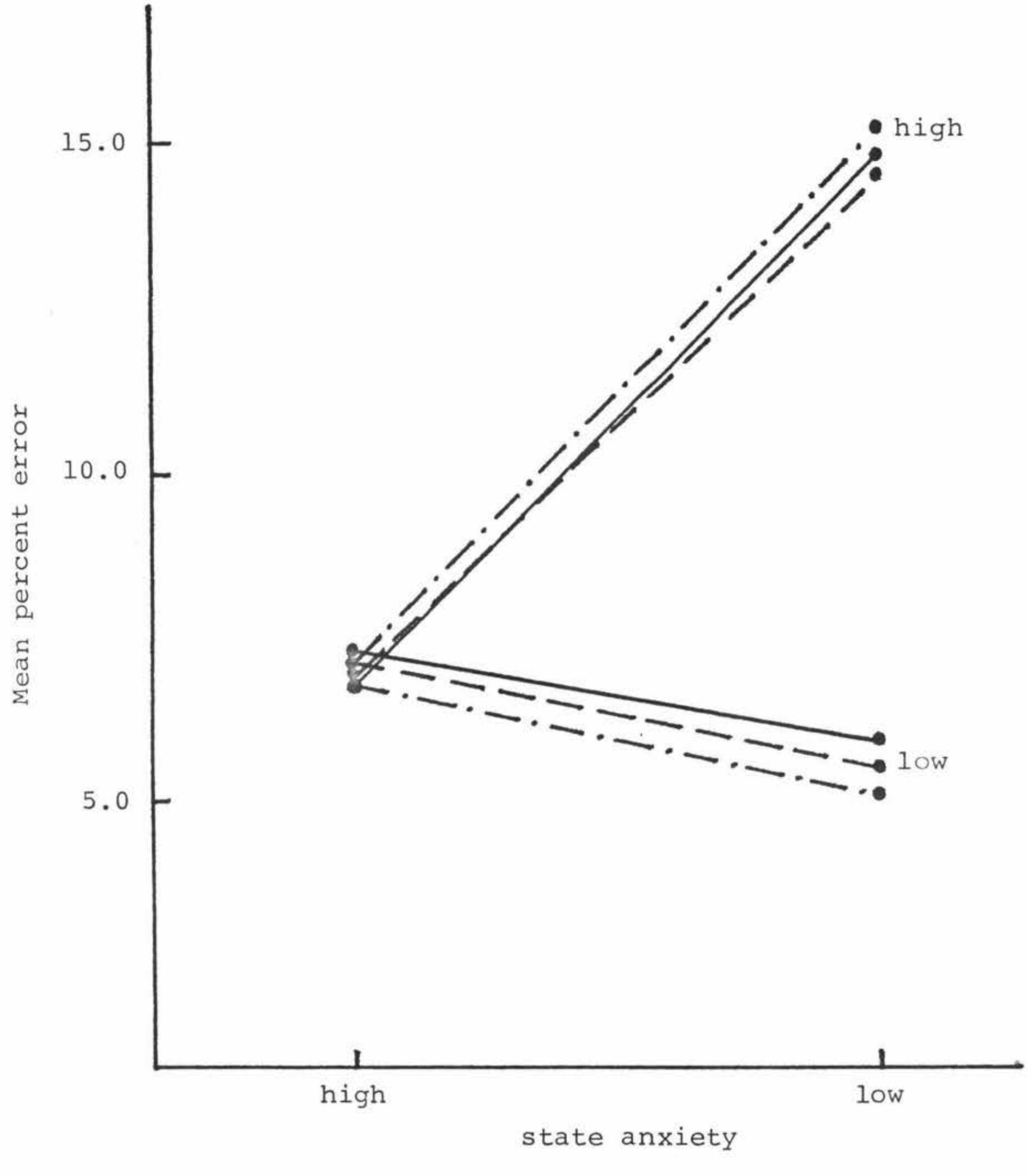

Figure 1. Mean percent error performance on PASAT as a function of high and low arithmetic (●——●), digit span (●— —●), Factor 2 (●– · –●), and state anxiety.

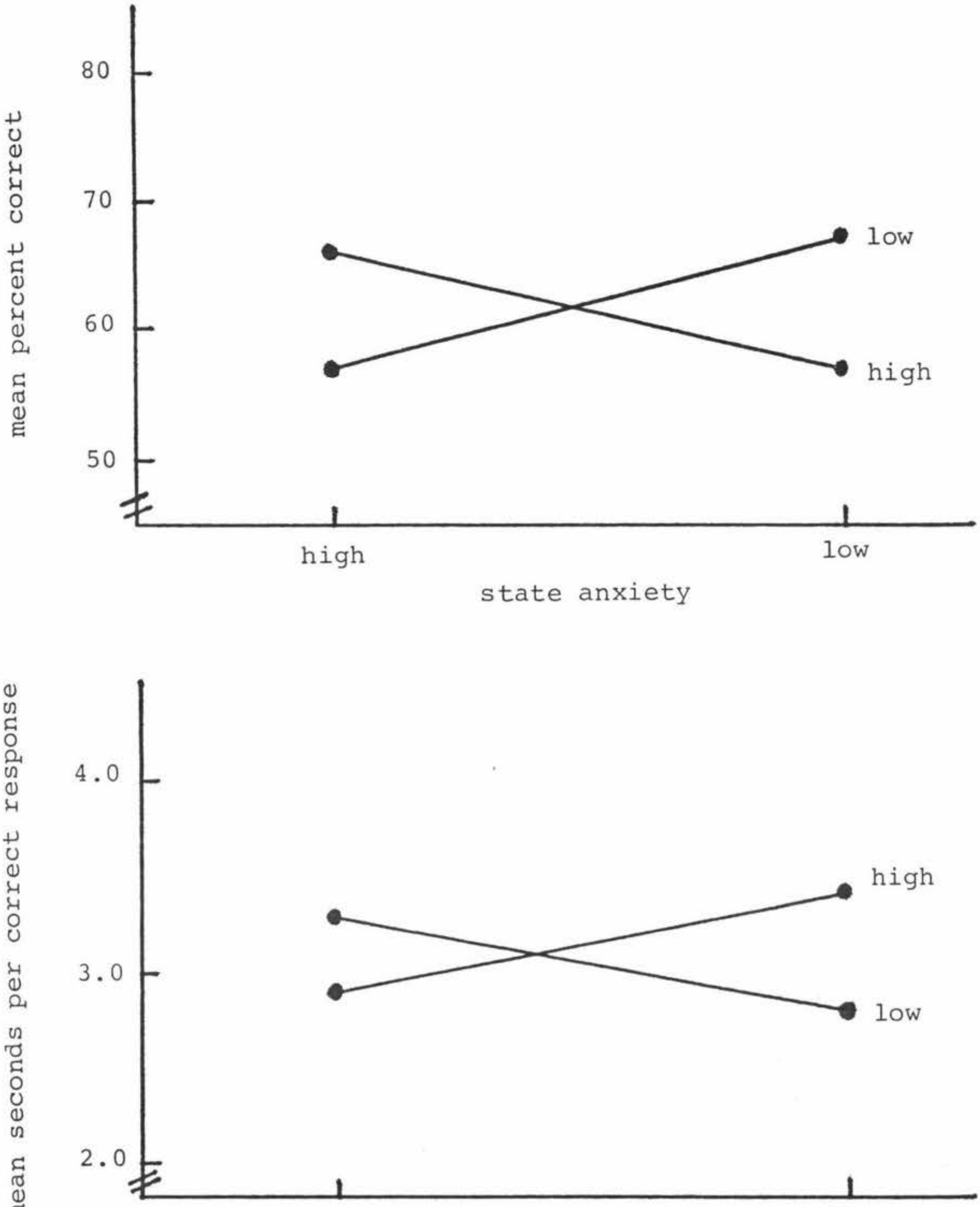

Figure 2. Rate of responding on PASAT as a function of trait anxiety (high and low) and State anxiety.

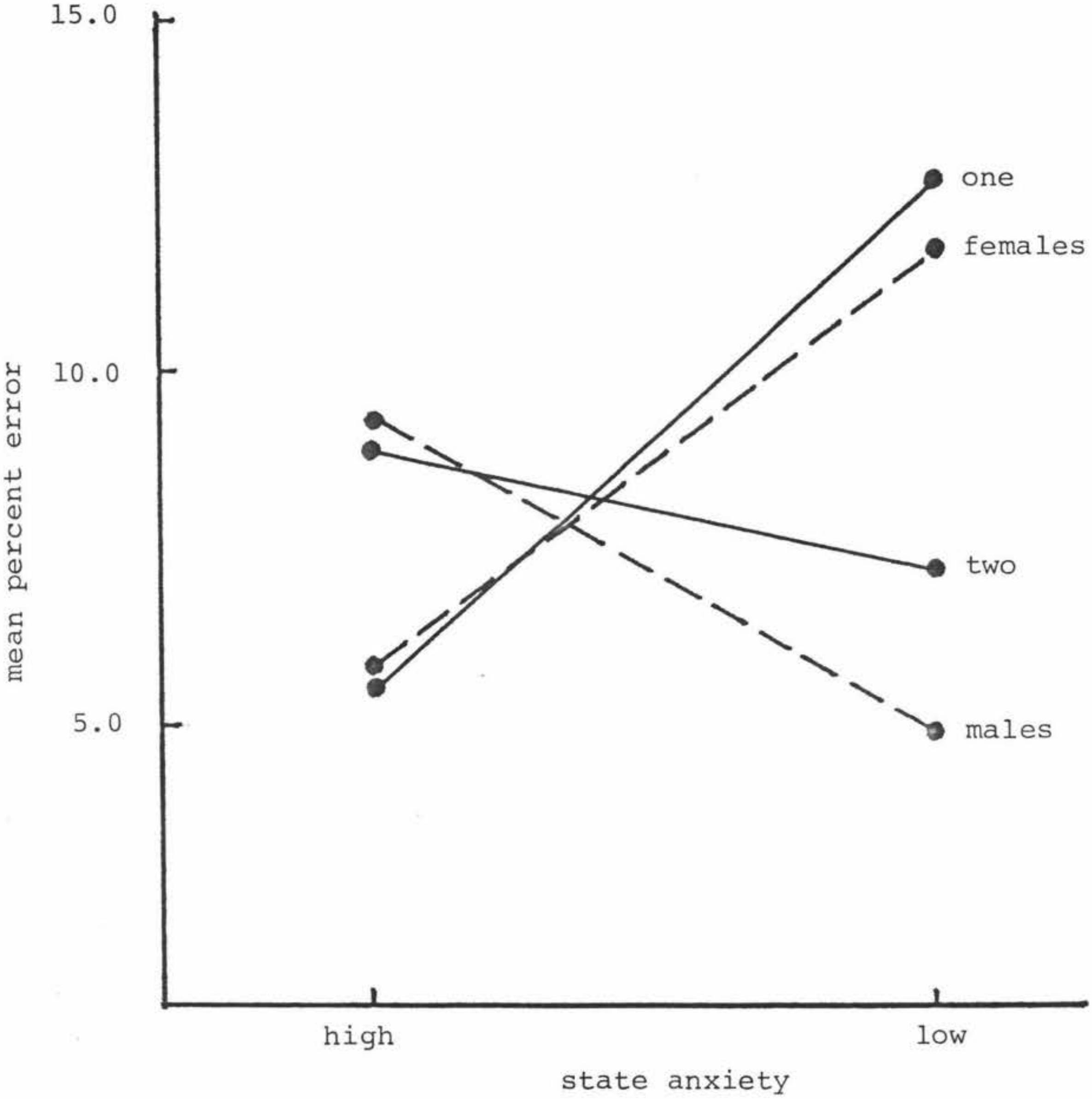

Figure 3. Mean percent error performance on PASAT as a function of strategy (one and two), sex, and state anxiety.

Supplementary Results

To aid the interpretation of the results and to enable comparisons to other studies correlations between the independent variables, the raw scores of the independent variables and the dependent variables were examined.

Generally, the correlations between state, trait, strategy and sex were non-significant (see Appendix D for details). However, the correlations between arithmetic, digit span and Factor 2 were significant (see table 5).

Table 5: Correlations between arithmetic, digit span and Factor 2

	Digit Span	Factor 2
Arithmetic	.42**	.51***
Digit Span	–	.83***

** $p < .01$

*** $p < .001$

The correlations between the dependent variables, that is, percentage correct, mean seconds per correct response and percentage error were significant (see table 6).

Table 6: Correlations between percentage correct, mean seconds per correct response and percentage error

	mean secs.	percent error
Percent correct	– .95***	– .45***
Mean secs.	–	.41**

** $p < .01$

*** $p < .001$

While the correlations between arithmetic ability and the dependent measures were significant (see table 7), the other correlations between Factor 2 and the dependent measures were non-significant, while the correlations between digit span and the dependent measures were only significant for percentage error (see table 7).

Table 7: Correlations between arithmetic, digit span, Factor 2, raw scores and percent correct, mean seconds per correct response and percent error

	Arith.	D.S.	F.2
percent correct	.53***	.22	.27
mean secs.	- .51***	- .15	- .24
percent error	- .37**	- .37**	- .27

** $p < .01$

*** $p < .001$

Comparison with norms

The following means and standard deviations describe the normal sample in experiment one of the present study compared with those obtained in other, normative, studies.

Gronwall (1977) reported that mean seconds per correct response on the PASAT first test (N = 80) = 3.2, S.D. = 25. The mean for the normal sample of the present study = 3.025, S.D. = .75.

Lezak, (1976) derived statistics from Gronwall and Wrightson (1974) and found that on the PASAT first test mean percentage correct = 68%, S.D. 13.08. The present normal sample mean = 62.99%, S.D. 12.1.

Gronwall (1977) reported that errors usually account for less than 10% of the total responses on the PASAT. The normal sample mean percentage errors = 8.49, S.D. 6.75.

As standard scores are obtained from WAIS subtest scores, whereas the present study used raw scores, these results cannot be compared. However, the normal sample mean arithmetic score = 15.10, S.D. 3.18.

Kear-Colwell and Heller (1978) reported for their sample (n = 56) that mean digit span = 12.23, S.D. 1.53. The normal sample mean digit span = 13.83, S.D. 1.84. Kear-Colwell and Heller reported for their sample mean Factor 2 = 19.2, S.D. 1.34. The present normal sample mean Factor 2 = 22.02, S.D. 2.36.

Spielberger, Gorsuch and Lushene (1970) reported (for N = 468, undergraduates) mean state anxiety = 35.73, S.D. 9.46; and mean trait anxiety = 37.96, S.D. 9.42. The means for the present normal sample were; state anxiety = 45.77, S.D. 10.17, trait anxiety = 38.31, S.D. 6.38.

Overall, the results from the normal sample of the present study were comparable to the previously obtained norms. State anxiety, however, was noticeably higher. Thus for the most part, it is concluded that the results of the present study are generalizable.

Interim Discussion

The results supported the hypotheses that arithmetic ability and STM factors significantly affect all measures obtained on the PASAT. That is, those who are relatively skilled at encoding, multiple input and transformation processes (Kerr, 1973), using numbers in an auditory modality have more available capacity to complete a task with similar parameters. This is because task demands can be met by the effort an individual can comfortably exert. As predicted neither state or trait anxiety measures showed significant main effects.

It is possible there were non-significant digit span main effects (on percent correct or mean seconds measures) because of the limited variation in the sample data. It could be argued that more subjects could complete the digit span task (see Appendix B) because the mental operations required for this task were less difficult. Whereas the mental control and arithmetic items involved more complex operations and thus significantly differentiated these abilities.

However since significantly fewer errors were made by the high digit span group than the low digit span group, it is possible that speed of item identification (Dempster, 1981) and tracking (Lezak, 1976) are related to PASAT performance in a way not revealed by the statistical analyses used in the present study.

Nevertheless, the implication remains that in a normal sample the abilities or skills involved in PASAT are similar to those used for mental arithmetic. The question remains whether a clinical sample would show the same result.

The interactions obtained between abilities and state anxiety on the percentage error measure, supported the hypotheses made. That is, the low arithmetic, digit span and Factor 2 groups' percentage errors increased as a function of anxiety. Where anxiety was high it is possible that 'worry' pre-empted available capacity (Eysenck, 1979, and see earlier discussion) so that increased effort did not meet task demands. Where anxiety was low it is possible that arousal affected performance (Posner 1971, 1973), and that defensiveness increased as anxiety did (Redfering & Jones, 1978).

This result shows that further research is needed into the distinction between the concepts of 'worry' and arousal in anxiety. However, in terms of Kahneman's (1973) theory it could be said that the allocation of effort policy (set) was altered as task demands became too great, so the subject's intentions changed. (See p.26)

Although the mean percentage error for the sample fell below the limits (10%) which Gronwall (1977) set for 'poor motivation' on PASAT. The mean percentage errors for all low ability/low anxiety groups was between 14-15%, whereas all other groups in the present case were between 6-7%, suggesting the demand characteristics of the situation (Orne, 1962) could have produced this result.

Posner (1971, 1973) demonstrated that high arousal improves perceptual analysis, but does not facilitate the operation of the other mechanisms that determine choice of response in a continuous reaction time task. Anxiety has arousal and worry components (Eysenck, 1979; and see earlier discussion), so even if worry does not produce a 'divided set', arousal could still hamper performance. Posner said this could occur because a decision is reached faster when alertness is high and is based on a reduced sample of evidence and is consequently more subject to error than when alertness is low. The high negative correlation between percentage correct and mean seconds per correct response and negative correlations between percent error and percentage correct could be interpreted from this view. Again the question of which state anxiety interactive effects would be found with a clinical sample could be asked.

While the modest correlation between trait and state anxiety indicates these measures are valid; the interactions of trait and state reflect the complexity of STAI as a measure. Furthermore, the reversed interactions (see Figure 2) suggests that the way a person responds to the PASAT test is related in different ways to each of these anxiety measures.

Comparison of sample means from the present study with STAI sample means shows that while trait anxiety was similar, state anxiety was much higher in the present sample. This suggests that the normal subjects did experience 'worry' about the PASAT, but that this worry affected performance to the extent it interacted with other task parameters and is largely reflected in the percentage error measure. The strategy and state anxiety interaction shows this.

More errors were made using strategy one than strategy two when state anxiety was reported to be low. This suggests that to minimize anxiety effects on a subject's response criterion, strategy two could be given. This question could be looked at with a clinical sample.

It also appears that it was the female subjects who were more likely to make more errors than males when state anxiety was reported to be low (see Figure 3). It is possible that the females perceived themselves as having less ability at this task (Feinberg & Helperin, 1978) and so found the task more difficult. But while this affected the percentage of errors made, it was not reflected in the anxiety measure.

The data from the supplementary results suggests that it is valid to discuss the findings of Experiment 1 in general terms.

Firstly, information processing as measured by the PASAT appears to depend upon the abilities, context and intent, determined by one's prior experience with similar tasks, this in turn defines the task difficulty and so the effort expended. Secondly, it seems a distinction may be made between perceptual and response readiness and the allocation policy of attentional effort as Kahneman suggested, for this task. However, assuming these abilities affect normal subjects' performance on PASAT and considering Gronwall and Sampson's findings with concussed patients, these findings might not necessarily be true for a patient population. Consequently it was decided to examine selected aspects of the above results for a patient sample. A non brain-damaged sample was selected to examine the effects that functional impairment might have on PASAT performance. That is, in a group differentiated by current diagnoses of mental illnesses it might be expected that personality or unspecified variables perculiar to clinical populations would have an overriding effect on PASAT performance and thus lessen the importance of cognitive abilities.

Chapter 7 - Experiment 2

Main effects hypotheses

The hypotheses carried forward from Experiment 1 were as follows: For each of the three dependent measures (percent correct, mean seconds per correct response, and percent errors), significant differences will occur between:

high and low (a) arithmetic ability (arith) groups

(d) state anxiety groups

(e) trait anxiety groups.

Also differences between strategy (strat) used and between males and females were tested. In addition differences between age groups was included. Age was an additional variable in this study because a greater age range was characteristic of this population. Also Gronwall (1977) considered that greater caution was needed in interpreting results from older patients.

Two-way interaction hypotheses

The hypotheses carried forward from Experiment 1 were as follows: For each of the three PASAT measures interactions were predicted to occur between the following:

(a) arithmetic ability and state anxiety

(d) state anxiety and strategy

(e) state anxiety and sex

(f) state and trait anxiety

(g) sex and arithmetic ability

(h) age and strategy.

Experimental Design

The design was the same as for Experiment 1, except that six independent variables were considered. They were: arithmetic, state anxiety, trait anxiety, strategy, sex and age. They were partitioned into two levels by a median split as before, (see Appendix B). The medians used were the same as for Experiment 1, except that for arithmetic a median of 10 was considered equivalent to a median of 14, because of the additional items included in the Experiment 1 test, (see procedure Appendix B). Also, so that sample means could be compared, 31 years and under was called level one of the age factor. Thus for comparison purposes the groups within the patient sample were comparable with groups within the normal sample on all the independent variables. The dependent variables and methods of analysis were as for Experiment 1.

Subjects Twenty patients from a local psychiatric hospital took part in the experiment. There were thirteen males and seven females. Their ages ranged from 14 to 65 years; the mean age was 41 years (see Appendix E for diagnoses and medication).

Apparatus and materials The PASAT tape was the same as in Experiment 1. The other tests used were the arithmetic subtest of the WAIS; administered and a raw score obtained according to the WAIS manual. The STAI was used as in Experiment 1. Because of the nature of the task strategy one and strategy two were given to all subjects and they could choose which to use.

Procedure Testing was carried out over a four month period during June - October, 1981. Subjects were seen within a week of being admitted to the hospital. The same experimenter was used for all testing sessions. Each subject in this experiment was seen for only one half-hour session. On this occasion the arithmetic subtest, strategy/PASAT and STAI were given. Subjects approached who did not wish to participate in this experiment, or who were unable to understand the practice trials of the PASAT were not included in the sample (12 people were in this category).

The PASAT was administered as in Experiment 1, except that all subjects were given the option of using either strategy (see above).

Results

Main effects hypotheses

Table 8 summarises the results for each of these hypotheses. (See also Appendix F).

Table 8: Experiment 2 main effect F values for each of the dependent variables

	Percent correct	mean secs.	percent error
Arithmetic	.00	.02	.03
state anxiety	.69	.81	6.25*+
trait anxiety	.05	.06	5.4*
strategy	.08	.04	7.37**
sex	1.14	.03	.01
age	1.69	3.65	1.78

df (1,16);

* $p < .05$

** $p < .01$

\+ (significant 2-way interaction occurred see table 9)

In Experiment 2 it was found that arithmetic ability was non-significantly related to PASAT dependent measures. State anxiety, trait anxiety and strategy used significantly affected only percentage of errors (see table 8). The main effects for sex and age were non-significant.

Two-way interaction hypotheses

Table 9 summarises the results for each of these hypotheses (see also Appendix F).

Table 9: Experiment 2 two-way interaction F values for each of the dependent variables

	Percent correct	mean secs.	percent error
Arith x state	4.54*	26.3***	4.45*
state x strategy	1.79	5.63*	.49
state x sex	1.62	1.16	.65
state x trait		insufficient n.	
sex x Arith	.92	5.04*	.04
age x strategy	3.74	2.33	.01

f (1,16);

* $p < .05$

** $p < .01$

*** $p < .001$

It was found that arithmetic ability x state anxiety significantly affected percentage correct, mean seconds per correct response and percentage error. Figure 4 illustrates this result. However, care is needed here as the validity of the interactions may be questionable since there was one subject only in the low state/ high arithmetic cell for this particular analysis. These interactions are described therefore in terms of the other three cell means. The simple effects were non-significant for the percentage correct measure. On the mean seconds per correct response, the high state, low arithmetic ability group took significantly longer on average to respond than did the high state, high arithmetic ability group ($F(1,16) = 6.20$, p .05). On the percentage error measure, the high state, low arithmetic ability group, made on average, more errors, than the low state, low arithmetic group ($F(1,16) = 10.93$, $p < .01$). This finding supports the view that arithmetic ability

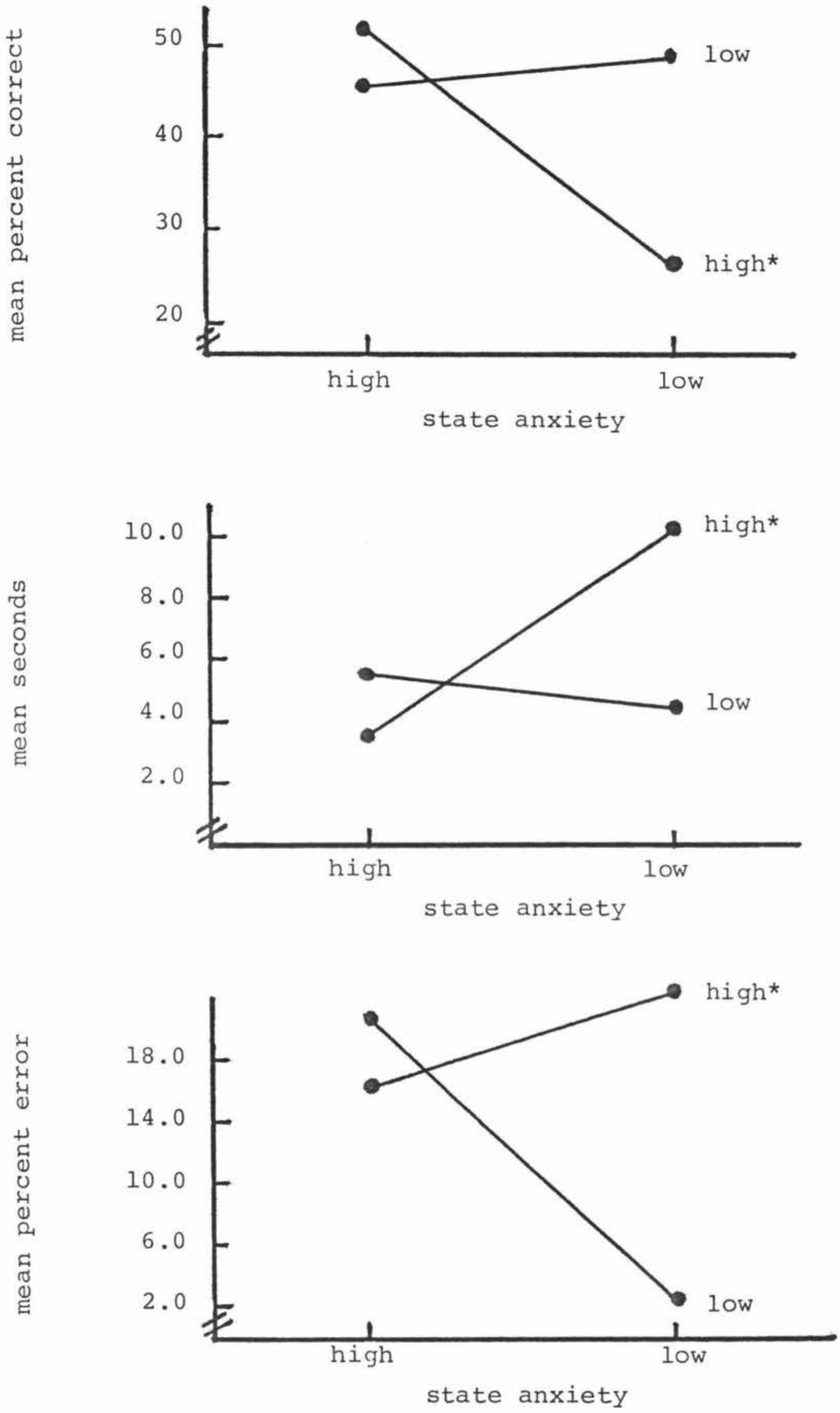

Figure 4. Experiment 2 performance on PASAT as a function of arithmetic (high and low) and state anxiety. (* = one subject)

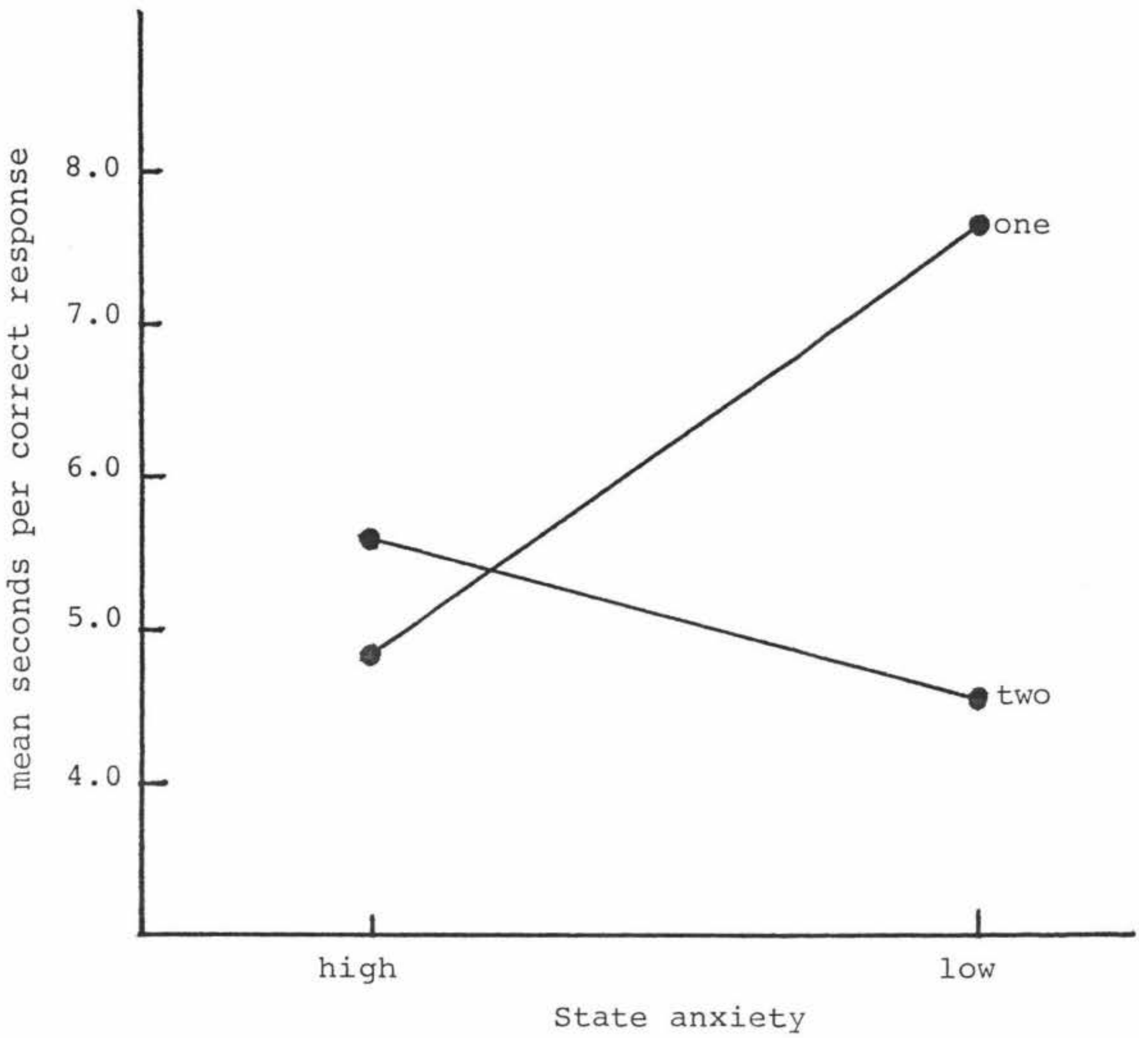

Figure 5. Experiment 2 mean seconds per correct response performance on PASAT as a function of strategy (one and two) and State anxiety.

in conjunction with high state anxiety affected responses on the PASAT.

Arithmetic x sex significantly influenced only the seconds per correct response measure (see table 9). On average females took longer to respond as their arithmetic ability decreased, whereas on average, males increased their rate of responding on PASAT as their arithmetic ability decreased.

Figure 5 illustrates how state anxiety x strategy used, significantly affected only the mean seconds per correct response measure (see table 9). If strategy one is used and anxiety is high responding is faster on average than when anxiety is low ($F(1,16) = 4.94$, $p < .05$). Whereas responding is slower if anxiety is low and strategy one is used than when anxiety is low and strategy two is used ($F(1,16) = 5.82$, $p < .05$). This finding is in agreement with a similar comparison in Experiment 1 (see Figure 3).

All other hypothesised two-way interactions were non-significant (see table 9 and Appendix F).

Supplementary Results

As in Experiment 1 correlations between the independent variables, independent variable raw scores, and dependent variables were obtained.

As was found in Experiment 1, sex did not correlate with any other variables. Whereas, in contrast to Experiment 1, while arithmetic did not correlate with any other variables; the correlation between state and trait anxiety was significant ($r = .58$, $p < .01$).

Also, as in Experiment 1, there was a significant correlation between percentage correct and mean seconds per correct response ($r = -.67$, $p < .001$), but as different from Experiment 1 the correlation between these measures and percentage error was non-significant.

Again, in contrast to Experiment 1 the anxiety measures were found to correlate with percentage error. (See table 10).

Table 10: Correlations between percentage error and anxiety measures

	state	trait
Percentage error:	- .50*	- .48*

* $p < .05$

The other notable correlations occurred between age, percentage correct and mean seconds per correct response (see table 11).

Table 11: Correlations between percentage correct, mean seconds per correct response, and age raw scores

	percentage correct	mean secs.
Age	- .48*	.44*

* $p < .05$

Clearly, these results suggest that anxiety will affect patients' PASAT performance, whereas arithmetic ability is more likely to affect a normal groups' PASAT performance. However the smaller patient sample size may have contributed to these results. Table 12 supplies a comparison of means between the present samples from the two experiments, and illustrates some further similarities and differences which were obtained. The means are for age level 1 (i.e. under 31 years).

This table shows how differences in arithmetic ability affected the PASAT dependent measures in the direction predicted for both samples (except for Experiment 2 percent error). Also this table shows how differences in state anxiety clearly affected patients' performance on the PASAT, but not the normal sample's performance (except for Experiment 1 percent error).

Table 12: Arithmetic and state anxiety means for PASAT measures on age level one in Experiment 1 and Experiment 2

	Experiment 1	N	Experiment 2	N
	mean % correct on PASAT			
High Arith	70.19	20	59.17	2
Low Arith	57.84	28	48.06	6
error+	115.05		158.42	
	mean secs / correct response			
High Arith	2.61	20	3.39	2
Low Arith	3.32	28	4.73	6
error	.48		2.47	
	mean % error			
High Arith	6.49	20	20.14	2
Low Arith	9.92	28	9.42	6
error	34.81		128.05	
	mean % correct			
High state anxiety	62.8	25	52.23	6
Low state anxiety	63.19	23	46.67	2
error	132.98		169.75	
	mean secs / correct response			
High state	3.03	25	4.28	6
Low state	3.02	23	4.75	2
error	.54		2.56	
	mean % error			
High state	6.87	25	14.86	6
Low state	10.25	23	3.84	2
error	36.99		101.3	

error+ = mean square of within groups variance

The characteristic type of error that concussed patients made in Gronwall and Sampson's (1974) study was late responses. Table 13 shows the frequency of type of error made by each sample in the present study. Most noticeable is the high proportion of miscellaneous errors made by the patient sample.

Table 13: Relative frequency of type of error made in both experiments as a function of total number of subjects in each experiment who made errors

Type of Error	Normals	Patients
late responses	.13	.11
response adding	.23	.15
retrieval	.34	-
miscellaneous	.29	.72

Comparison with Norms

The Experiment 2 clinical samples' performance on the PASAT was worse than the norms (see page 64); mean seconds per correct response = 5.22, SD = 1.66; percentage correct = 46.36%, SD = 12.8[2], percentage error = 16.24%, SD = 11.45.

The WAIS arithmetic subtest mean raw score for the clinical sample = 9.65, SD = 3.34.

Spielberger, Gorsuch and Lushene (1970) reported for a sample of 461 neuropsychiatric patients, mean trait score = 46.62, SD 12.41; mean state score = 47.74, SD 13.24. For the clinical sample of the present study, mean trait anxiety = 52.2, SD 11.23, and mean state anxiety = 52.45, SD 14.69.

[2] (mean percentage correct for MC patients, test 1 = 45.65% - derived from Gronwall and Sampson's 1974 data)

In comparison with the norms therefore information processing as measured by the PASAT was reduced, while both trait and state anxiety were higher.

Interim Discussion

The results from the Experiment 2 patient sample showed that arithmetic ability was not related to performance on the PASAT. However descriptive comparison of Experiment 1 and Experiment 2 sample means (see table 12) showed that there was a difference occurring in the same direction. It is possible that the Experiment 2 result is due to a smaller sample size which resulted in a lower power on the statistical tests (Keppel, 1973).

However, the two-way interaction results (see Figure 4) showed that low arithmetic ability in conjunction with high anxiety significantly reduced PASAT performance in comparison to other conditions. This is similar to the finding for Experiment 1 (see Figure 1). So it is clear that anxiety affects arithmetic ability to some extent and this affected PASAT performance, particularly on the percentage error measure. That is, those who experienced high state and high trait anxiety made more errors.

Those who used strategy two made fewer errors than the strategy one group. But whereas strategy interacted with anxiety to affect percentage errors in Experiment 1, strategy interacted with anxiety to affect rate of responding (mean seconds per correct response) in Experiment 2. In terms of Kahneman's (1973) theory, as task demands increased, task irrelevant stimuli interfered with performance, to increase percentage errors but not effort, in Experiment 1, to the extent it was affected in Experiment 2. The results from both experiments show that while strategy one may enable a maximal performance, equally task demands may interact with personality variables such as anxiety and confound performance. This preliminary evidence suggests therefore, that strategy two be given to reduce task difficulty and so allow effort to meet PASAT demands. It also concurs with Kerr's (1973) hypothesis that processing demands are a function of the mental operations required.

The Experiment 2 sample was, as a group, more anxious on both trait and state measures than a similar neuro-psychiatric normative sample. The trait anxiety was significantly correlated with state anxiety, so, in line with Spielberger, Gorsuch and Lushene's (1970) predictions the Experiment 2 sample were more disposed toward state anxiety than the Experiment 1 sample. Both these anxiety measures correlated with the PASAT percentage error but neither the anxiety measures or percentage error correlated with the rate of responding measures. Again, this finding corresponds with Eysenck's (1979) hypothesis (see page 25). Thus, in Experiment 2 performance effectiveness is affected more by anxiety than it was in Experiment 1, or in terms of Posner's (1971, 1973) hypothesis, more responses of all kinds were made when anxiety was high because the response criterion was lowered.

Whatever theoretical account is accepted it is clear that information processing capacity as measured by the PASAT was greatly reduced in the Experiment 2 sample compared with the Experiment 1 sample. Whereas the Experiment 1 sample performance was similar to the norms given by Gronwall (1977), the Experiment 2 sample performance was similar to at least Gronwall and Sampson's (1974) first test, percentage correct measure for their MC sample. But whereas the concussed patients typically made late response errors, the Experiment 2 patient sample made mostly miscellaneous errors.

It could be argued that both the present and Gronwall's MC clinical groups have reduced 'allocation of effort' for a task requiring selective attention, as a result of impaired unit formation (grouping of stimuli) and figural emphasis. Thus they both have reduced performance efficiency. And if performance effectiveness is a function of the relationship between performance efficiency and effort, then the concussed patients' performance was more effective. While error rate could reflect 'poor motivation' (Gronwall, 1977), it could equally be suggested that the Experiment 2 patients did not recognise their errors or increase their effort because the task was too difficult.

Finally, the results from Experiment 2 are similar to Experiment 1 in that there were no clear sex differences in PASAT performance. However the sex x arithmetic ability interaction in Experiment 2 showed that arithmetic ability and PASAT performance increased together for males, while they decreased together for females, and suggests that sex differences in arithmetic ability could influence performance on a task which involves addition of digits. Similarly, while there were no age main effects in the Experiment 2 results, the correlations obtained between age raw scores and percentage correct and mean seconds per correct response suggest that rate of performance could be related to age. Both the sex and age effects found here warrant further investigation.

Chapter 8 - General Discussion

Introduction

The aim of the present study was to investigate the effects of measures of general abilities and anxiety factors upon PASAT performance in normal subjects. Those abilities most clearly associated with PASAT performance in the normal sample of Experiment 1 were investigated with a clinical sample in Experiment 2. A more general purpose has been to examine differing perspectives of information-processing capacity theory. The present chapter will present a general overview of the results and conclusions of the experiments in terms of the above goals. Some implications for clinical use of the PASAT will be discussed.

The independent variables

The information-processing capacity allocated to a task is a function of effort supplied to task demands. As the demands of the task increase, the discrepancy between the effort demanded and the effort actually supplied increases steadily (Kahneman, 1973). Generally the results of the present experiments support the hypothesis that task demands may be a function of individual abilities. Those who have more ability have more spare capacity because the effort required for a task is less.

In Experiment 1, performance on the PASAT improved on all measures as arithmetic ability and STM capacity increased. The arithmetic ability measure raw scores significantly correlated with the PASAT measures, whereas the STM capacity raw scores did not in Experiment 1 (see table 7). This suggested that arithmetic ability shared more variance with the PASAT task demands than did the STM capacity measure, so the arithmetic ability measure was given to the clinical sample of Experiment 2. In Experiment 2, it was found that, when the age factor was removed, arithmetic ability was related, but non-significantly, to PASAT performance (see table 12). This result suggests that the spare capacity available for PASAT performance increases as the general ability to perform transformation operations increases (Kerr, 1973). These results agree with Corballis' (1962) findings that the PASAT has a large recent memory component (reported in Sampson and Gronwall, 1974), but not with Sampson's (1954) finding of low correlations between serial addition performance and arithmetic ability (also reported in Sampson and Gronwall, 1974). Therefore Gronwall and Sampson's (1974) argument that cognitive abilities had an insignificant effect upon PASAT performance was not substantiated by the present study. Therefore it cannot be maintained that information processing capacity is constant and independent of environmental or task conditions. Alternatively, it is argued that information processing capacity varies as a function of effort supplied to task demands. And that more capacity is available if a perceiver has schema available for a task, than if he has not (Neisser, 1976).

The way in which STM is related to PASAT performance appears to be a function of the effort allocated to task demands too. As the task demands of STM measures become more similar to PASAT task demands the relationship of STM capacity to PASAT performance is clearer. In the present study, digit span ability was not related to percent correct and mean seconds per correct response PASAT measures. However, when the mental control subtest score was added to the digit span score to give a Factor 2 ability measure this significantly affected all PASAT measures. The mental control subtest items involve recall and serial addition. This concurs with Kerr's (1973) hypothesis that task demands are a function of the type of mental operations required in a task. Consequently, the similar descriptions used for PASAT and Factor 2 measures viz. 'attention and concentration' seem valid.

Alternatively, it is possible that the relationship between Factor 2 and the PASAT might be explained in terms of rate of mental activity rather than type of mental operation. Kahneman (1973) argued that more effort was required for a task which is characterised by greater 'time-pressure' demands, because the subject's rate of activity must be paced by the rate of delay of the stored elements. He pointed out that a concept of rate is meaningful only when the units of activity (perceptual grouping) are specified. Thus it could be concluded that PASAT performance is related to short-term memory tasks only when the tasks require similar mental operations or rates of activity. Since digit span is related to speed of item identification (Dempster, 1981); it is possible therefore that the PASAT rate of performance depends upon the figural emphasis decision given to unit formation (Kahneman, 1973).

The hypothesis that high state anxiety would pre-empt spare information processing capacity and reduce PASAT performance effectiveness, but not necessarily efficiency (Eysenck, 1979) was substantiated in both experiments in the present study. As expected the manifestation of anxiety were not specific to the effort supplied to task demands, since state anxiety interacted with all other measures to affect only the percentage error measures in Experiment 1. In Experiment 2 there was a stronger relationship between anxiety and performance effectiveness because the percentage of errors on the PASAT increased with state anxiety and trait anxiety. Again the manifestations of anxiety were not specific to effort since the state anxiety and arithmetic ability interactions were not clearly related to performance efficiency. It could be argued that task-irrelevant processing interacted to some extent with task demands to increase task difficulty or 'time-pressure'. However, in the present study, the operationalised definition of anxiety as a function of 'worry' and arousal does not provide a sufficient explanation of the effects of anxiety. In Experiment 1, although mean state anxiety was relatively high compared with the norms (see page 65), it is possible that state anxiety as measured by the STAI has a relationship that is not linear, with PASAT performance.

Comments made by subjects in Experiment 1 such as, "the beginning and end parts of the test were more stressful than the middle", or "how I felt varied with each trial", suggests that transient variations of anxiety occurred during this task which may have corresponded to transient changes in the demands of the tasks. This would make it difficult to give an overall impression of 'state' of anxiety. Kahneman (1973) discusses similar problems with physiological measures of arousal. Alternatively, these findings could reflect a source of bias in Experiment 1. Because the subjects were asked after performing the task whether they had experienced anxiety, it is possible that perceived poor performance resulted in defensiveness (Redfering & Jones, 1978). However, in Experiment 2, Posner's (1971, 1973) hypothesis of a lowered response criterion with increased anxiety more adequately explains the results. Clearly further research is needed to distinguish behavioural dimensions of anxiety and arousal.

Thus, while Gronwall and Sampson (1974) maintained that it is level of arousal which varies whereas processing capacity is constant and independent of environmental or task conditions, the present results suggest otherwise. Not only does processing capacity vary, but so does level of arousal (in a psychological sense) as a function of environmental and task conditions. Furthermore, there is some evidence that the psychological dimension of anxiety could be a relatively more important determinant of task performance in some populations.

The results from both experiments in the present study indicate that anticipations or 'set' are a determinant of effort demands. In Experiment 1 percentage errors increased as a function of anxiety when strategy one was used and decreased as a function of anxiety when strategy two was used. In Experiment 2, strategy interacted in a similar way with anxiety to affect task demands (mean seconds per correct response). This suggests that instructions may interact with personality variables to affect perceptual readiness.

In Experiment 2, those who used strategy two made significantly fewer errors than those who used strategy one. Since the number of steps in the transformation process was fewer for strategy two than strategy one this finding supported Kerr's hypothesis that processing demands are a function of the type of mental operation required. Gronwall and Sampson's (1974) argument that concussed patients made 'a trade between arousal level and instructions ('set')' could be re-interpreted in Kahneman's terms. That is, 'the mobilization of effort in a task is controlled by the demands of the task, rather than by the performer's intentions'. This process manifests as attention given to figural emphasis. So, if the PASAT can be performed more effectively using strategy two than strategy one this supports Kahneman's argument that a task such as PASAT depends upon the allocation of capacity given to task relevant spatio-temporal perceptual units in preference to others. Thus PASAT performance could reflect the level of selective attention a person can use.

There were no significant sex differences in PASAT performance, this finding agreed with Gronwall (1977). However, in Experiment 1 females made more errors as a function of anxiety and in Experiment 2 arithmetic ability and PASAT performance increased together for males, while they decreased together for females. While this result does not support Kear-Colwell and Heller's (1978) finding that males have greater digit span than females, it is possible that females perceived themselves as having less ability at a task which involves arithmetic and so found the task more difficult (Feinberg & Helperin, 1978).

In Kahneman's (1973) terms the source of such a sex difference could be based on the argument that while task demands usually determine effort, attention is always selective and the policy of allocation reflects permanent dispositions and temporary intentions. Further research is needed to determine whether or not sex differences in PASAT performance exist.

The dependent variables

Gronwall and Sampson (1974) saw the three PASAT dependent measures as indices of channel capacity and rate of information processing. The results from the present study suggest that other factors could influence these indices.

In Experiment 1 arithmetic ability and STM span measures affected the percentage correct and mean seconds per correct response measures. As Kahneman (1973) pointed out, "the rate at which mental activity is performed is a primary determinant of effort ... but a concept of rate becomes meaningful only when the units of activity are specified". Furthermore, Kahneman said, "a certain level of organization may be dominant ... performance is monitored at the completion of units at that level" (p.191). In these terms it is possible that ability is related to the units of activity processed in a task; both would increase together. Thus the concept of rate as a 'how much you can do' construct (Gronwall and Sampson 1974) is not an as accurate representation of these measures as a concept of an allocation policy of effort and attention.

The results from the present study suggest that the percentage error measure of the PASAT could give some indication of spare capacity since, generally, spare capacity available for perceptual monitoring decreases with increasing involvement in a primary task. In Experiment 1 the percentage of errors made on the PASAT increased as arithmetic ability and STM span decreased. Whereas in Experiment 2 the percentage of errors made on the PASAT increased with state anxiety, trait anxiety and strategy one. In Experiment 1 there was no clear pattern of type of errors, whereas in Experiment 2 mostly 'miscellaneous' errors were made. In the normal sample, where abilities were associated with PASAT performance, spare capacity decreased with increased task demands. In the clinical sample where anxiety was associated with PASAT performance spare capacity decreased with increased anxiety. These findings support Kahneman's (1973) predictions that "the effectiveness of selection depends on the ease with which the relevant stimuli can be segregated at the stage of unit formation, and that the effectiveness of rejection of irrelevant stimuli depends on the amount of capacity demanded by a task" (p.135).

In relation to the stated aim of this thesis, the conclusion is that Kahneman's (1973) theory of attention and effort is more useful than Gronwall and Sampson's (1974) use of Broadbent's (1971) theory for explaining the underlying cognitive processes of PASAT performance.

Implications for models of information processing

Two different models of information processing have been considered in the present thesis for interpreting the limitations to PASAT performance.

Broadbent's (1971) model describes the locus of limitation for information processing as the channel capacity or the rate at which the nervous system transmits information. This model has not on all occasions, supplied an adequate interpretation of the processes underlying PASAT performance. One major finding which is contrary to this model is that task conditions or arithmetic abilities are related to PASAT performance in normal subjects. Broadbent (1971) would have predicted that limitations to arithmetic ability are structural, whereas most evidence suggests it is a learned ability.

Another finding, that a measure of STM span was related to PASAT performance in normal subjects cannot be successfully interpreted by this model. It was found that digit span was not clearly related to PASAT performance, whereas a filter that allows inputs into perception in single file might have predicted that digit span would be strongly related to PASAT performance. However, when mental control, a subtest which allows for recall and some transformation processing, was added to digit span, then the resulting Factor 2 score was strongly related to PASAT performance.

Finally, the finding that anxiety, a personality variable interacted with abilities, sex and strategy used, demonstrated that PASAT performance is not as independent of environmental conditions as Gronwall and Sampson's (1974) interpretation of Broadbent's (1971) theory would predict.

Kahneman's (1973) theory which describes information processing in terms of the effort allocated to a task has no definite locus of limitation and sc it is more successful than Broadbent's (1971) model in interpreting the results of the studies reported in the present thesis.

There are four primary hypotheses of this model. The first is that the limits to attention are variable. The second is that the amount of attention or effort exerted at any time depends primarily on task demands. Eventually increased effort is typically insufficient to fully compensate for the effects of increased task complexity. The third is that the allocation of attention is a matter of degree. The fourth hypothesis is that attention can be allocated to facilitate the processing of selected perceptual units or the execution of selected units of performance. The policy of allocation reflects permanent dispositions and temporary intentions.

One major prediction of this model, supported by the present study was that information varied according to abilities and anxiety factors in a normal sample and according to anxiety factors and instructions in a clinical sample. It was considered therefore that task demands were a function of abilities and possibly personality factors.

Another prediction from this model, supported by this study was that the amount of attention or effort supplied to perceptual units rises with demand, but not sufficiently. When a task is made more complex, performance slows down and errors increase in spite of augmented effort. The finding that errors were a function of abilities, anxiety and strategy supported this prediction.

Finally, the prediction that the policy of allocation reflects permanent dispositions and temporary intentions was supported by the results from the experiments in the present study.

In terms of the foregoing discussion Kahneman's (1973) effort theory appears to be most useful at this stage for planning future research based on attention and the problem of capacity. However, whether or not it will prove to be of assistance in the interpretation of findings from other paradigms and experimental situations must remain a topic for future investigations.

Topics requiring further investigation

The specific issues of anxiety, sex and age effects have already been mentioned in this regard. However, of more overall importance is whether or not there are separate mechanisms of attention. Of particular interest is whether perceptual processes could be distinguished from an allocation policy. The other main issue concerns the explanatory power of effort theory under abnormal (clinical) conditions when cognitive processes are impaired.

More recently, Broadbent (1977) has proposed that perceptual selection occurs in two stages. An early global stage that packages information from the environment into different packages or segments. This stage is largely passive. A later verification, or more active stage, works with more detailed information from these segments. He suggests that one way to demonstrate this distinction would be to investigate whether particular interests or motives of an individual act at the global or local level. For example, if the specific constructs with which an individual construes his environment were known; would the recognition of perceptual units vary with the emotionality of these constructs: and would task performance vary with the level of organisation of perceptual units. Further investigation of PASAT parameters could be considered too. For example, whether performance is related to the task demands requiring double digit answers on PASAT. And also some manipulation of the task context measured in terms of the number of trials required to learn a set of rules might reflect 'allocation policy'. Either way, further examination of effort theory and its related hypotheses by means of Broadbent's (1977) experimental paradigm may prove a fruitful topic for future research into the relationship between perceptual processes and the allocation of effort.

On the other hand, Neisser (1976) argued that no separate mechanisms of attention have been found because none exist. Furthermore, he proposed that selective attention is a positive process, not a negative one, perceivers pick up only what they have schemata for. At present this theory has more explanatory power than either effort theory or Broadbent's (1971, 1977) hypotheses, because under abnormal (clinical) conditions it cannot be explained, in terms of attention, which mechanisms have failed.

Thus Gronwall and Sampson (1974) eliminated the possible mechanisms proposed by Broadbent's (1971) theory that could produce the characteristic post-concussion defects. So they were left with reduced channel capacity as an explanation. Similarly, unless the aforementioned distinction could be demonstrated in Kahneman's (1973) theory, then one would be left with reduced effort as an explanation of functional cognitive impairment.

However, by taking Neisser's (1976) perspective, Gronwall and Sampson's (1974) evidence can be reconsidered. Neisser's (1976) cyclic model of perception argued that attention is nothing but perception: we choose what we will see by anticipating the structured information it will provide. Thus PASAT performance reflects a cycle of anticipations, explorations, and information pickup. So cognitive impairment is a problem of selective attention.

Miller and Cruzat (1981) found that concussed patients were no more distracted by irrelevant information than normal subjects. This result agreed with Gronwall and Sampson's (1974) failure to demonstrate a deficit in selective attention after closed head injury (see Chapter 4). Nevertheless, concussed patients typically have 'poor attention and are highly distractable', so Miller and Cruzat concluded that the 'right aspect of selective attention' had not been tapped.

Gronwall and Sampson (1974) reported earlier studies which described concussed patients' deficits in terms of reduced 'mental speed and the power to sustain attention' and the inability 'to keep up a sustained effort'. Also comments made by patients to Gronwall and Sampson that the PASAT numbers were "just a blur" and "I don't have time to hear the numbers" suggested to them that input analysis was deficient. However they could not demonstrate this using masked messages of varying approximations to english. So they could not explain why, in terms of selective attention, concussed patients' performance, while quantitatively less, was qualitatively no different to the normals. Neisser (1976) would argue that this result was a function of schema. That is, it is more natural to listen to verbal material; we are relatively more skilled at anticipating the structure of such information, in even degraded messages. So it is possible that different schema produced the PASAT and message-repetition task results. So a test which uses 'old and well-established habits that are least likely to be affected by concussion', (Gronwall, 1977), might explain why a deficit in selective attention could not be demonstrated.

Also, it is puzzling that Gronwall and Sampson concluded that concussed patients 'made less use of available stimulus information' on the PASAT and the message-repetition task, after demonstrating that input analysis of stimuli was not deficient in concussed patients. Also they reported testing two concussed patients on a perceptual task (the Necker Cube). Neither patient could see any reversals and both were so distressed, this investigation was not pursued. It is possible therefore that a problem of selective attention is a disruption of the interaction between perception of a particular object or event and a more general schema.

The implications of theory in the interpretation of clinical symptoms is illustrated by the explanation for post-concussion syndrome. The symptoms of this syndrome are poor concentration, poor memory, fatigue, irritability or headache (Gronwall, 1976). Gronwall and Wrightson (1974) argued that the development of this syndrome after concussion depended largely upon "a patient's reaction to a disabling condition he cannot understand. How he responds will depend on his personality and on the explanation and support that he receives", rather than severity of injury.

Furthermore, Gronwall (1976) observed that often patients with relatively minor injury were not able to perceive the degree of their recovery. This occurred because reduced channel capacity meant that "feedback from actions may not be available to allow accurate evaluation of performance. Feedback whether from outside sources or internal, would be lost in the system, because there would be no spare circuits available to monitor this information at the same time as doing the task".

These findings re-interpreted in terms of Kahneman's effort theory would explain post-concussion syndrome symptoms as due to reduced spare capacity so that effort is not sufficient to compensate for the effects of task demands. Also, the evidence suggests that recovery involves a learning process too. So after concussion it is possible that the policy of allocation of effort no longer reflects permanent dispositions and temporary intentions.

Implications for the Clinical use of PASAT

For clinical purposes it could be considered that PASAT performance reflects the schemata that are manifested by the specificity of an individual's anticipation. So clinical recovery is not only physiologically a function of time, but also a function of schematic organisation. Thus PASAT could be used more widely as a measure of such organisation. However possible confounding factors such as abilities and personality variables would need to be considered together with PASAT measures. To assess the efficiency of processes of selective attention the interpretation of task demands (percentage correct or mean seconds per correct response) should be considered together with spare capacity (percentage errors). It might be useful to estimate this efficiency by reducing task demands (with the use of strategy two) for some patients. Thus a clearer picture of the difficulty of a task or amount of instruction and feedback an individual patient needs could be gained.

Conclusions

This thesis has demonstrated that related general abilities and personality factors affect PASAT performance; and that Kahneman's (1973) effort theory may be used to explain the underlying processes of PASAT performance. As such, effort theory supplies an alternative approach which may clarify the difference between perceptual processes and allocation of attention which are not easily examined by Broadbent's (1971) more linear model of information-processing of perceptual information.

Issues apparently worth further investigation with the attention and problem of capacity paradigm include its usefulness to assess the contribution abilities and personality differences make to cognitive functions. Effort theory, which postulates a close association between task demands and the allocation of effort involved in particular aspects of cognitive tasks, would also be worth further study with this and other experimental paradigms.

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Appendix A

The PASAT - from Gronwall (1977)

Apparatus

Commercial tape-recorder. Pre-recorded tape, male speaker, with one practice list of ten single digits recorded at 2.4 sec. intervals, followed by four trials of 61 digits each (numbers 1 - 9 used in same random order on each trial). The trials are recorded at a rate of one digit every 2.4, 2.0, 1.6 and 1.2 secs. Duration of each digit is approximately .4 secs. Intensity level is well above threshold, and adjusted to 'comfortable' listening for each patient. Prepared form for recording responses.

Instructions

> "You will hear a list of single numbers, read one after the other. I want you to add the numbers in pairs, so that each number is added to the one just before it, not to your answer. Add the second number to the first, the third to the second and so on."

A demonstration is given using an unpaced trial of ten digits spoken by the tester, followed by the taped practice trial, until the subject understands what he is to do. If strategy two is used the additional instructions are:

> "an alternative strategy that has been found to be useful for completing this task is to add each successive pair of numbers, so that one can complete at least half the additions, particularly on the fastest two trials".

Next is said:

> "Right now we will try the first test. This first one is just as fast as the practice part you have just done, but it is longer, six times as long. Don't worry if you make a mistake or leave some out. I want to see not only how long you can keep going without stopping, but also how quickly you can pick up again if you do stop."

At least thirty seconds intervals is allowed between trials. Before each trial after the first subject is warned that the speed will be slightly faster than the one he just did. Responses were recorded directly onto the prepared sheet (an example follows).

PASAT RECORD FORM

2	2.4	2.0	1.6	1.2		2.4	2.0	1.6	1.2		2.4	2.0	1.6	1.2
7(9)					9(11)					2(8)				
3(10)					7(16)					7(9)				
4(7)					6(13)					5(12)				
8(12)					5(11)					9(14)				
1(9)					8(13)					2(11)				
5(6)					1(9)					3(5)				
6(11)					4(5)					9(12)				
9(15)					1(5)					7(16)				
1(10)					2(3)					4(11)				
3(4)					6(8)					5(9)				
6(9)					3(9)					7(12)				
4(10)					7(10)					6(13)				
3(7)					5(12)					8(14)				
2(5)					8(13)					1(9)				
7(9)					3(11)					3(4)				
8(15)					9(12)					1(4)				
5(13)					1(10)					9(10)				
9(14)					4(5)					2(11)				
4(13)					8(12)					5(7)				
2(6)					6(14)					6(11)				

<u>TOTAL CORRECT</u> <u>TIME per CORRECT RESPONSE</u>

2.4 sec pacing ....

2.0 sec pacing ....

1.6 sec pacing ....

1.2 sec pacing ....

<u>ERRORS</u>

Late responses ....

Response adding ....

Retrieval ....

Miscellaneous ....

Ommissions ....

TOTAL TIME .... MEAN ...... SECS per CORRECT RESPONSE

Appendix B

The median split and procedure used for making the high-low categorization of the independent variables.

The median (M) was midway between the scores $X_{[N/2]}$ and $X_{[(n/2) + 1]}$. A score below M was categorized as low and above as high. The range is $X_{[n]} - X_{[1]}$.

Experiment 1

1. Arithmetic ability M = 14.5, range = 14
2. Digit span M = 14, range = 8

   Eleven cases scored 14 and were therefore categorized as follows:

   [digits backwards ≤ digits forwards] = low (5)

   [digits backwards > digits forwards] = high (6)
3. Factor 2. M = 22, range = 10

   Ten cases scored 22 and were assigned high if digit span was high (4); and low if digit span was low (6).
4. State anxiety M = 44, range = 39
5. Trait anxiety M = 37, range = 24

Experiment 2

1. Arithmetic ability M = 10, range = 10

   Since the patients in this sample were not given the extra four multiplication items this median is essentially equivalent to the median used for Experiment 1.
2. State anxiety M = 43, range = 43
3. Trait anxiety M = 35, range = 48

Appendix C

Means for Experiment 1

Abbreviations used in this appendix are:

IV	= independent variable	DV	= dependent variable
Arith	= arithmetic	% cr	= percent correct
DS	= digit span	$\bar{x}$ sec	= mean seconds per correct response
F2	= Factor 2	% x	= percent error
state	= state anxiety	error term	= mean square of within groups variance
trait	= trait anxiety		
Hi	= high or level one		
Lo	= low or level two		

The following data is the means and number of subjects (n) in each cell for Experiment 1.

Experiment 1 main effects, means, subjects and error term.

IV	DV	Hi	Lo	error term
Arith	% cr	70.19 (20)	57.84 (28)	115.05
	$\bar{x}$ sec	2.61 (20)	3.32 (28)	.48
	%x	6.49 (20)	9.92 (28)	34.81
DS	% cr	66.30 (24)	59.67 (24)	154.92
	$\bar{x}$ sec	2.89 (24)	3.16 (24)	.61
	%x	6.25 (24)	10.73 (24)	34.1
F2	% cr	67.22 (24)	58.75 (24)	144.95
	$\bar{x}$ sec	2.78 (24)	3.27 (24)	.55
	%x	6.15 (24)	10.83 (24)	43.52

IV	DV	Hi	Lo	error term
state	% cr	62.80 (25)	63.19 (23)	115.05
	$\bar{x}$ sec	3.03 (25)	3.02 (23)	.48
	% x	6.87 (25)	10.25 (23)	34.81
trait	% cr	63.00 (24)	62.97 (24)	118.97
	$\bar{x}$ sec	3.07 (24)	2.98 (24)	.48
	% x	7.85 (24)	9.13 (24)	47.42
strat	% cr	63.77 (28)	61.90 (20)	154.92
	$\bar{x}$ sec	3.08 (28)	2.95 (20)	.61
	% x	8.83 (28)	8.02 (20)	34.07
sex*	% cr	67.92 (13)	61.16 (35)	132.99
	$\bar{x}$ sec	2.75 (13)	3.13 (35)	.54
	% x	7.67 (13)	8.80 (35)	36.99

* Hi = males, Lo = females

Experiment 1 two-way interaction effects means, subjects, and error term.

IV	DV		Hi	Lo	error term
state x arith	% cr	Hi	2.55 (8)	3.26 (17)	
		Lo	2.65 (12)	3.41 (11)	.48
(state)	$\bar{x}$ sec	Hi	71.67 (8)	58.63 (17)	
		Lo	69.20 (12)	56.63 (11)	115.05
	% x	Hi	7.23 (8)	6.70 (17)	
		Lo	5.99 (12)	14.90 (11)	34.80

IV	DV		Hi	Lo	error term
state x DS	% cr	Hi	66.06 (13)	59.27 (12)	
		Lo	66.59 (11)	60.07 (12)	154.92
(state)	$\bar{x}$ sec	Hi	2.95 (13)	3.13 (12)	
		Lo	2.81 (11)	3.20 (12)	.61
	% x	Hi	6.89 (13)	6.86 (12)	
		Lo	5.50 (11)	14.61 (12)	34.07
state x F2	% cr	Hi	68.33 (12)	57.69 (13)	
		Lo	66.11 (12)	60.00 (11)	144.05
(state)	$\bar{x}$ sec	Hi	2.73 (12)	3.31 (13)	
		Lo	2.82 (12)	3.23 (11)	.57
	% x	Hi	6.69 (12)	7.04 (13)	
		Lo	5.61 (12)	15.31 (11)	33.52
state x strat	% cr	Hi	65.33 (15)	59.00 (10)	
		Lo	69.96 (13)	64.79 (10)	144.05
(state)	$\bar{x}$ sec	Hi	3.01 (15)	3.07 (10)	
		Lo	3.16 (13)	2.82 (10)	.57
	% x	Hi	5.49 (15)	8.94 (10)	
		Lo	12.68 (13)	7.10 (10)	33.52
state x sex*	% cr	Hi	63.44 (8)	62.50 (17)	
		Lo	75.08 (5)	59.89 (18)	132.99
(state)	$\bar{x}$ sec	Hi	2.98 (8)	3.06 (17)	
		Lo	2.39 (5)	3.19 (18)	.54
	% x	Hi	9.35 (8)	5.70 (17)	
		Lo	4.97 (5)	11.72 (18)	36.99

IV	DV		Hi	Lo	error term
sex* x arith	% cr	Hi	72.08 (7)	63.06 (6)	
		Lo	69.17 (13)	56.42 (22)	110.38
(sex)	$\bar{x}$ sec	Hi	2.51 (7)	3.04 (6)	
		Lo	2.67 (13)	3.40 (22)	.44
	% x	Hi	7.42 (7)	7.96 (6)	
		Lo	5.99 (13)	10.46 (22)	42.32
state x trait	% cr	Hi	66.12 (16)	56.90 (9)	
		Lo	56.77 (8)	66.61 (15)	122.07
(state)	$\bar{x}$ sec	Hi	2.89 (16)	3.28 (9)	
		Lo	3.42 (8)	2.80 (15)	.51
	% x	Hi	6.39 (16)	7.72 (9)	
		Lo	10.78 (8)	9.97 (15)	42.99

* Hi = males, Lo = females

Appendix D

Supplementary results to Experiment 1

Table 14; correlations of categorized independent variables and dependent variables.

Table 14: Rank correlation co-efficients (N = 48)

	sex	strat	state	trait	Arith	DS	F2	% cr	$\bar{x}$ sec
strat	-.06								
state	.12	.04							
trait	-.05	.00	.29*						
Arith	.15	-.14	-.20	.00					
DS	.14	.08	.04	.17	.42**				
F2	.05	-.08	-.04	.25	.51***	.83***			
% cr	-.25	-.07	.01	-.00	-.50***	-.28	-.35**		
$\bar{x}$ sec	.22	-.09	-.01	-.06	.50***	.19	.33*	-.95***	
% x	.08	-.06	.25	.09	.25	.34*	.35*	-.45***	.41**

* $p < .05$
** $p < .01$
*** $p < .001$

Table 15; correlations of independent variable raw scores and the dependent variables.

Table 15: Rank correlation co-efficients (N = 48)

	sex	strat	state	trait	Arith	DS	F2	% cr	$\bar{X}$ sec
strat	-.02								
state	-.03	-.32*							
trait	-.05	.01	.23						
Arith	-.20	.01	-.25	.02					
DS	-.08	.07	-.02	.14	.38**				
F2	-.09	.06	-.12	.05	.43**	.89***			
% cr	-.25	-.07	-.14	-.04	.53***	.22	.27		
$\bar{x}$ sec	.22	-.09	.17	.07	-.51***	-.15	-.24	-.95***	
% x	.08	-.06	-.13	-.15	-.37**	-.37**	-.27	-.45***	.41**

* $p < .05$
** $p < .01$
*** $p < .001$

Appendix E

Diagnosis and medication of the clinical sample used in Experiment 2.

Subject	Diagnosis	Medication (trade name)
1	Schizophrenia	Stelazine
2	Anxiety neurosis	Trilafon, Pipanol, Ativan
3	Korsakoff's psychosis	Hemineurin
4	manic-depressive psychosis	Trilafon
5	Schizoid personality disorder	Largactil
6	Schizo-affective psychosis	Stelazine, Melleril, Largactil
7	depressive disorder	Sinequan, Stelazine, Valium
8	depressive illness	Stelazine, Melleril, Largactil
9	adjustment reaction	Stelazine, Largactil
10	acute schizophrenic episode	Largactil, Stelazine, Melleril
11	behaviour disorder	Tegretol, Serenace
12	manic-depressive psychosis	Anafranil
13	Korsakoff's psychosis	Melleril
14	Schizo-affective psychosis	Modecate, Tofranil
15	Chronic progressive confusion	no psychogenic drugs
16	involutional melancholia	Anafranil, Stelazine
17	depressive neurosis	no psychogenic drugs
18	manic-depressive psychosis	Trilafon, Pipanol, Rohypnol
19	personality disorder	Stelazine
20	not available	no psychogenic drugs

Note: 1. Diagnoses are shortened in some cases

2. An indication is given of psychogenic medication only

Appendix F

Means for Experiment 2

The following data is the means and number of subjects (n) in each cell for Experiment 2. For a key to the abbreviations used see Appendix C.

Experiment 2 main effects, subjects, and error term.

IV	DV	Hi	Lo	error term
Arith	% cr	46.50 (5)	46.31 (15)	145.26
	$\bar{x}$ sec	5.12 (5)	5.25 (15)	1.19
	% x	17.49 (5)	15.82 (15)	90.75
state	% cr	47.75 (15)	42.17 (5)	169.74
	$\bar{x}$ sec	5.03 (15)	5.77 (5)	2.56
	% x	19.49 (15)	6.49 (5)	101.29
trait	% cr	46.14 (18)	48.34 (2)	181.81
	$\bar{x}$ sec	5.29 (18)	4.58 (2)	3.01
	% x	18.04 (18)	.00 (2)	111.99
strat	% cr	45.83 (12)	47.14 (8)	142.87
	$\bar{x}$ sec	5.25 (12)	5.16 (8)	2.35
	% x	21.00 (12)	9.10 (8)	96.83
*sex	% cr	48.21 (13)	42.17 (7)	159.1
	$\bar{x}$ sec	5.21 (13)	5.23 (7)	2.92
	% x	15.32 (13)	17.95 (7)	111.55
age	% cr	50.84 (8)	43.37 (12)	158.42
	$\bar{x}$ sec	4.39 (8)	5.76 (12)	2.47
	% x	12.10 (8)	18.99 (12)	128.05

* Hi = males, Lo = females

Two-way interaction effects means, subjects, and error term

IV	DV		Hi	Lo	error term
state x Arith	% cr	Hi	52.71 (4)	45.95 (11)	
		Lo	21.67 (1)	47.29 (4)	145.26
(state)	$\bar{x}$ sec	Hi	3.87 (4)	5.45 (11)	
		Lo	10.14 (1)	4.68 (4)	1.19
	% x	Hi	16.10 (4)	20.72 (11)	
		Lo	23.08 (1)	2.35 (4)	90.75
state x strat	% cr	Hi	48.50 (10)	46.25 (5)	
		Lo	32.50 (2)	48.61 (3)	165.94
(state)	$\bar{x}$ sec	Hi	4.78 (10)	5.54 (5)	
		Lo	7.62 (2)	4.54 (3)	2.31
	% x	Hi	22.12 (10)	14.22 (5)	
		Lo	15.39 (2)	.56 (3)	86.97
state x sex	% cr	Hi	51.76 (9)	40.21 (4)	
		Lo	41.74 (6)	50.00 (1)	159.1
(sex)	$\bar{x}$ sec	Hi	4.81 (9)	6.12 (4)	
		Lo	5.37 (6)	4.40 (1)	2.92
	% x	Hi	18.52 (9)	8.12 (4)	
		Lo	20.94 (6)	.00 (1)	111.55
state x trait	insufficient n for two-way interactions				
sex x Arith	% cr	Hi	44.17 (2)	48.94 (11)	
		Lo	48.06 (3)	39.06 (4)	174.74
(sex)	$\bar{x}$ sec	Hi	6.72 (2)	4.94 (11)	
		Lo	4.06 (3)	6.11 (4)	2.48
	% x	Hi	17.17 (2)	14.98 (11)	
		Lo	17.71 (3)	18.13 (4)	153.24

IV	DV		Hi	Lo	error term
age x strat	% cr	Hi	55.17 (5)	43.61 (3)	
		Lo	39.17 (7)	49.25 (5)	142.87
(strat)	$\bar{x}$ sec	Hi	3.95 (5)	5.14 (3)	
		Lo	6.18 (7)	5.18 (5)	2.35
	% x	Hi	16.49 (5)	4.79 (3)	
		Lo	24.21 (7)	11.69 (5)	96.83

Appendix G

Supplementary results to Experiment 2

Table 16; correlations of categorized independent variables and dependent variables.

Table 16 Rank correlation co-efficients (N = 20)

	sex	age	state	trait	Arith	% cr	$\bar{x}$ sec
age	.17						
state	-.18	.00					
trait	.10	-.07	.58**				
Arith	-.30	.00	.07	.19			
% cr	-.20	-.29	-.19	.05	-.01		
$\bar{x}$ sec	.01	.42	.20	-.13	.03	-.67***	
% x	.11	.30	-.50*	-.48*	-.07	-.09	.21

* $p < .05$

** $p < .01$

*** $p < .001$

Table 17; correlations of independent variable raw scores and the dependent variables.

Table 17 Rank correlation co-efficients (N = 20)

	sex	age	state	trait	arith	% cr	$\bar{x}$ sec
age	.28						
state	.07	.03					
trait	.09	.18	.77***				
arith	.24	.17	.01	.08			
% cr	-.20	-.48*	.03	.01	.01		
$\bar{x}$ sec	.01	-.44*	.10	.20	.02	-.67***	
% x	.11	.05	.46*	.48*	-.18	-.09	.21