ACTIVE CONTROL IN

HUMAN INFORMATION PROCESSING

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ABSTRACT

It is argued that man has considerably more control over the use of his intensive resources than most existing theories of voluntary and involuntary attention indicate. Contrary to the view of Kahneman (1973), data is presented which indicates that man can use his knowledge of a task to take active control of information processing through a task-specific change in activation state ("controlled activation", Hamilton and Hockey, 1974).

Nine experiments, eight which use variations on the active/passive paradigm (Hamilton and Hockey, 1974) and one which uses a closed system thinking task (Hamilton, *et al.*, 1977) are reported. Results are presented which indicate that when subjects are allowed to predict time-of-arrival of designated critical items, auditorily presented on the same sensory channel, they will produce a controlled modulation in activation state in phase with critical item presentation which serves to increase receptivity when critical items arrive. Further evidence is presented which suggests that a controlled activation can be used to maintain currently wanted behaviours even when other activities in which subjects engage would tend to force state into an inappropriate configuration.

The results suggest that the usefulness of controlled activation is limited not only to situations in which preview of task demand is available, but also to situations in which sufficient time for activation state change to develop is available. Evidence which

suggests the existence of individual differences in the ability to modulate state is also presented.

The implications the controlled activation process hold for future models of the information processing system are discussed. It is argued that these models must present an integrated system which allows for voluntary control of both the intensive and interpretive resources. After Hamilton, et al. (1977) it is suggested that control in such a system is hierarchially structured.

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CHAPTER I

ORIENTATION TO THE ISSUE AND HISTORICAL REVIEW

OVERVIEW

William James (1890) has described attention as the process that determines which stimulus, from among all those possible, shall become the focus of consciousness and, consequently, dominate behaviour. James recognized two methods by which stimuli come to occupy consciousness: attention may be spontaneous and non-voluntary or it may be voluntary. Spontaneous attention corresponds to the situation in which stimuli appear to claim awareness, where the intrinsic qualities of the stimulus place demands on the organism's activity. By contrast, James had noted that voluntary attention is always "undertaken for the purpose of some remote end which the effort will serve" (p. 420). Attention here suggests a state which the organism achieves in a controlled manner. It implies that the act of attending to stimuli will promote them to a position where they either come to dominate behaviour or persist in doing so.

Research on selective attention during the past 20 years has tended to discriminate these two aspects. The work of Berlyne (1960, 1961) on the attentional demands of stimuli and the Russian physiologists (Sokolov, 1963) on the manifestations of selection within the organism promote the view of attention as a spontaneous process. Berlyne has noted that stimuli have different attention-getting values, depending upon their novelty, complexity, uncertainty and conflict generating power.

Selection of stimuli with these properties has been inferred through their ability to induce an orientation reaction in the organism.

The orientation reaction (OR), originally documented in the laboratories of Pavlov)1927) and Sokolov (1963), consists of a pattern of vegetative and electrodermal state changes and receptor adjustments. As a group, these physiological changes are generally accepted as representing the organism's attempt to facilitate the intake of information concerning the stimulus (investigation) and to mobilize the effector mechanism for response.

Voluntary attention, on the other hand, is identified in the information processing approaches of Broadbent (1958), Triesman (1960) and others. Their concern has been with the nature of the interpretive process applied to stimuli to which the system is already oriented. The experimental situation characteristically employed in studies of voluntary attention is one in which the subject is instructed to prepare a response based upon information delivered from a specified source(s). No orienting behaviour beyond orientation to the information source(s) is evident. The theories resulting from investigations in this mode center on the flow of information through the system to response. In essence, they assume that information received passes through a series of stimulus-interpreting mechanisms. The output of each of these mechanisms in turn determines which portion of the information will proceed further along the chain of mechanisms to response.

Research on both of these aspects has been conducted under the heading of "selective attention," yet they seem to imply different types of activity. The work of Berlyne and Sokolov suggests that attention is an uncontrolled orienting and physiological response elicited by stimuli with special properties. This type of attention can be represented as in Figure 1.1.

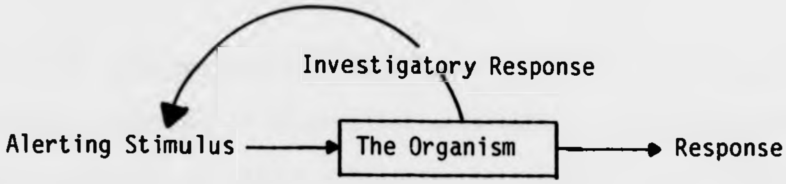

Figure 1.1: Attention as an investigatory response.

The information processing approach to voluntary attention, on the other hand, implies that attention is a controlled interpretive process applied to stimuli to which the system is already oriented in order to produce response. This type of attention can be represented as in Figure 1.2.

Figure 1.2: Attention as an interpretive process.

Despite the fact that one of these types of attention deals with an involuntary and the other with a voluntary act, another critical distinction between the two appears to lie in the type of resources they employ in order to focus attention. The involuntary models suggest that attention is concentrated by the application of orienting and physiological (or intensive) resources which facilitate the intake of information concerning the alerting stimulus. The voluntary models suggest that attention is the result of the application of goal-directed interpretive resources which, in essence, ensure that one class of information available within the system rather than another is fully processed. Within this latter view, there has been considerable evidence to suggest that experience with the output of the interpretive process causes modification in the nature of the process itself. There is also evidence to suggest that when the task involves more than one source of information the organism can, with experience, develop a coherent strategy of alternating orientation biases--in essence, producing voluntary orienting responses--in order to cope effectively with the demands of the task which is being attended (Senders, 1965). Figure 1.3 shows how this type of attention may be presented.

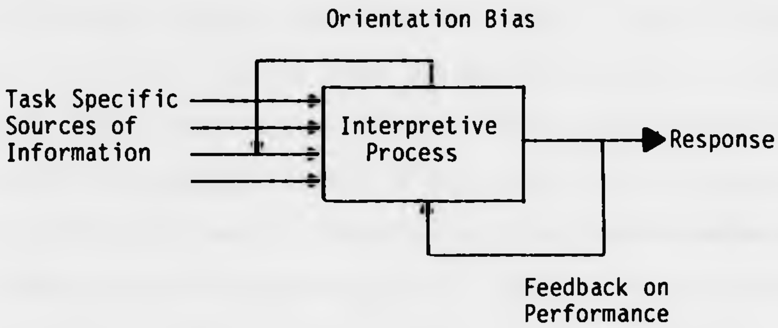

FIGURE 1.3: Attention as strategic orientation control.

Yet, within the information processing models it has been unclear to what extent the organism uses intensive resources to concentrate attention. Theories of involuntary attention tend to imply that the intensive aspects--the different states of the physiology which provide a task-specific energy input to the attentional process--do not come under voluntary control; but common sense belies this view. It would seem that in tasks of voluntary attention a similar process would be needed to help the organism to concentrate attention upon the task in hand in advance of and in order to facilitate reception of inputs into the interpretive system.

This thesis is concerned with the possibility that knowledge gained from both the investigatory and the interpretive views of attention can be integrated to advance an idea of "active control" in information processing through the controlled use of intensive resources.

It will address, as part of the exploration, two central questions which seem to remain partially unanswered by present-day theories: What is the nature of the control process underlying acts of attention? How does the organism concentrate his attention?

The next chapter will discuss the point at which the research of this thesis departs from existing models. It will introduce the idea of active control and summarize pertinent research. Chapters III through V will replicate key research results and present experiments designed to expand understanding of the concept of active control. The final chapter will seek to integrate the concept with previous theories of attention and to suggest possible features of a model of active control in human information processing. The remainder of this chapter reviews the historical development of the investigatory and interpretative models in order to summarize their contributions to understanding of the attentional experience. These contributions fall into two categories: descriptions of the kind of stimuli the organism chooses to look at or listen to, and understanding of the benefit derived from the intensive attentional response.

THE KIND OF STIMULI THE ORGANISM CHOOSES TO LOOK AT AND LISTEN TO

The Involuntary Models

The topic of involuntary selective attention reached prominence in Western literature primarily through the work of Berlyne (1960). He concentrated his investigations on the factors governing stimulus selection in the absence of obvious motivating forces such as biological need. A simple example of this situation is a well nurtured cat playing contentedly with a stuffed toy on the living room rug.

From all appearances, the cat is totally absorbed in play and oblivious to peripheral sounds and activity. Suddenly, the cat ceases play, pricks up its ears, stands motionless and stares at the front door, from which come the faint sounds of unfamiliar footsteps in the passage. The cat remains in this position for a few moments and then resumes play.

Berlyne attributed control of selection in situations like this to the properties of the stimulus. He described novelty, complexity, uncertainty and conflict-generating power (collectively termed the "collative variables") as stimulus properties which claim attention. Consonant with the theory of Hull (1943), Berlyne regards attention as a perceptual response coordinating the drive stimulus (S_D) in the external environment with the goal stimulus (S_G) within the organism to produce a response. The directional selective element of attention in response to stimuli with one or more of the collative properties, therefore, is due to the higher reaction potential (${}_S\bar{E}_R$) of the perceptual response that these stimuli evoke. Berlyne regards the ability of stimuli with the collative properties to elicit the OR as evidence of their attention attractiveness.

The OR, as originally documented in Pavlov's laboratory, referred to the reflex redirection of sensory organs toward the source of stimulation. Later, Sokolov (1963) expanded the concomitants of the OR to include a collection of physiological changes believed to be controlled by activities in the brain stem reticular formation (Moruzzi and Magoun, 1949). The OR, therefore, is generally accepted as including the following (Lynn, 1966):

1. Redirection of sensory receptors toward the source of stimulation.

2. Rise in general muscle tonus and cessation of on-going activity.

3. Increased sensitivity of the sensory organs (inferred through):

    a. pupillary dilation,
    b. lowered auditory threshold, and
    c. lowered retinal light threshold.

4. EEG desynchronization (i.e., change toward faster, lower amplitude activity).

5. Vegetative state changes:

    a. vasodilation in the head, vasoconstriction in limbs,
    b. increased electrical conductance of the skin (GSR occurs),
    c. respiration rate changes (i. e., delay followed by increased amplitude, decreased frequency), and
    d. heart-rate deceleration.

A further, highly characteristic feature of the OR is its rapid habituation with repeated stimulus presentations.

Enough variation among components of the reaction has been documented for different types of reaction, relating to different classes of stimuli, to be described (Lynn). Furthermore, Voronin and Sokolov (1960) have found intra-individual variation in the strength as well as in the nature of the reaction. Sokolov regards the generalized vasodilation in the head, distinguishing the OR from a similar "defensive" reaction, as the operational definition of the OR. Western authors favour GSR occurrences (Germana, 1968) or EEG desynchronization (Berlyne and Borsa, 1968) as the determining characteristic.

Sokolov (Sokolov, 1960, 1963; Voronin and Sokolov, 1960) has presented the most comprehensive theoretical model of the OR. The model assumes that afferent stimulation reaches both the cortex and reticular formation. In the cortex, this stimulation is compared with existing "neuronal models" containing information (e. g., intensity, duration) regarding past stimulation. When mismatch occurs between existing neuronal models and new stimulation, the cortex sends excitatory impulses to the reticular formation which, in turn, triggers the components of the OR. If, on the other hand, current stimulation matches existing models, no excitatory impulses reach the reticular formation via the cortex and the OR is blocked.

Berlyne (1961) proposed conflict-generation among competing response tendencies as the primary dimension of the collative variables, with the other properties acting to increase the OR. He supported this argument by showing a monotonic relationship between strength of the OR (inferred through the size of the GSR exhibited) and the degree of conflict, as measured by the number of response alternatives in an experimental task. Although Berlyne's demonstration of the effect of conflict on elicitation of the OR has been accepted in the literature, the difficulties involved in "semantic" categorization of stimulus situations suggests that conflict is not a truly workable definition of OR determiners.

In addition, evidence from other sources has prompted a re-interpretation of variables governing the occurrence of the reaction. Unger (1964), for example, has shown that an OR occurs in response to a violation of expectation, such as in the presentation of an out-of-series number (e. g., 1, 2, 3, 4, 6). Maltzman, Harris, Ingram and Wolff (1971) found that expectation need not be as obviously defined as in Unger's study. They regularly alternated illumination between an adaptation level and a lower level. Both types of change elicited the OR, but the change to the lower level elicited stronger ORs than did restoration of the adaptive level. That stimuli of particular significance to the subject also elicit an OR has been clearly demonstrated in a study by Biryukov (reported in Razran, 1961). Fox cubs initially exhibited the OR to mice squeaks but the response habituated quickly with repeated presentations. When the cubs had been allowed to eat the mice, however, the OR returned and remained highly impervious to extinction.

Thus, the major body of work underpinning theories of involuntary attention has been concerned with describing the properties of stimuli which govern their selection. Collectively, these studies suggest that three basic categories of stimuli elicit the OR:

1. Those possessing the collative properties.
2. Those that violate the organism's expectations of stimulation.
3. Those that are of special significance to the organism.

The Interpretive Models

The second chain of research involves studies of voluntary attention and is not so concerned either with the nature of the stimulus or with the source of information as are the involuntary models. In this research chain, selection of the source of information is dictated by the nature of the task or, as James said, "by virtue of some remote end which the effort will serve." Thus, the focus of studies of voluntary attention has been on the nature of the process that ensures that one source of information rather than another dominates behaviour.

Most modern-day theories of voluntary attention are mechanistic and structural and are couched within the view of the human organism as an information processing channel. Norbert Wiener (1948) is largely responsible for at least the seed of this idea. He argued that:

1. Information is quantifiable.
2. The control processes of biological systems are similar to those of mechanical systems.

The first of these premises received considerable impetus when Shannon and Weaver (1949) provided a mathematical definition of the information potentially available in a system. Although Shannon and Weaver were concerned with the transmission of information through physical systems, the potential of "information theory" as a psychological tool was quickly recognized. It is responsible for the view of man as a communication channel which receives and transmits information. It has also led to the specification of three basic concepts within cognitive psychology:

1. Noise exists in the human system.
2. Man's capacity to store information is limited.
3. The rate at which man can process information is limited.

Some researchers have been more concerned with the mathematical applications of information theory than others. However, these three basic concepts have received general acceptance even among the most non-mathematically inclined.

Wiener's second premise--that control mechanisms of biological systems are similar to those of mechanical systems--has also been the springboard for further research and theoretical development. Wiener regarded feedback as a viable control mediator in biological systems as well as in mechanical systems. In the physiological literature, it has been suggested that feedback is the basis of control in homeostasis (Hoagland, 1949), reflex activity (Palliard, 1960) and intra-muscular activity (Eldred, Granit and Merton, 1953), while in the human skills literature it has been widely regarded as the basis for movement control.

Both information theory and the mechanical control analogies have limitations which reduce their applicability to human behaviour. Information theory, for example, does not distinguish between what is marginally wrong and what is decidedly wrong, even though these two types of error represent different levels of performance. Additionally, informational analyses are difficult to apply in situations where the probabilities of events are in constant flux rather than static. The BIT rate, furthermore, is a relative statistic for non-selective communication systems while man consistently demonstrates selectivity in dealing with his environment. Finally, information theory has tended to focus research interest on the limits of performance rather than on the more pertinent "average" performance.

Similarly, early analogies of mechanical control had limitations primarily because they were not sophisticated enough to explain the complexities of human behaviour. However, as computer technology developed and began to expand the capabilities of automated control, analogies of this type appeared to fit human behaviour better and grew swiftly into the basis for a descriptive model for human systems. These more sophisticated machine analogies provide a basis for defining human performance in terms of information processing routines.

In selective attention, this approach revolves around the choice of an information channel and is generally not concerned with arousal or motivational variables. The typical experimental situation is one in which the subject is presented with more information (usually auditorily delivered) than he can handle. Selection and storage properties are inferred from output and no orienting behaviour beyond orientation to the source of information is observed.

The pioneering research results leading to the formalization of this approach came from Broadbent and Cherry:

1. If a subject is trying to listen and respond to two or more messages at once, the amount of interference between tasks is dependent upon the amount of information they convey (Webster and Thompson, 1953, 1954; Broadbent, 1952b, 1956).

2. If the subject is trying to respond to only one message, pre-instruction as to which is the critical message results in better performance than post-instruction (Cherry, 1953; Broadbent, 1952a).

3. A physical cue (e. g., loudness, location, pitch) facilitates selection if selective response is required but not otherwise (Broadbent, 1951b; Cherry, 1953).

Broadbent (1958) integrated these and related findings to advance a model of selective attention which has remained the cornerstone of theories of voluntary attention. He described a series of stimulus-interpreting mechanisms in which the output of one mechanism provides the input to another. Broadbent proposed the existence of a limited capacity information channel (P-system) in the central nervous system capable of processing only a limited amount of information in a period of time. The P-system is protected from informational overload by a selective filtering mechanism which, although able to accept input from many sources, selects information from one source to pass further up the system for processing toward response. Inasmuch as pre-instruction aids performance, selection must occur prior to introduction into the limited capacity system, at the input, rather than response stage, thus justifying the location of the filter in the model.

The other major component of the system, a short-term memory (buffer) store, precedes the filter and allows items to be held in store until other items have passed through the P-system (Broadbent, 1954b). This buffer store appears limited, however, both in the amount of time it can preserve information (Broadbent, 1957) and in the amount of information it can maintain at one time (Cherry; Triesman, 1964a).

Objections to the filter model came from many sources and initially were primarily directed toward the properties of the filtering mechanism and, indeed, toward the concept of filtering altogether. As it was originally proposed, the filter:

1. Effectively prevented all but the selected input from passing on to the P-system;
2. Made its selection on the basis of physical cues only, and
3. Was limited in the rate at which it could switch the basis for selection from one input source to another.

Objections to the first two of these properties came from Moray and Triesman. Using a shadowing task, Moray (1959) found that a subject noticed and recalled the occurrance of his own name in the message of the irrelevant ear. Triesman (1964a) noted that, when the same message was presented to both ears, subjects were aware of the fact even if the messages were presented by different voices and in different languages understood by the subject. These studies ruled out the possibility of the filtering mechanism completely blocking further processing on the basis of a physical cue and opened investigation of content as a selection cue.

In a series of experiments, Triesman (1964a, b, c) compared the effect of physical and contextual cues in selection. She presented two messages on the same auditory channel and in the same voice. The relevant message to be shadowed was a passage from a novel, while the irrelevant message was variously a passage from another novel, a technical discussion, a passage in a foreign language which the subject knew or didn't know, or nonsense phonemically similar to English. The results showed that the greater the difference in content between the messages, the easier it was to shadow the relevant. The effect was, however, small and not as great as cases in which a physical cue is present, thus indicating that, although selection on the basis of contextual cues is possible, it is not as efficient as selection by physical cues. Further to this, Triesman found that, given the presence of a physical cue, a contextual cue does not benefit performance.

In another shadowing task, Triesman (1964b) presented an irrelevant message of a passage from a novel while the relevant message contained approximations to English from first through twelfth order. Both passages were read by the same voice and came from the same location. When the irrelevant message contained low order approximations, the subject frequently shifted to shadowing the irrelevant passage, an effect which decreased as the order approximation increased. In another task (Triesman, 1960), subjects were instructed to shadow what was presented to one ear while the two messages, a prose passage and low order approximation to English, alternated presentation ears. Although subjects occasionally continued to shadow the designated ear, usually they followed the context for a brief period of time immediately after the switch and then reverted to what was instructed. Subsequent research results have shown that selection can be made on the basis of voice qualities and on the basis of semantic and syntactic continuity (Moray and Barnett, 1965; Gray and Wedderburn, 1960).

The conclusion to be drawn is that, contrary to the simplicity of filtering by a physical cue alone as postulated in Broadbent's original model, items that have been perceived can exert enough control over the setting of the selective mechanism that the items that follow are more likely to be selected.

These studies led to alternative proposals to filtering. One of these comes from Deutsch and Deutsch (1963; Norman, 1968, proposed a similar theory) and suggests that it is not physical cues that govern selection but the nature of the stimuli. They maintain that all stimuli are analysed on all dimensions and receive a "priority rating," determined by the state of the organism, which results in high priority stimuli being selected for response. Although this may account for why the subject heard his own name in the irrelevant message in Moray's experiment, it does not explain why selection without physical cues is difficult. Basically, the concept suffers from sheer complexity of the operations involved. Firstly, it is difficult to speculate on the nature of the analytic process and, indeed, the authors provide little guidance here. Secondly, as Broadbent (1971) notes, the size of the task of analysing all stimulus features, even of those stimuli on irrelevant channels, belies the notion of the "economy" in processing which selection is supposed to achieve.

Triesman (1960) advanced a more intuitively agreeable alternative that accounts for the effect of content. She postulates the presence of a set of "dictionary units" corresponding to words. Signals from the senses excite the dictionary unit corresponding to the word presented. When the strength of the signal in the unit reaches the unit's threshold, it fires, representing perception of the word. As is the case in ordinary language where a stimulus series contains sequential dependencies, the firing of one dictionary unit reduces the thresholds of those words which are likely to follow, thus inceasing their probability of being fired and, hence, perceived.

Triesman located the dictionary units beyond the selective filter. But, unlike Broadbent, she attributed to the selective mechanism the ability to attenuate, but not to block, stimuli that do not possess a desired physical characteristic. The possibility therefore exists that the low strength signal from an irrevelant message could fire a suitably low threshold dictionary unit, resulting in perception of a word from an irrelevant message. However, those units most likely to fire would be those receiving the stronger signal (i. e., the ones corresponding to items in the message selected by the filter). In the case of certain critical words, such as the person's name, the units are judged to have permanently lowered thresholds.

Triesman (1969) provided a more elaborate functional description of her model in terms of a collection of perceptual analyzers, each of which operates upon a different dimension of the stimulus. Isolation of a selected message is achieved through more efficient passage of that message through the analyzers; however, irrelevant messages are nevertheless analysed, although less efficiently. Unlike the original filter, therefore, stimuli from different sources can be processed in parallel at least up to some point. Triesman maintains that the switch to serial processing must take place when inputs compete for the same analyzer or set of analyzers. Unfortunately, Triesman's model is quite vague, especially when it comes to defining the nature of a dimension upon which an analyzer or group of analyzers can operate. The model seems to assume that an analyzer (or group of analyzers) can be dedicated to a dimension or group of dimensions which can serve as a "perceptual unit."

However, Triesman's model appeared to incorporate the empirical evidence quite effectively and, for this reason, gained general acceptance in the literature. Indeed, Broadbent (1971) revised the old filter model in light of this new evidence. He did, however, change some of the Triesman terminology in order to suggest broader application and prevent confusion. Thus, he prefers to speak of "category states" rather than dictionary units, indicating that the concept is not limited to words but includes other classes of stimuli, and dispelling any inclination toward presumption about word meaning. Indeed, Triesman's perceptual analyzers achieve the same goal. Similarly, to dissociate "threshold" from any psychophysical meaning, Broadbent refers to the concept as "pigeon-holing."

At this point, the first two properties of the original filter concept were stretched, if not bent. The filter could not block completely and selection could be made on other than physical cues when appropriate conditions prevailed.

In Broadbent's model, the limited capacity P-system was capable of only serial processing of inputs. It was the responsibility of the filter to accomplish queuing of inputs to the system. Consider, therefore, the third property of the filter in the original model--that of a limit to the rate of switching between input sources. (With revisions to the model occasioned by the above results, switching time between selected perceptual units is probably more apt.) Broadbent (1954b) had performed an experiment in which subjects were asked to report information in the order in which it was presented. When pairs of stimuli were presented rapidly (one item/ second), one member of each pair to each ear, performance was poor but, as the rate was decreased, performance improved. When allowed to reproduce the items ear by ear, however, subjects' performance was as good as at fast rates. It was on the basis of these results that Broadbent reasoned that the filter required a minimum period of time to switch between the sources of input it selected from the buffer store.

This conclusion, however, was questioned by Moray (1960). Using a task in which inputs alternated rapidly between ears, Moray found subjects as successful in reproducing items ear by ear as in the order in which they were presented. Moray's results tended to indicate faster switching than originally suggested. However, Broadbent and Gregory (1961), using a similar task, found that post-instruction as to order of report did not impair performance, as would be implied. They concluded that not switching but, rather, simultaneous selection of both ears occurred so that where stimuli alternate, items will pass the P-system in input order. This conclusion, however, was left somewhat open to question when finer details of the results are considered. For example, most studies of this sort show evidence of mixed orders of report as well as ear by ear, although the former is generally not as successful. However, the fact that mixed order reporting occurs suggested that fast switching may be possible, although perhaps not easy.

Other evidence came from Gray and Wedderburn (1960), Yntema and Trask (1963), Broadbent and Gregory (1964) and Bryden (1962, 1964). These studies were generally concerned with the effect on performance of simultaneously presenting material from two different classes, with the classes alternating input channels. Results showed subjects could report class by class (alternating ears) as well as ear by ear. Apparently rapid switching is possible but whether or not it will be used depends upon the nature of the task and whether the subject finds it a viable strategy for dealing with that task. Fairly recently, Ostry, Moray and Marks (1976) have shown that rapid switching (2 to 4 times/second) predominates after considerable practice.

This latter result is indicative of a significant direction which work within the interpretive models has taken especially during the last 5-10 years. It is beyond the scope of this review to dwell upon the actual research results and the sub-issues that were raised, but it is important to note how conceptualization of the interpretive system has changed since the original filter model appeared. So much space has been devoted to discussion of the original filter model because of its historical importance and because efforts to disprove at least parts of it have led theory within the interpretive models to the point where it seems to stand today.

One of the key issues which arose from this research concerned whether serial or parallel processing occurred. Since the 1958 version of the filter model, most alternative models have assumed that parallel processing proceeds at least up to some point within the system (e. g., Triesman, 1960, 1969; Norman, 1968; Deutsch and Deutsch, 1963, 1967; Neisser, 1967). Additionally, these models tend to assume that some sort of bottleneck in the structure of the system occasions the switch from parallel to serial processing. The question has been, Where? Triesman (1969) and Neisser (1967) seem to agree that the bottleneck occurs when inputs compete for the same analyzers. This theory, as noted earlier, is vague enough to allow the bottleneck to occur almost anywhere. Deutsch and Deutsch (1963, 1967) locate the bottleneck at the stage of perceptual response, but this idea has been countered (e. g., Triesman and Geffen, 1967; Triesman and Riley, 1969). Thus, some studies have suggested that processing can be totally parallel (e. g., Lindsay, 1970), while others suggest that it cannot (e.g., Moray and O'Brien, 1967).

Where it is that the system must switch from parallel to serial processing (if this must occur) seems, therefore, to be a function of task variables such as the nature of the input(s), the rate of presentation and the required response. The question then turns into one of how the task variables cause the switch in processing mode.

The shifting bottleneck in the information processing system has been explained in terms of the capacity of the system. Moray (1967) and Kahneman (1973) provide good descriptions of how capacity limitations determine where parallel and serial processing would be expected to be observed. In essence, when parallel processing is observed, the total amount of capacity required does not exceed the total amount available. However, when only serial processing is observed, the task which is being attended to requires so much capacity that it is not possible to process competing inputs (or responses or outputs) at the same time.

Moray (1967) has described how the allocation of the available capacity is quite purposeful. Allocation of capacity appears to come very much under the voluntary control of the subject, except for certain special cases (of which the OR is one). Similarly, capacity allocation is not all or none. Subjects can elect to direct sufficient capacity to one of two concurrent tasks so as to produce highly efficient performance on that task or they can elect to divide capacity between the two tasks so as to produce less efficient but basically equal performance on the two tasks (Ninio and Kahneman, 1973 is an example).

Fairly recently, evidence has been accumulated to show that the amount of capacity a task requires is a funciton of variables like practice and Stimulus-Response (S-R) compatability. Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) describe such effects in detail. They note that when a task is highly practised and when the S-R compatability within the task is high, subjects appear to perform at least parts of the task for fairly long periods without any investment of capacity or attention.

As noted in the introduction to this review, the way in which the research presented in this thesis differs from the apparent goals of research within the interpretive models of attention centers more upon the nature of the resources that are employed than upon other aspects of the models. Within the interpretive models, the resources employed tend to consist of the processing routines or the interpretive pathways. Considerable progress has been made in specifying the nature of these routines, how they develop and how they are controlled. In order to understand how understanding of the intensive resources has progressed, another body of research warrants review.

THE BENEFIT THE ORGANISM DERIVES FROM THE PHYSIOLOGICAL COMPONENTS ASSOCIATED WITH THE ATTENTIONAL RESPONSE

The Orientation Reaction

Although there has not been dispute about the fact that the physiological components of the OR aid the individual in dealing with the alerting stimulus, there is not universal agreement on the nature of the benefit the organism derives. Two types of interpretation have been advanced. On the one hand, Sokolov gives a detailed, functional analysis of components of the OR, recognizing a measure of adaptive directionality in the response. On the other hand, the interpretation prevalent in Western literature regards the physiological components of the OR as evidence of an increase in arousal level, benefiting the organism through a general energizing of behaviour.

Sokolov (1963) maintains that the OR functions to increase the organism's intake of stimulus information by lowering sensory thresholds and to ensure response readiness through mobilization of the effector system. Thus, he regards pupillary dilation as causing increased retinal sensitivity, changes in respiratory rate as causing increased olfactory sensitivity and increased skin conductance as decreasing the threshold for cutaneous sensitivity. Central aspects of the OR, Sokolov maintains, increase the capacity of stimulus-analysing mechanisms. The redirection of blood flow from limbs to the brain caused by simultaneous vasocontstriction in the limbs and vasodilation in the head is assumed to facilitate functioning of these mechanisms. Similarly, EEG desynchronization is believed to maximize the probability of stimulation reaching the cortex in a seemingly critical phase for the acceptance of new information. Lindsley (1960) provides evidence in support of this analysis of EEG functioning. However, other of Sokolov's assumptions have received little direct investigation to date.

Three features of the OR emphasize the directionality to which Sokolov subscribes. Firstly, the correlation between aspects of the OR elicited--both those which are intra-individual and those which are inter-individual--are relatively low. No detailed investigation of these findings has been undertaken. Yet, the major theoretical interpretation presenting itself (Kahneman, 1973) is that the OR represents a loosely organized set of responses that frequently occur together because they are adaptive in dealing with similar situations (e.g., similar stimuli). The further possibility is that inter-individual variations in response reflect variation in the organism's evaluation of the demand of the stimuli.

The occurrence of both generalized and localized reactions is also indicative of some form of directionality in the OR. The most useful distinguishing feature between the two types of reaction is the location of the high frequency EEG rhythms. The generalized reaction is the first elicited and displays EEG desynchronization over the entire cortex. The localized reaction, on the other hand, occurs with repetition of the stimulus and is characterized by EEG desynchronization only in the area of the cortex corresponding to the sensory modality on which the stimulus was presented.

The third and most obvious feature of the OR indicative of directionality is receptor re-adjustment toward the source of the stimulus. Pavlov's (1927) original documentation of the OR as receptor re-adjustment emphasized the selectivity of the response. However, the introduction of electro-physiological recording techniques into OR research served to increase the component list. In Western research, similar features had already been integrated to advance a concept of activation or arousal, believed to have a general energizing effect upon behaviour. Primarily because of the similarity between electro-physiological features of the OR and those indicative of increased activation, the OR was quickly subsumed under the activation concept. As a result, the gross selective behaviour of the OR was over-shadowed by the non-directionality associated with activation.

The Arousal Concept

Lindsley (1951,1960), Duffy (1962) and Malmo (1959) have been responsible for the major facets of the concept of activation as it has been known for many years. They have argued that various autonomic, electrocortical and skeletal-muscular measures (Duffy describes them in some detail) are indices of the organism's physiological state. Furthermore, they note that these state indices vary in direct relationship to one another so that it is possible at any given time to locate the organism on a unidimensional continuum ranging from coma to extreme excitability. The point on this continuum where the organism is located at any particular moment has been termed the organism's activation or arousal level.

Activation level has not been viewed as static but as extremely labile, subject to alteration by a number of variables. In the OR context, particular stimuli are regarded as being high in arounsal potential. But other types of variables are also regarded as serving to increase or decrease activation. These include the activities in which the organism engages; environmental factors such as noise, temperature, illumination, the administration of drugs, and fatigue or sleep deprivation; and motivational factors such as knowledge of results, the presence of an audience or supervisor, time pressure and monetary incentives. The organismic factors of sex, age, temperament and time of day also affect activation.

Traditionally, activation has been assumed to relate to some aspect of intensity or alertness in the organism. Duffy (1957) relates activation to the intensity of behaviour. Hebb (1955) regards activation as corresponding to the intensity of factors motivating behaviour and draws a close link between activation and drive theory. Berylyne (1960) defined activation simply as a measure of how wide awake the organism is.

Separation of the differences in these views is not easy and may be purely semantic. Such resolution is, furthermore, not crucial in the context of this discussion. What is significant to note here is the similarity among them. They all agree that activation has an effect upon performance that is devoid of directional elements. Duffy warns against confusion between the intensity of behaviour and the direction of behaviour; Hebb maintains that the activation system does not determine the energy of response but whether the energy is available; Berlyne states that such intensive aspects of behaviour as arousal correspond to how effectively the environment in general, rather than the stimulus being attended to, is in control of behaviour.

The Yerkes-Dodson Law

The relationship between activation level and task performance has traditionally been expressed in terms of the Yerkes-Dodson law (1908), originally developed in the field of animal discrimination learning. The law presumes an inverted U-shaped relationship between activation and performance. Performance improves as activation level increases (beneficial increases) up to a point beyond which further increases in activation result in a deterioration in performance (detrimental increases). The law further states that the optimal level of activation is lower for complex tasks than it is for simpler tasks, with simplicity and complexity inferred from error rate under normal conditions.

During investigations of the performance-activation relationship, one or more of the variables affecting activation have been introduced in order to manipulate levels. Frequently, changes in activation level have been inferred from a change in error-rate rather than measured on physiological state indices.

To illustrate applications of the Yerkes-Dodson law, the increased activation level assumed to be caused by continuous loud noise has been found to improve performance in simple tasks but to cause a deterioration in complex ones (Broadbent, 1954a). The decreased activation level produced by sleep deprivation , on the other hand, has been found to cause a deterioration in performance (Wilkinson, 1960).

When stressors are applied in combination, the effect upon performance is usually assumed to be an interaction of the two. Wilkinson (1963) has demonstrated that in subjects performing a serial reaction task there is an interaction for the combination of noise and sleep deprivation and the combination of knowledge of results and noise. In the first case, sleep-deprived subjects made more errors in quiet than in noise, yet rested subjects made more in noise than they did in quiet. The results have been explained by presuming that the increased activation caused by noise counteracts the decreased activation produced by sleep-deprivation and results in an overall beneficial effect upon the performance of sleep deprived subjects. Noise in isolation, however, produces a detrimental increase in activation.

In the second case, the number of slow reactions was least when subjects worked in quiet with the motivating factor of knowledge of results and greatest when they worked in quiet without knowledge of results. Thus, the effect of the motivating knowledge of results produced a beneficial increase in activation. The addition of noise, however, reversed the results, producing a detrimental increase in activation in the motivated state and a beneficial increase in the unmotivated state.

The Yerkes-Dodson law has provided a reasonable description of results in a variety of studies (Kahneman, 1973, reviews several). However, the fit is not perfect and other evidence has encouraged a re-examination of the performance-activation relationship. This re-examination generated two new concepts, one derived from re-assessment of the notion of activation level and the other from a re-assessment of task complexity.

Re-examination of Activation Level

Lacey (1967) reviews a large body of evidence indicating that the correlation among various activation measures is lower than the unidimensional hypothesis predicts. He argues that three different activation systems (autonomic, electrocortical and behavioural) must be distinguished and that each of these systems is more independent than originally thought. Lacey considers the frequency with which all three types of activation occur together to be evidence of system interaction rather than of system coupling. He has cited evidence in which dissociation among two or more of these systems is observed. For example, Bradley (1958) administered atropine to cats. Although behaviourally the cats remained aroused, their EEG activity resembled that of sleeping animals. When physostigmine was administered, on the other hand, the opposite was observed: the EEG activity was that expected of an alert animal while the behaviour was that of a drowsy one.

Lacey further notes that within the range of physiological indices of activation the magnitude of reactivity is not highly correlated (Elliott, 1966). Although various indices may change in the apparent direction of sympathetic dominance, the magnitude of change varies from one individual to another and from one stimulus to another (Schnore, 1959).

Lacey has termed the appearance of particular patterns of physiological activity in a specific stimulus situation as "situational stereotypy." He maintains that situational stereotypy indicates the goal-directedness rather than the general energizing quality of physiological state change. This point will be discussed shortly. One special case of situational stereotypy, however, is particularly damaging to the notion of a unidimensional concept of activation. In the foreperiod of a reaction time task cardiac deceleration, traditionally associated with decreased activation, frequently occurs in conjunction with pupillary dilation and increased blood pressure, traditional associates of increased activation (Lacey, 1967). Lacey uses "directional fractionation" to describe these cases where one or more physiological indices exhibit changes in the opposite direction of that associated with sympathetic dominance. These instances are in conflict with a description of the organism by location on a unidimensional continuum of activation. They promote, instead, the possibility of location in a multidimensional space. This notion is already implicit in some work (Broadbent, 1971; Kahneman, 1973; Pribam and McGuinness, 1975; Hamilton, Hockey and Rejman, 1977). Indeed, Hamilton, Hockey and Rejman suggest abandonment of the activation level concept in favour of one of activation "state."

Re-examination of Task Complexity

Broadbent (1971), Davies and Tune (1970) and Kahneman (1973) in reviews of stress literature note studies in which performance does not mirror predictions of the Yerkes-Dodson law. Two types of interpretation may be placed upon these failures. Either it is possible that different stressors do not affect performance in the same way or it is possible that different tasks are not affected by a single stressor in the same way. (Indeed, both of these interpretations may be true.) Broadbent discusses evidence in support of the first possibility. When subjects perform a serial reaction time task under normal conditions, the initial rate of work is maintained for a period of about one-half hour, after which the average rate decreases (Broadbent, 1953). Under noise stress, Broadbent found the rate of work remains the same as under normal conditions but errors increase after the first one-half hour at work. Pepler (1959) and Wilkinson (1959) found that, while sleeplessness decreased rate of work but did not affect error-rate, error-rate increased immediately under extreme heat (Pepler).

In reviewing vigilance literature, Davies and Tune (1970) cite evidence supporting the second interpretation, noting that improvement, deterioration and no change in performance have all been noted under noise stress. Apparently, the effect observed is a function of task variables. Hockey (1973, 1970) and Easterbrook (1959) have provided data on this point. However, Hamilton, Hockey and Rejman, (1977) conducted the most definitive investigation to date. They studied the performance of subjects under noise stress on a variety of tasks. From their studies, they expected noise stress to produce the following pattern of effects (p.474-475):

A. The deployment of attention over competing sources in the task will change and sources which have a high probability of yielding information relevant to the task criterion will be favoured. The same effect may be obtained with competing output response. The consequences for performance can not be known independently of task specification and knowledge of the scoring criterion.

B. The holding capacity of primary memory will diminish, although immediate input will be more strongly registered.

C. The conditions required for an increase in processing rate will exist but choice of tasks which are data-limited (Norman and Bobrow, 1975) in operation will lead only to speed-accuracy trade-offs.

Such breakdown of effect, according to the nature of the information processing activity involved, argues against simple description of task complexity as determined by error-rate. Rather, it emphasizes the importance of describing the "quality" of task through reference to the nature of the activities required. Hamilton, et al. developed this concept by investigating a task in which the "weighting" of various component functions was manipulated within the experimental situation. Their results reflected the same pattern of effects as would be predicted from knowledge of the effect of noise upon each component individually.

Theoretical assimilation of these new concepts reduces the Yerkes-Dodson law to a simple rule of thumb at best. The relationship between activation and performance can not be defined only in terms of increments and decrements in activation level and error but requires incorporation of a qualitative evaluation of both activation and task state. Implicit in this assumption is that the physiological state of the organism may at the same time be injurious to some aspects of behaviour and beneficial to others.

Some evidence of situational stereotypy relates directly to this point. Heart rate deceleration and increased pupil diameter are typically observed in situations where the subject is engaged in attentive observation of the environment, such as in the foreperiod of a reaction time task (Lacey, 1967) and picture examination (Libby, Lacey and Lacey, 1973). When active manipulation of information begins, however, heart rate accelerates while pupil diameter continues to increase (Lacey, Kagan, Lacey, and Moss, 1963; Tursky, Schwartz and Crider, 1970). The foreperiod of a reaction time task has also revealed evidence of a particular pattern of EEG activity. Walter, et al. (1964) describe a slow, surface-negative shift from EEG baseline which they have termed the "Contingent Negative Variation" (CNV) because of its apparent contingency upon the occurrence of a second signal to which resonse is required. (Tecce, 1972, reviews much of the CNV literature.)

In reaction time tasks where either cardiac deceleration or the CNV has been studied, their appearance is associated with short reaction times. When reaction times are longer, they do not appear. This evidence argues that a state of activation in which cardiac deceleration and the CNV are present is likely to benefit attentive observation but that a state of activation in which they are absent does not. Future research continuing the line of attack introduced by Hamilton et al. may produce an index referencing task state to its optimal activation state.

In summary, activation state changes can no longer be plausibly accepted as having universal effect upon performance. Thus, we must gravitate toward the type of directionality Sokolov recognized in the OR. In non-stress conditions, activation state changes must be assumed to incease the efficiency of behaviours to which the system is biased (task set). Under stress, on the other hand, the activation state produced must be assusmed to benefit performance only if it is compatible with the bias of the system.

The interpretive view of attention in combination with the unidimensional concept of activation has tended to disregard the importance of the intensive aspects of behaviour in the control of information processing activities. The evidence discussed above, however, suggests that a re-evaluation is warranted. Behavioural evidence suggests that different information processing activities are differentially affected by a given physiological state. Physiological evidence indicates that particular physiological states accompany efficiency in particular tasks. Moreover, the physiological evidence suggests that the process of arriving at a beneficial or desired state for performance of at least some activities is not controlled by extra-organismic factors alone.

Kahneman (1973) has made considerable progress in assimilating these and related findings into his concept of mental effort. He concurs with the view of the organism as limited in its capacity to perform information processing activities. Kahneman maintains that each activity requires a standard investment of this limited capacity. When ongoing activities do not require the total capacity of the system, the reserve or spare capacity is devoted to continuous perceptual monitoring. When, however, ongoing activities require more than the standard investment, spare capacity is diverted to them. Kahneman equates this investment of spare capacity with the investment of mental effort. He furthermore regards capacity as intimately related to the organism's state of physiological activation such that moment-to-moment fluctuations in physiological activity reflect the organism's investment of spare capacity. Kahneman describes the allocation of spare capacity as essentially a homeostatic one. The organism is unable to invest in anticipation of task demand but must make corrective adjustments based upon evaluation of the discrepancy between actual investment and that required.

Kahneman sees investment of effort in the activities of involuntary attention as being an operant response and considers a higher processing requirement to be the common denominator among stimuli which elicit the OR. Kahneman regards the effort to be invested in the activities of voluntary attention as a function of the evaluation of the need for increased effort that the organism makes after having begun the activity.

REVIEW AND THE CONCEPT OF ACTIVE CONTROL

The review in this chapter was aimed at summarizing the broad generalizations underlying theoretical investigations of selective attention and at sketching the nature of the issues that have prompted these investigations. This review has been deliberately broad brush because a detailed discussion of the depth of understanding achieved by these investigations would tend to obscure the point at which the central idea of this thesis departs from existing views.

Existing models of selective attention raise a paradox. Research on both voluntary and involuntary attention has been conducted under the heading of "selective" attention. Yet, taken together, they suggest that man has little control over the intensive aspects of selection. The theories of involuntary attention present the view of attention as a demand placed upon the organism. The theories of voluntary attention present the view of attention as a goal-directed, interpretive process applied to stimului already within the information processing system. Within this latter view, the intensive aspects of behaviour have tended to be regarded as akin to the hardware of a computer. While the condition of the hardware affects the overall level of performance, control of information processing is almost totally vested in the software, or the information routines of the system.

This chapter reviewed the dramatic changes which have occurred with respect to views of the intensive aspects of behaviour. These changes have brought about what Sanders (1979) terms functional or energetic models of the information processing system. Kahneman (1973), Hamilton et al. (1977), Norman and Bobrow (1975) are examples of such models. The critical difference in these models as opposed to the interpretive ones reviewed earlier is that they allow for the intensive aspects of behaviour to be included, along with the information processing routines, in the pool of resources which man can draw upon.

However, specification of the nature of control of these intensive resources is still unclear. Kahneman (1973) suggests that they come under only homeostatic control. Spare capacity, effort or increased activation is not invested until the standard investment has proved insufficient to meet task demands. He describes the situation as one in which activation is driven by the task rather than one in which activation drives the task. Thus, Kahneman noted that it is not possible to wake up and perform; it is only possible to perform and wake up.

This statement does not seem intuitively plausible. Certainly it must be critical to the sophisticated organism to be able to coherently deploy all resources, to be able to concentrate upon the task in advance of actually beginning to process the information presented by the task. The suggestion offered in this thesis is that a controlled and predictive use of the intensive resources, which will be called "active control," is at least part of the basis for how this concentration upon the task is achieved.

CHAPTER II

THE INTRODUCTION OF SELECTION-IN-TIME AND CONTROLLED ACTIVATION

AN EVERYDAY EXAMPLE

On the way home from work, a man has purchased a lottery ticket. At the time, he selects a four digit number--the four digits which make up his house number. He registers his choice with the agent and walks home, knowing that the day's winning number will be announced on the radio at 8:00 P. M. Moments before eight o'clock, he tunes in the radio and soon hears the announcer introduce the lottery report. The man listens intently: "Today's winning number is . . ."

How do existing theories of selective attention cope with this type of experience? The models of involuntary attention simply do not. They are only concerned with attention when it is claimed by a stimulus which is not sought. They are not concerned with attention when it is freely given. The man's experience is clearly within the scope of voluntary attention. Certainly, the dictionary units corresponding to radio sound, the subject of the lottery or the digits themselves are temporarily lowered, paving the way for information of this type to be processed or interpreted in advance of any other.

While this explanation is theoretically plausible, the man in the example would find it difficult to recognize his own activity within this interpretation. If he were asked to describe his attentive experience in detail, the man may say something to the effect, "I'm very excited and I'm hoping that my number is a winner. I'm putting all my energy into listening. I can almost feel how hard I'm trying to listen to the report. I want to be sure I hear the winning number and hear it well."

This statement suggests a large measure of active participation in the selection of inputs. It also places more emphasis upon the quality of the listening than do the interpretive theories of attention.

Hamilton and Hockey (1974) have described the problem and the experience in the example somewhat differently. They note that theories of voluntary attention have stressed man's attempts to "economize on stimulus loading by selecting particular types of input at the expense of others." Hence, a great deal of research effort has been invested in describing how man is able to isolate designated critical information from among competing streams of information. Research of this type has emphasized choice of an information processing channel or perceptual unit.

What, these studies ask, is the nature of the process which allows man to isolate critical information presented sequentially on the same sensory channel? Hamilton and Hockey suggest what they call the "intuitive idea" that in these situations economies are achieved by allotting full processing capacity to the critical information. They developed an experimental paradigm and conducted a series of experiments in order to test their hypothesis. Because the research presented in this thesis is most appropriately regarded as an attempt to replicate and extend their work and to integrate the collected findings with existing theories of selective attention, the Hamilton and Hockey paper warrants a comprehensive review at this time.

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unwanted inputs, Hamilton and Hockey posit a process which amplifies desired inputs. They cite research results collected from reaction time studies as evidence that such a process is possible. Posner and Boies (1971), for example, conducted a series of experiments demonstrating that when the stimulus requiring response is preceded by a warning signal, reaction times are faster than when no warning signal is present. They have shown that reaction time is dependent upon the length of the interval between the warning signal and the stimulus, with the optimal interval .2-.5 sec. Posner and Boies interpret these faster reaction times as the result of subjects' preparation to receive the stimulus and they regard the nature of the preparation as a change toward increased alertness. Support for this can be found in the fact that faster reaction times are associated with the occurrence of the CNV (Walter, et al. 1964)), a surface negative shift away from EEG baseline in the foreperiod of reaction time trials.

Hamilton and Hockey also note that Tecce (1972) has demonstrated subjects' ability to control both the amplitude and timing of the CNV. Teece has distinguished two types of CNV which are differentiated by the amount of time required to reach peak amplitude. Type A reaches peak rapidly and commonly occurs when subjects are uncertain about the time at which the stimulus requiring response will occur. Type B occurs when the length of the interval between the warning signal and the stimulus is more clearly defined. Peak amplitude is reached most rapidly in trials with the shortest foreperiod. Tecce further notes that when subjects are given special instructions which serve to increase their desire to decrease response latency, amplitude of the CNV increases. Tecce's interpretation that the CNV represents an increase in "vigilance" is similar to what Posner and Boies suggest.

Tecce regards the fact that instructions to subjects alter the amplitude of the CNV as evidence that subjects can exert "conative control" over the process.

Through reference to this literature, Hamilton and Hockey suggest that the process they propose--one whereby extraction of critical items from among an auditorily presented sequence is achieved via amplification of critical items--is a function of a change in alertness.

They rely on this literature as well in implying, further, the importance of some temporal predictability in execution of such a process. The importance of timing, they note, has been emphasized by several authors. Lashley (1951) stressed that several types of human activity which require integrated successive movement are only possible if man has applied some temporal organization to the sequence of events. It would not be possible to produce these events smoothly if the only existing association among them were an S-R bond between an event and the one adjacent to it. While Lashley drew his examples primarily from movement, he suggested that temporal organization is also the basis of speech. Martin (1972) has expanded this idea, arguing that rhythmic activity is centrally (as opposed to peripherally) organized and forms the basis of all forms of sequential behavior. In fact, Martin suggested that man can make use of the temporal structure of speech and its sequential redundancies to achieve efficient listening by actually alternating between storing and processing inputs.

Hamilton and Hockey integrated these two lines of thought, questioning whether such a fundamental temporal organization, in conjunction with the time preparation process, would enable subjects to cycle preparations in order to receive critical items through time. They conducted six experiments to test this notion.

Their basic experimental paradigm dealt with three variables. First, it required subjects to select designated critical items from among a series of nine stimulus items occurring at regular intervals in time. The critical items were usually identified as the second, fourth, sixth and eighth of the nine-item sequence. Second, Hamilton and Hockey tested the relative efficiency of two attentional strategies. Under an "active" extraction process, subjects were encouraged to prepare specifically to receive the critical items, to try to "grab" the items as they arrive. Under the "passive" process, on the other hand, subjects were to treat all items in the same way at the input stage and select the critical items for reporting at the retrieval stage.

Third, Hamilton and Hockey varied the rate of presentation. In an initial experiment, subjects were tested on the two strategies with stimulus items presented at .375, .5 or .75 seconds. Each trial was preceded by 6 seconds of lead-in beating from a metronome to indicate the rate at which the items that followed would be presented.

The results show that, at the fastest rate of presentation of the items, active performance is no better than passive. At the slower rates of presentation, active performance improves markedly while passive performance remains essentially unchanged. These results were interpreted as demonstrating that the improvement in performance under the active process is attributable to a selective treatment of the critical iterms at the point of intake rather than retrieval. The effect of this treatment is to give critical items a higher status in store relative to non-critical items. Furthermore, they noted that the efficiency of the active process is clearly rate dependent.

Hamilton and Hockey asked if, at least in some respects, it is possible to regard this selection-in-time as similar to some of the research conducted within the interpretive models of attention. The obvious analogy is dichotic listening, with the unwanted items being similar to the unattended ear. If the analogy is a good one, then the variables governing performance in the present task should be similar to those governing selection in dichotic listening.

Hamilton and Hockey conducted a second experiment to investigate the effect of varying the integrity of the unwanted relative to the wanted items and to identify possible interaction of the effect of stimulus material with that of rate. The work of Triesman (1960, 1969) would suggest here that performance should improve as the distinctiveness of the wanted and unwanted sets increases. Additionally, if the wanted and unwanted items correspond to two sources of stimulation (or channels), there should be a rate limitation which is independent of the effect of the integrity of the stimulus sets. This latter hypothesis derives from the work of Broadbent and Gregory (1964), in which they distinguish two separate processes, "response set," corresponding to the integrity of the items and "stimulus set," corresponding to the channels by which the items arrive.

In this second experiment, subjects were presented with four different types of stimulus lists. In each list, random digits were the critical item set. Random digits, random letters, a single repeated digit or a single repeated letter composed the unwanted set. Subjects performed only the active strategy over both a "fast" and a "slow" rate of presentation.

The results show that as the integrity of the wanted and unwanted sets increases performance improves. Performance was worst with the all-random condition and improved progressively with random letters and same digit, with peak performance obtained where the unwanted set was composed of the same letter. As in the first experiment, performance improved as the rate of presentation decreased. This improvement was seen with each type of stimulus material. There was, however, also a significant interaction overall between the type of material and the effect of rate.

The authors noted here that there is very probably a ceiling effect on performance that confounds the effect of rate with that of the integrity of the two sets of items. They suggest that increasing the range of presentation rates may provide data that dissociates one effect from the other.

To test this hypothesis, in a third experiment Hamilton and Hockey employed six rates of presentation, including rates both faster and slower than previously used, and two types of stimulus items, random digits in the critical set and a single letter or a random letter in the unwanted. Again, there was clearly an effect of rate and an effect of stimulus item set. However, the data do not provide definitive evidence of either the presence or absence of an interaction of the two. The authors did not pursue this line of inquiry further, although they did express their own assumption that the rate limitation is independent of the nature of the stimulus items. Hamilton and Hockey channeled further efforts instead into specifying the nature of the factors governing the rate limitation.

As discussed earlier, research on the interpretive models has emphasized that selection of one channel over another is achieved, in essence, by attenuating the message on the unwanted channel. A rate limitation in these models is considered to be a function of the time it takes to shift the bias of selecting from one channel to another. Hamilton and Hockey, however, favour the interpretation that active extraction is an amplification process in which the critical items receive "something extra" relative to the unwanted set. As they state, however, operationally these negative and positive interpretations are indistinguishable.

Using a concept put forward by Wickelgren and Norman (1966), Hamilton and Hockey describe the impact of the amplification process as increasing the acquisition strength of the critical set. Wickelgren (1970) describes the "acquisition" phase of memory processes as that which initiates construction of potential as opposed to usable memory traces. In a subsequent "consolidation" phase, the potential memory trace is transformed to a usable one. The implicit assumption is that the items with the greatest acquisition strength are those most likely to result in retrievable information. Thus, Hamilton and Hockey assumed that the differential in acquisition strength between wanted and unwanted sets is a function of a switch between the amplification mode and a "neutral" one.

Through a second line of inquiry, Hamilton and Hockey sought to specify the point at which the benefit of active extraction is exerted upon the information processing system. They offered three alternative hypotheses, diagrammed on the next page, and conducted a series of experiments to test them.

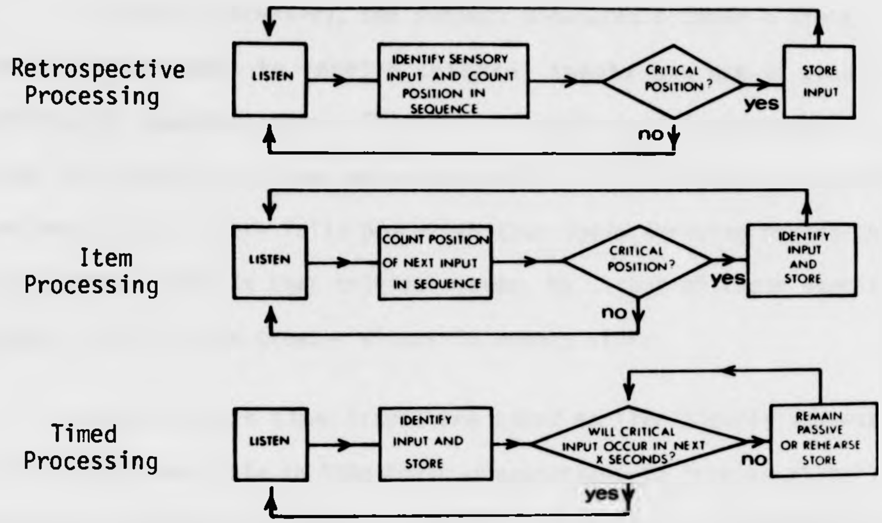

Figure 2.1: Three alternative processes for isolating critical items. From Hamilton and Hockey, 1974, p.72.

The problem, as Hamilton and Hockey state, is to "indicate how S is able to time the switching between a state of 'monitoring the environment' and a state of 'storing inputs' so as to accord preferential treatment" to the critical item set. The three types of processes diagrammed above--retrospective, item and timed processing--are the alternatives the authors suggested, although they did note that others are possible.

In retrospective processing, all items are extensively processed. Each item is named, identified for position in sequence and classified as critical or unwanted. The items are then screened with only the critical items passing to a further stage of rehearsal, which increases the strength of the memory trace. In item processing, all items are processed only to the stage which identifies their position in the sequence. In a subsequent stage, only those items which fill a critical position are fully identified and stored.

In timed processing, the subject modulates between a state of maximum preparedness to receive critical inputs and one of passive acceptance of unwanted items. The basic assumption of timed processing is that an item which arrives when the subject is in a state of maximum receptivity will be more fully processed than those arriving during the passive state. That is that critical items, by virtue of their special treatment, will attain greater status in memory store.

The reaction time literature cited earlier clearly suggests that subjects are able to time their preparations to receive stimuli; that their preparation results in "better" reception is inferred from shorter reaction times. The point of departure of the Hamilton and Hockey hypothesis of timed processing is the assumption that the subject is able to exert enough control over the preparation process to be able to produce it when "necessary" and over an extended period of time.

In order to evaluate the retrospective processing hypothesis, Hamilton and Hockey needed to vary the original experimental method. To establish the parallel validity of this second method, they conducted an experiment in which they simulated the active and passsive strategies using different instructions to the subjects. In the previous experiments, subjects' cooperation in employing the two strategies was enlisted explicitly through a lecture prior to presentation of the experimental stimuli. In this variation, the strategies were induced through control of the situation.

Subjects were presented with lists of random consonants alternating with random digits. Three rates of presentation were employed. The passive strategy was simulated by a post-instruction as to which item set is critical (to-be-reported). The active strategy, on the other hand, was induced through a pre-instruction identifying the critical set (letters or digits).

The results are similar to those obtained under the active/passive instructions. The major difference is that at the fastest rate of presentation there is comparatively good performance in the pre-instruction condition compared to that in the post-instruction condition. Hamilton and Hockey concluded that, operationally, pre/post-instruction and active/passive strategies are equivalent.

With the validity of the pre/post design established, Hamilton and Hockey proceeded to test the retrospective processing hypothesis. They started with the basic assumption that all three of the alternative hypotheses offered should be subject to a rate limitation--performance in each should suffer if the amount of time available to complete the processing cycle is small and benefit if it is large. Their rationale for this particular experiment was along the following lines: In retrospective processing, items are extensively processed--named, tagged for position, classified as critical or unwanted. If critical items are identified by item category rather than by position in sequence and if the occurrence of a critical item is independent of position, then retrospective processing is the best method of coping with the task of reporting the critical set. Therefore, any rate limitation of retrospective processing should be independent of the position in sequence of items belonging to the critical set.

Two types of stimulus lists were employed, alternating letters and digits (fixed item order) and (essentially) random arangement of items from the letter and digit set (varied in order). Lists were presented at either a fast or a slow rate. The critical item set was identified either by pre- or post-instruction, as in the previous experiment.

The results show again that performance in the post-instruction (passive) condition does not benefit from a decrease in rate of presentation. Under pre-instruction as to critical set, however, performance improves with decreasing rate but only when the item order is fixed. Apparently, when the subject is unable to predict the position-in-sequence of the critical items, he derives no benefit from a decrease in rate. Therefore, the active extraction rate limitation is not due to retrospective processing and is likely to be explained either by item or timed processing.

In a final experiment, Hamilton and Hockey evaluated these alternative hypotheses. They note that the fundamental feature of item processing is identification of critical item position in sequence; in timed processing, it is identification of critical item time of arrival. If the time of arrival of items is less predictable, under the timed processing hypothesis the subject should derive no benefit from an overall decrease in presentation rate. However, if item processing is the most appropriate explanation, performance should improve as the average rate of presentation decreases.

Subjects were again instructed in the original active/passive strategies. All items were random digits with the critical set specified as the second, fourth, sixth and eighth of the nine-item sequence. In one presentation condition, items occurred regularly at either one second/item or .33 seconds/item. In a second condition, the items were presented irregularly in time with an average seconds/per item approximating either 1 or .33 seconds.

The results are dramatic. Active performance under the regular timing condition shows a marked improvement in performance at the slow rate of presentation. Passive performance in both regular and irregular timing and active performance under irregular timing evidence no rate limitation. From these data, the most plausible of the three interpretations of active strategy efficiency is clearly timed processing. Hamilton and Hockey conclude that active strategy superiority at the slower rates of presentation is not only dependent upon subjects' knowledge of critical item position but also, and most importantly, upon their ability to predict the time of arrival of these items. Their interpretation of the active extraction process as one that improves "receptivity" and thus increases the acquisition strength of critical items becomes more plausible in the light of this evidence.

The authors do raise the possibility, however, that under the item processing hypothesis, where the position of two items arriving close together could be confused, regular timing could be expected to result in better identification of item position than does irregular timing. As one method of countering possible objections to timed processing on these grounds, the number of order errors (critical item order transpositions in report) and item errors (critical item omissions from report) in active extraction were tabulated. The proportion of error attributed to order errors found in irregular timing was essentially the same as that found in the regular timing condition at both presentation rates. Therefore, it is highly unlikely that the irregular condition poses any special difficulty for the item processing interpretation which dissipates in regular timing.

As noted earlier in this review of the Hamilton and Hockey research, the authors implied involvement of some sort of physiological process in active extraction by citing CNV literature. Indeed, the authors put forward the idea that active strategy superiority is attained by virtue of a process they call "controlled activation."

A critical difference between "controlled activation" as seen in this paradigm and the preparations to receive a stimulus seen in the reaction time studies is the requirement that subjects modulate preparations over time. Thus, the whole notion of controlled activation suggests that man has a much greater degree of control over his intensive resources and is able to use these to greater advantage than the interpretive models or the OR theories portray.

Hamilton and Hockey noted that they believe controlled activation may have broader significance for the control of attention in all sequentially structured streams of information than in only this particular case of a regular, periodic presentation. They cited Martin's concept of "attentional cycling" in dealing with points of high information in speech as an example. Indeed, this author's example of the man with the lottery ticket may be an example of a situation where a process such as controlled activation could be employed in listening to speech. The man may employ a controlled activation process to increase his listening efficiency when he knows that the moment at which the number will be presented approaches.

THE RESEARCH PRESENTED HERE

As with any new idea, the number of questions raised almost exceed those that are answered. Hamilton and Hockey enumerate several possible avenues of further research which might extend the concept of controlled activation. The research presented here addresses some of the issues--some which Hamilton and Hockey opened, as well as others. It does not present a systematic investigation on any point but, rather, takes a shotgun approach to the topic. The buckshot has fallen roughly into a pattern. The arrangement of experiments within the next three chapters reflects this pattern.

Chapter III examines more closely the relationship between active extraction and a concept like "pigeon-holing" or "dictionary units" using the type of investigation which Hamilton and Hockey initiated.

Chapter IV reports two experiments which employ variations on the original active/passive paradigm. In one, recognition memory is used to test the discriminability of critical versus non-critical items through a signal detection analysis. The other questions whether subjects are able to use the controlled activation process to economize on stimulus loading in list lengths far in excess of nine items.

Chapter V seeks to provide physiological evidence in support of the controlled activation process and the control of activation state in a more general context.

The basic focus of concern throughout this research is the control of selective attending. However, as Hamilton and Hockey suggest, there is, at least at this early stage, a possibility that processes like controlled activation have as broad a significance in describing all types of behaviour that "take control of the mind in clear and vivid form" (James, 1890, p. 403) as do the structural models. Chapter VI explores how the controlled activation process seems likely to reflect upon future models of the human information-processing system by suggesting possible basic mechanisms and operational characteristics of the control of the intensive resources.

CHAPTER III

CONTROLLED ACTIVATION AND CATEGORIZED INFORMATION

INTRODUCTION

The four experiments reported in this chapter seek to satisfy two goals. Firstly, since the active/passive paradigm is a comparatively new one, some attempt at replication of the Hamilton and Hockey (1974) research is warranted. Experiment One reproduces the basic results, with only minor variation in the nature of the experimental design.

Secondly, Hamilton and Hockey left open the question of how selection-in-time relates to concepts like "dictionary units" and "pigeon-holing," and other concepts grounded in the interpretive resources. Although they stated the assumption that in the active/passive paradigm the effect of one is independent of the other, their experimental results did not clearly support this point. Experiment Two takes their approach to the problem, again in an effort to replicate their results in this area, while Experiments Three and Four vary the approach in an attempt to specify more clearly the nature of the relationship between the two types of process.

All four of the experiments in this chapter (indeed most of the nine experiments described in this thesis) employ the active/passive paradigm. Therefore, many of the procedural details of one are common to the others. In order to minimize redundancy, those aspects of the procedure which are most likely to be standard across experiments are described below, along with the basic rationale for the approach. The details peculiar to the individual experiments are described as each is introduced.

BASIC METHODOLOGY

The rationale for the active/passive paradigm is as follows: If subjects are to take active or predictive control of a task, it is essential that they have sufficient advance information to be able to plan the sequence of activities that will lead to control. Therefore, subjects must know both the nature of the information processing activities required and the point in time at which each activity is required. Many experiments on selective attention in essence require performance of two alternative activities at the same time. (Dichotic listening, for example, asks subjects to select one category of information while simultaneously rejecting another.) In the present experiments, possible competition between activities is reduced by asking the subject to alternate between heightened receptivity and passive acceptance through time.

In the active strategy mode subjects are auditorily presented with a series of nine regularly occuring stimulus items. Specific knowledge of the required activities is provided in the task instructions. The second, fourth, sixth and eighth items in the list are designated as wanted or critical items. Subjects are asked to listen to the list with a view to remembering the critical items for report when the list has finished. In order to secure these items in memory, subjects are instructed to listen only for the critical items, ignoring the unwanted (first, third, fifth, seventh and ninth) as they are presented. An indication of the point in time at which items will arrive comes from a few seconds of lead-in beating from a metronome indicating the rate at which the items of the list will be presented.

Evidence cited earlier suggested that subjects' preparations to engage in specific activities reach an optimal level after some period of time. For example, Posner and Boies (1971) estimated this interval at .5 seconds in a reaction time task. Hamilton and Hockey have shown that active extraction is subject to a rate limitation which they conclude is due to the time-course of preparations--in this case, to receive items. Most experiments reported here involve at least two presentation rates in order to provide some data on the time-course of preparations involved.

So that comparison may be drawn between the data accumulated when subjects behave actively and when they do not, a passive strategy condition was also employed in the majority of the experiments. In the passive strategy, rather than listening for critical items at input, subjects were instructed to listen to all nine items with equal attention and then select from memory the critical items for reproduction. These two modes of operation are consistently termed "active" and "passive" strategies in the methodological descriptions.

No controlled method of ensuring subjects' active and passive operation was used. Cooperation was enlisted via a "persuasive" tape-recorded lecture on the nature of the strategies and the stimulus lists. The following is an example of this lecture:

> "During the next few minutes you are going to hear several lists of words (digits, letters). Each list is nine words long. You are to listen to each list and when it has finished write down the words that appeared second, fourth, sixth and eighth in the list.
>
> "For instance, if the list is--wall, house, horn, chair, lamp, glass, clock, book, floor--you will write down--house, chair, glass and book.

"You may write down the words in any order you wish just as long as your word placement on the answer sheet coresponds to the position the words had in the list. If you can not make a reasonable guess at a word, leave that space blank on your answer sheet.

"The words are presented at one of two (one - four) steady rates. Preceding each list you will hear three seconds lead-in beating from a metronome which will indicate the speed at which the list that follows will be presented. For instance, at the slow rate, what you will hear will sound like this:

(example)

while at the fast rate it will sound like this:

(example)

"Basically, there are two strategies which you can use to do this task. They are called the active and the passive strategies. When you are using the passive strategy, you are to listen to all nine words in the list equally hard. Do not try to practise the words or organize them into groups. Then, when the list has ended, go back through your memory and write down the words in the second, fourth, sixth and eighth positions. In other words, when you use the passive strategy, you want to remember all nine words in the list but write down only the ones in the second, fourth, sixth and eighth positions.

"When you are using the active strategy, you are to try to 'grab' the words you need as they arrive Try to concentrate as much as you can when a word you need comes along. If you do this well, you'll see that you end up with only the words in the second, fourth, sixth and eighth positions in your memory and you write these down on your answer sheet.

"You will be using both the active and passive strategies during this experiment. You may find that one strategy is easier to use than the other. Please do not let this influence your concentration on using the strategy you are assigned. It is more important to me that you use the strategy that I ask than it is important to you that you make few mistakes."

Certain other elements of the experimental designs remained basically standard across the experiments. Stimulus lists were recorded on tape, either reel-to-reel or cassette, and delivered to subjects via headsets, vortexion amplifier, or through the amplifier of the tape recorder on which the lists were recorded (Ferrograph or Sony reel-to-reel or ITT cassette).

Subjects' responses were recorded on prepared answer sheets. Before the trial blocks began, subjects were thoroughly instructed in the layout of the response sheets. Testing did not begin until each subject expressed clear understanding of where on the sheet to place each response.

The stimulus items in the first four experiemnts were pronounced by a male voice and in the remaining experiments by a female voice. In all cases extreme care was taken to pronounce the items clearly and without undue variation in inflection from one item to another.

EXPERIMENT ONE

The first experiment is aimed purely at replication. The only significant modification in design is the use of words as the stimulus items rather than the letters and digits Hamilton and Hockey routinely employed. There is no reason, however, for expecting this change to affect the overall pattern of results.

Methodology

Stimulus Items: 120 monosyllabic words of four or more letters were selected from the Thorndike and Lorge (1944) list of AA words (frequency of occurrence in the English language of at least 1/1,000). These words were arranged into 92 lists of nine words each.

The words were drawn without replacement until the pool was exhausted. No word appeared more than once in a list.

46 lists were recorded on tape at the rate of 1.33 seconds per item, while the remaining 46 lists were recorded at .5 seconds per item. Each list was immediately preceded by four seconds of lead-in beating from a metronome indicating the rate at which the list items that follow will occur.

Subjects: 10 (5 male and 5 female) third and fourth year undergraduate and postgraduate students.

Design and Procedure: Subjects were divided into two groups of five subjects each. Each group performed both the active and the passive strategies during the experimental session.

The session consisted of four blocks of trials with 10 trials in each block. Different lists were used for each group in order to balance any random effects of word sequence occurring in the lists. Group one performed the active strategy in the first and fourth block and the passive strategy in the second and third, while for Group two the converse was true. For Group one, the first five lists of the first and third blocks were presented at the slower rate of presentation and the second five lists at the faster rate. In the second and fourth blocks, the rates of presentation were reversed. Similarly, Group two heard the first five lists of the first and third blocks at the faster rate of presentation and the second five lists at the slower rate, with this order reversed in blocks two and four.

Following the lecture detailing use of the strategies, eight practice trials, two of each strategy-rate combination, were presented. At the beginning of each block, subjects were re-instructed in the strategy they were to use for that block. When a switch in strategy from one block to the next occurred, subjects were given one practice trial with the new strategy.

A minimum of 20 seconds recall time separated each list in the blocks of trials. Between blocks two and three, subjects were given a two-minute rest break. Stimulus lists and instructions were recorded on reel-to-reel tape and delivered to subjects via headsets.

Results and Discussion

The results of Experiment One closely parallel those of Hamilton and Hockey. Performance, as measured by the efficiency of recall of the critical items, remained about the same across both rates in the passive strategy. In the active strategy, performance improved at the slow relative to the fast rate of presentation.

Responses were scored on both a strict ordered and an absolute basis. Under ordered scoring, a response was considered correct only if it appeared in the space on the answer sheet corresponding to the position that item held in the list. Under absolute scoring, a response was considered correct if it was reported as a member of the critical set, irrespective of order.

Mean percent of error for both active and passive strategies, under absolute and ordered scoring, is plotted against rate of presentation on the abscissa in Figure 3.1. Inasmuch as ordered scoring did not change the results beyond an overall increase in error, only the ordered data was subjected to an analysis of variance. A summary of this analysis is presented in Table 3.1. The interaction of strategy and rate of presentation is significant at $P<.01$ ($F = 5.67$; d.f. = 1.30).

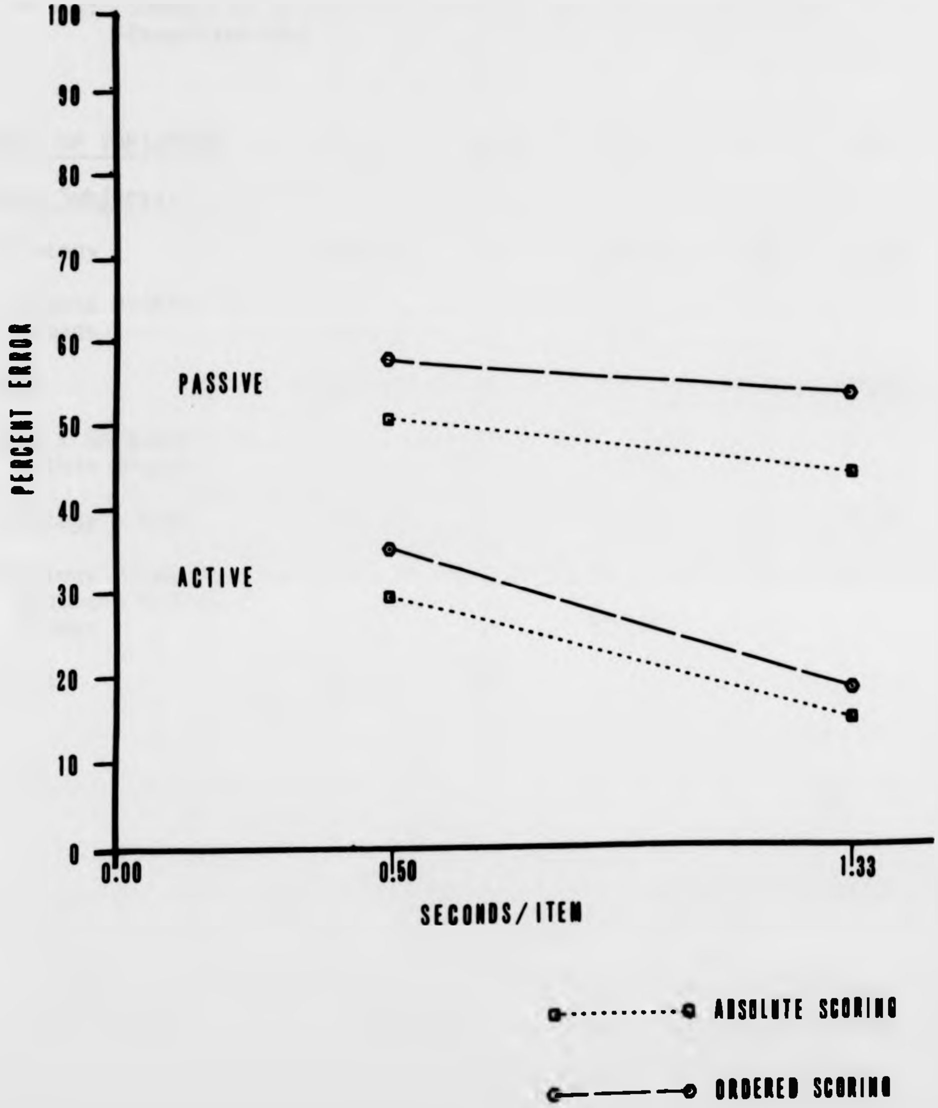

FIG. 3.1: EXPERIMENT ONE, MEAN PERCENT ERROR IN THE ACTIVE AND PASSIVE STRATEGIES AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 10).

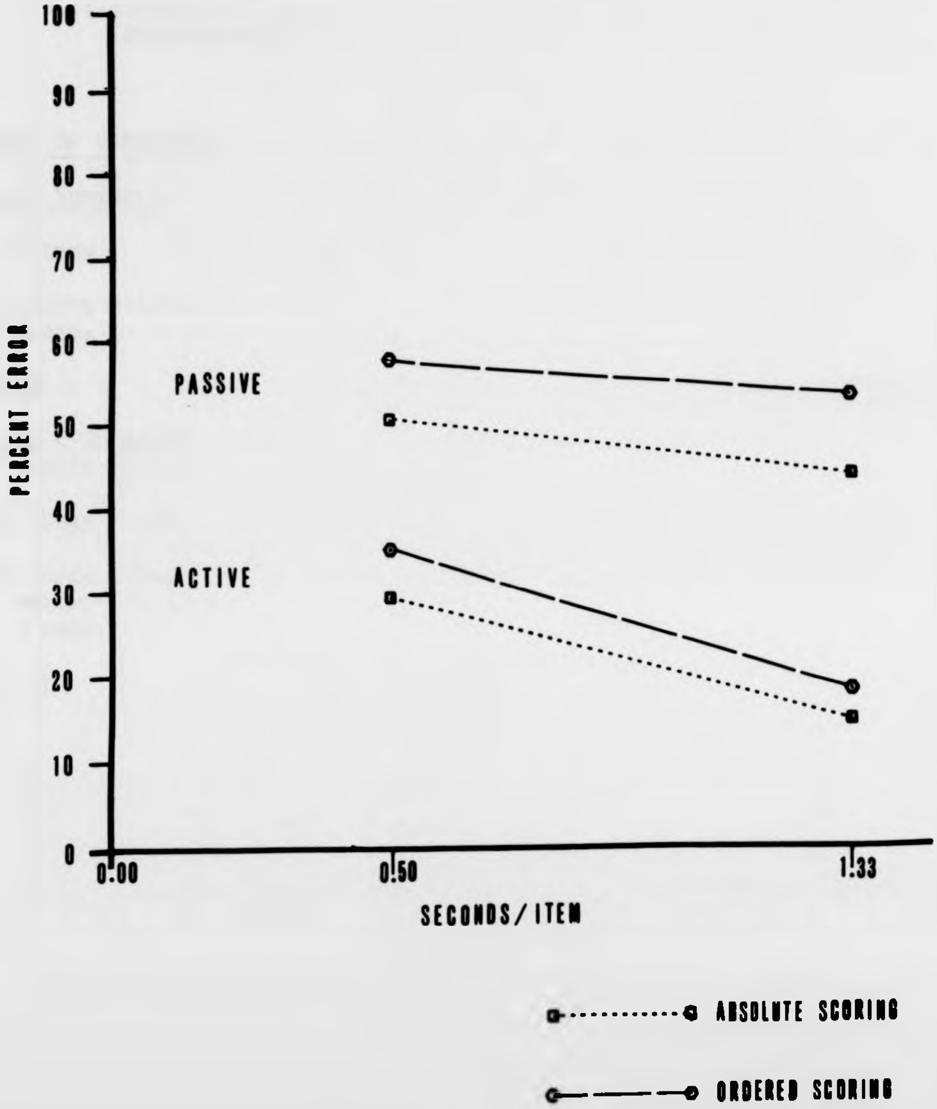

FIG. 3.1: EXPERIMENT ONE, MEAN PERCENT ERROR IN THE ACTIVE AND PASSIVE STRATEGIES AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 10).

Table 3.1: Summary of analysis of variance of ordered data from Experiment One

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Within Subjects:					
Strategy	1380.63	1	1380.63	51.94	<.01
Subjects Within Groups	239.13	9	26.57		
Rate	180.63	1	180.65	47.64	<.01
Rate x Subjects Within Groups	34.13	9	3.79		
Strategy x Rate	70.23	1	70.23	5.67	<.01
Strategy x Rate x Subjects Within Groups	111.53	9	12.39		
Total	2016.18	30			

The results of Hamilton and Hockey (Experiment One) indicate that active performance deteriorates to that of passive at faster rates of presentation. In their data, the slope of the active function intercepts that of the passive at .375 seconds per item. In the present experiment, no attempt was made to increase the presentation rate further because of the difficulty involved in pronouncing words clearly at rates much faster than .5 seconds per item. However, it is assumed that, if distinct pronunciation could be achieved at faster rates, performance in the active strategy would, at some point, deteriorate to the level of performance in the passive strategy. Thus, the present experiment is taken as confirming the basic results achieved under the active/passive paradigm.

Hamilton and Hockey raised the possibility of viewing selection-in-time as a special case of the dichotic listening situation. If this analogy is a good one, they predicted that two types of effect should be observed. Firstly, as the integrity of the unwanted and wanted sets increases, performance should improve. Secondly, the rate limitation on active strategy efficiency should be independent of any effect exerted by the nature of the stimulus sets.

Using the active extraction process, Hamilton and Hockey demonstrated the first of these expectations but not the second. (They did, however, suggest that, if an appropriate data transformation could be found, this apparent interaction may be removed.) Hamilton and Hockey did not investigate this particular point further but went on to provide additional data supporting the hypothesis of selection-in-time and the broader concept of controlled activation. The remaining three experiments in this chapter resume the line of inquiry they started.

The goal of these experiments is to provide more definitive evidence on the nature of the relationship between the active use of the intensive and interpretive resources.

EXPERIMENT TWO

Like Experiment One, Experiment Two is primarily a replication of a combination of Hamilton and Hockey experiments. It provides for the joint manipulation of rate of presentation and type of stimulus material. One major change in design is the inclusion of both active and passive strategies.

Methodology

Stimulus Item Sets: 80 lists of nine items each were prepared, 20 lists of each of the following four types: 1) Material RC--random consonants selected from all 21 consonants of the alphabet in each of the nine list positions; 2) Material RD--random digits in non-critical positions (1, 3, 5, 7, 9) and random consonants in critical positions (2, 4, 6, 8); 3) Material FC--fixed consonant in non-critical positions and random consonants in critical positions (e.g., G, W, G, X, G, B, G, H, G); 4) Material ASC--acoustical similar consonants (e.g., B, C, D, G, P, T, V) in non-critical positions and random consonants (selected from those not in the acoustically similar group) in critical positions. All classes of item were sampled without replacement until the pool was exhausted. No item from any class appeared more than once in a list.

Subjects: 32 (16 male, 16 female) undergraduates, psychology postgraduates and psychology staff.

Design and Procedure: Four lists of each type of material were recorded at each of four rates of presentation, .33, .67, 1 and 2 seconds per item. Lists were separated by 10 seconds of recall time. 16 lists, one of each material-rate combination, were randomly arranged and recorded. These lists served as practice trials. The remaining 64 lists (four of each material-rate combination) were recorded in random order to serve as the experimental trials.

Subjects were divided into two groups. Although both groups received a lecture similar to that described in the general methodology preceding Experiment One, one group adopted the active strategy throughout while the other performed only the passive strategy. Subjects were tested individually or in groups of up to four. Following presentation of the 16 practice lists, subjects were permitted to ask questions relating to the procedure. No advance information concerning material variations was given.

Test trials were presented in two blocks of 32 trials each with a three minute rest break separating the blocks. Lists were played via cassette recorder and vortexion amplifier.

Results and Discussion

Responses were scored on a strict ordered and an absolute basis. Mean percent error is plotted against rate of presentation under both absolute and ordered scoring for the active strategy in Fig. 3.2 and the passive in Fig. 3.3.

As in previous experiments, active strategy efficiency improves as the rate of presentation decreases. Unlike previous

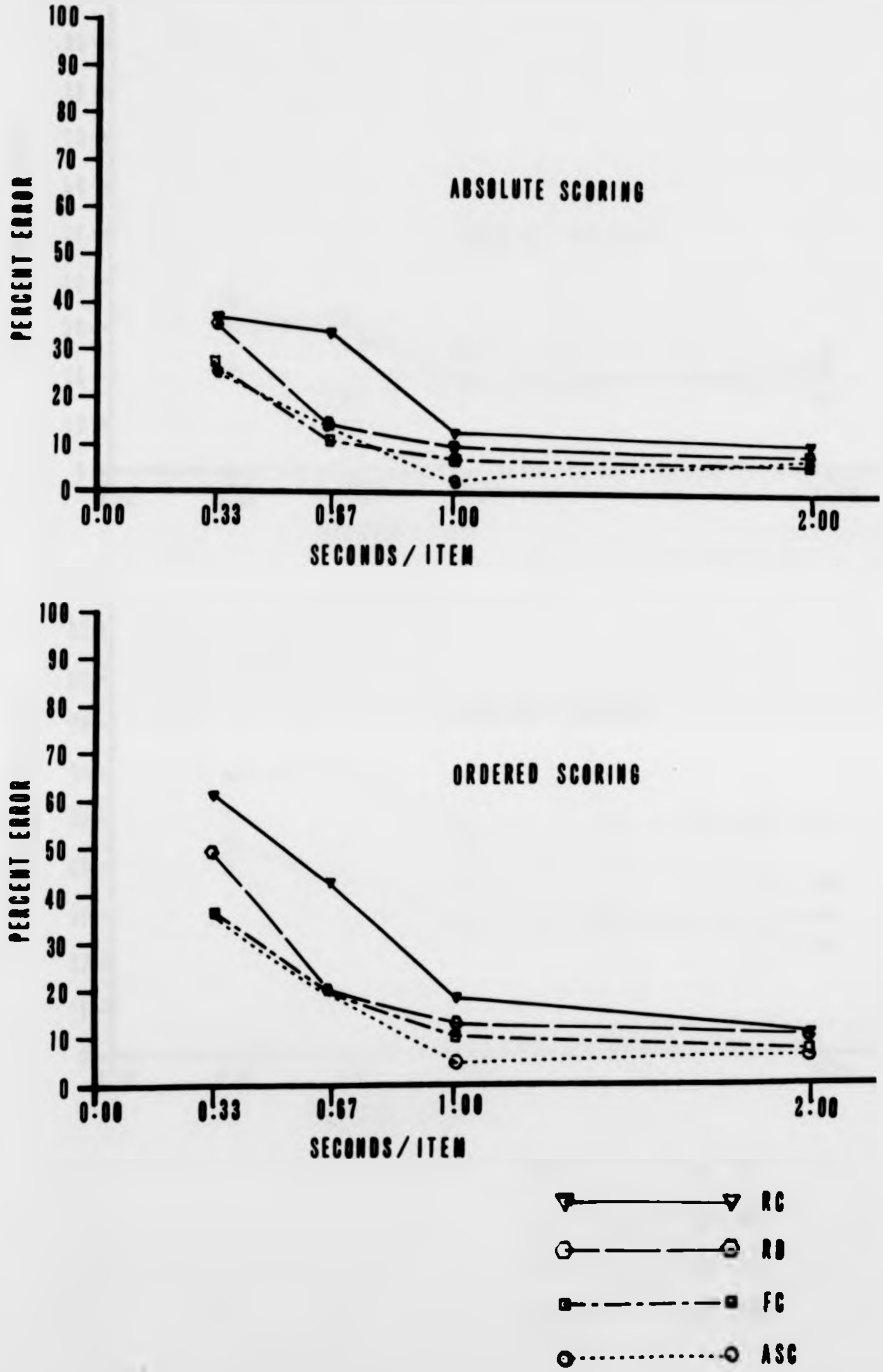

FIG. 3.2: EXPERIMENT TWO, MEAN PERCENT ERROR IN THE ACTIVE STRATEGY, FOR EACH TYPE OF MATERIAL AT FOUR RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 16).

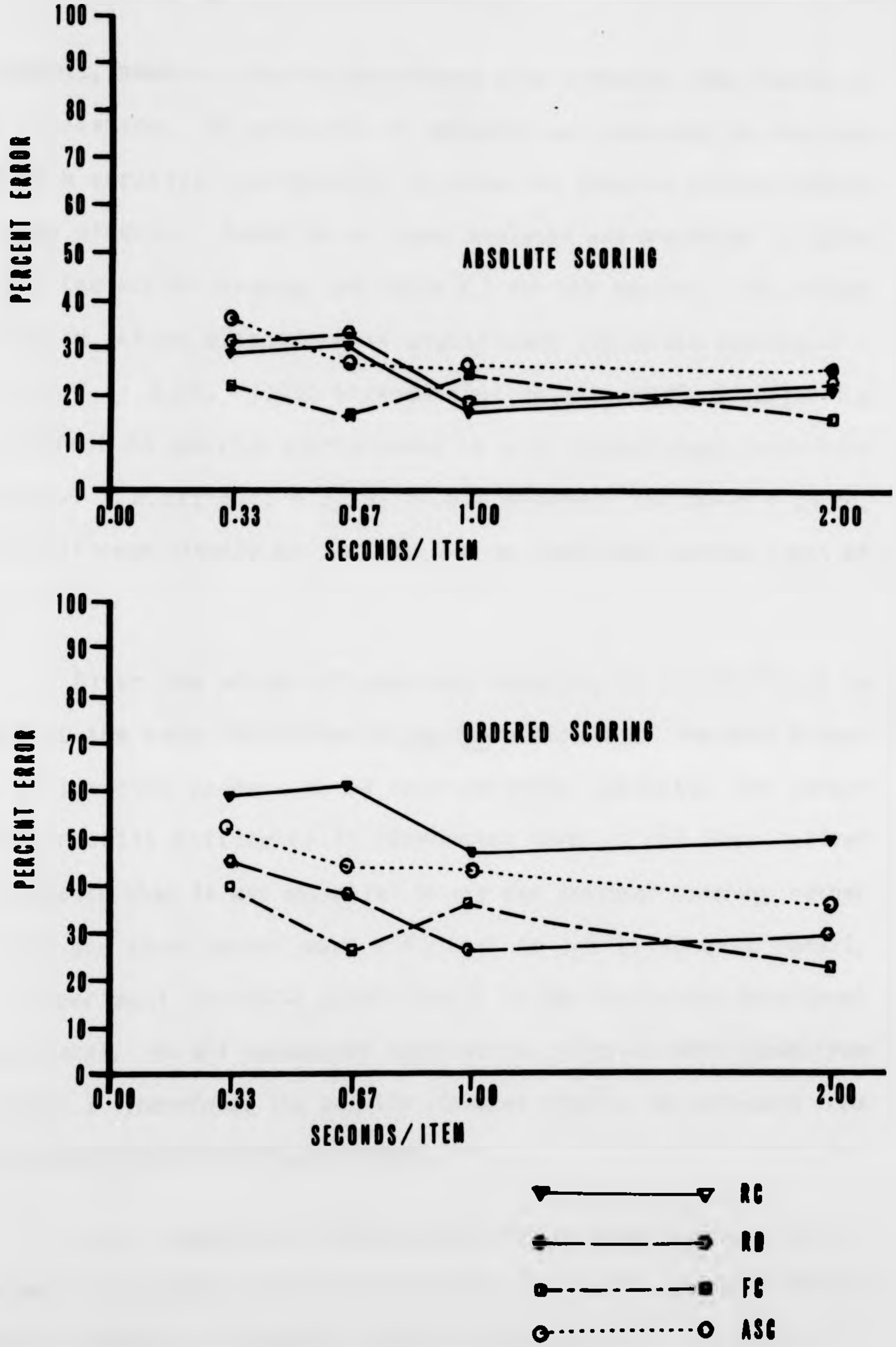

FIG. 3.3: EXPERIMENT TWO, MEAN PERCENT ERROR IN THE PASSIVE STRATEGY, FOR EACH TYPE OF MATERIAL AT FOUR RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 16).

experiments, however, passive performance also evidences some degree of rate limitation. An analysis of variance was conducted on the data from each strategy individually in order to examine further within strategy effects. Summaries of these analyses are presented in Table 3.2 for the active strategy and Table 3.3 for the passive. The effect of rate in active extraction is significant (absolute scoring--$F = 65.26$, d.f. = 3,15, $P<.01$; ordered scoring--$F = 94.28$, $P<.01$). The rate effect in passive performance is also significant (absolute scoring--$F = 6.81$, d.f. = 3,15, $P<.01$; ordered scoring--$F = 15.28$, $P<.01$) although clearly not as large nor as consistent across types of material.

Given the weight of previous results, it is difficult to interpret the rate limitation in passive efficiency. The most plausible explanation appears to be uncooperative subjects; the author clearly recalls difficulty in persuading some of the less "naive" participants that it was essential to use the assigned strategy rather than the one that seemed most efficient in achieving best recall. (This experiment pre-dates establishment of the Psychology Department Subject Panel. In all subsequent experiments, subjects were taken from that panel.) Therefore, the passive strategy results are excluded from further discussion of this experiment.

Other aspects of the active strategy results also parallel those which Hamilton and Hockey obtained. There is a significant effect of the type of material in both the absolute ($F = 20.57$; d.f. = 3,15; $P<.01$) and the ordered data ($F = 35.64$; $P<.01$).

Table 3.2: Summary of analysis of variance on Experiment Two active strategy data under both absolute and ordered scoring

ABSOLUTE SCORING

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Within Subjects					
Material	131.78	3	43.93	20.57	<.01
Material x Subjects Within Groups	96.09	15	2.14		
Rate	632.09	3	210.07	65.26	<.01
Rate x Subjects Within Groups	145.28	15	3.23		
Material x Rate	85.69	9	9.52	3.66	<.01
Material x Rate x Subjects Within Groups	350.94	125	2.60		
Total	1441.87	170			

ORDERED SCORING

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Within Subjects					
Material	263.89	3	87.96	35.64	<.01
Material x Subjects Within Groups	111.05	15			
Rate	1353.42	3	451.14	92.48	<.01
Rate x Subjects Within Groups	219.52	15			
Material x Rate	99.44	9	11.05	2.79	<.01
Material x Rate X Subjects Within Groups	535.37	125	4.00		
Total	2582.69	170			

Table 3.3: Summary of analysis of variance on Experiment Two passive strategy data under both absolute and ordered scoring

ABSOLUTE SCORING

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Within Subjects					
Material	73.39	3	24.46	4.84	<.05
Material x Subjects Within Groups	91.22	15	5.05		
Rate	85.67	3	28.56	6.81	<.01
Rate x Subjects Within Groups	188.77	15	4.19		
Material x Rate	91.22	9	10.14	4.81	<.01
Material x Rate x Subjects Within Groups	284.59	125	2.11		
Total	814.86	170			

ORDERED SCORING

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Within Subjects					
Material	507.29	3	169.10	27.85	<.01
Material x Subjects Within Groups	273.27	15	6.07		
Rate	214.98	3	71.66	15.28	<.01
Rate x Subjects Within Groups	211.08	15	4.69		
Material x Rate	97.50	9	10.83	2.62	<.01
Material x Rate X Subjects Within Groups	558.68	125	4.14		
Total	862.80	170			

The error-rate for each material also follows a logical pattern. Performance is worst when items are randomly drawn from the consonant set but improves as the distinctiveness of the wanted and unwanted sets increases. Performance is slightly better when the non-critical set is composed of a fixed consonant (FC) or of random digits (RD) than when the non-critical set is composed of acoustically similar consonants (ASC).

Hamilton and Hockey tried to demonstrate that the rate effect in active extraction is independent of the effect of material by testing increased presentation rates. Manipulation of this variable in the present experiment was no more successful than in the previous work. The material x rate interaction is again significant (absolute scoring-- $F = 3.66$, d.f. = 3,125, $P<.01$; ordered scoring--$F = 2.79$, $P<.01$). However, as in the earlier data, a ceiling effect on performance is clearly evident at the slower presentation rates.

Thus, the results of Experiment Two and the Hamilton and Hockey data have left the same question partially unanswered: What is the nature of the relationship between selection-in-time and the effect of material? Hamilton and Hockey suggested that increasing the difficulty of the task might help separate the rate limitation from the effect of the categorization of wanted and unwanted material. They increased difficulty by increasing rate of presentation, but this step did not help resolve the interaction either in their data or here.

When the results for each type of material in Experiment Two are collapsed across rates of presentation in Fig. 3.4, it appears that acoustically grouping non-critical items (ASC) is not as effective an informational cue to employ as fixed or random consonants. Thus,

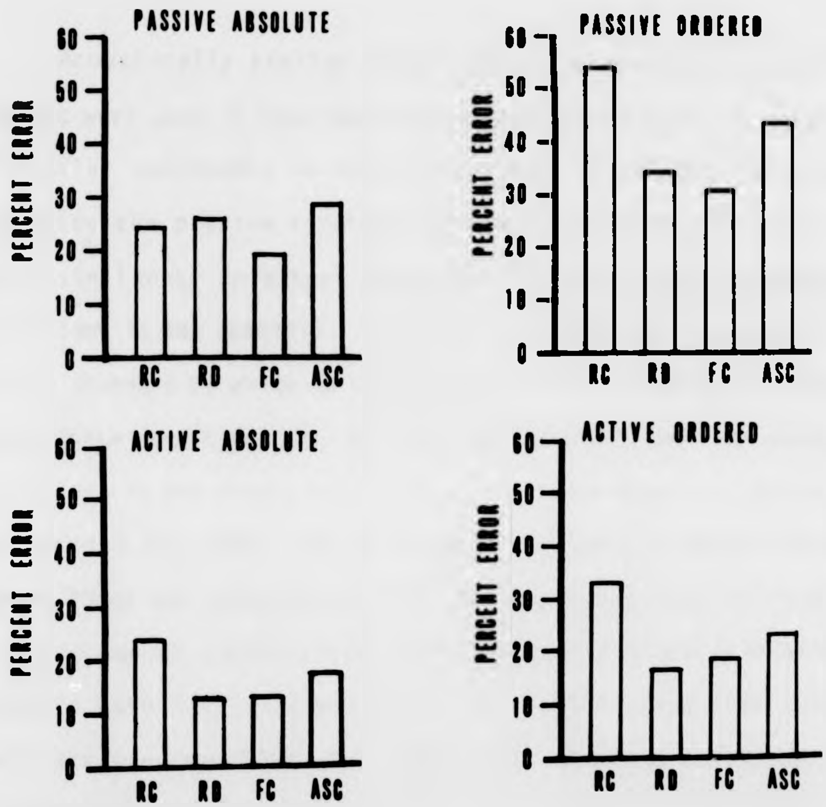

FIG. 3.4: EXPERIMENT TWO, MEAN PERCENT ERROR IN THE ACTIVE AND PASSIVE STRATEGIES FOR EACH TYPE OF MATERIAL AVERAGED ACROSS RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING.

Experiment Three seeks to manipulate task complexity in a different way by using acoustically similar words as the stimulus items.

EXPERIMENT THREE

Acoustically similar words rather than acoustically similar consonants were used in Experiment Three because the range of acoustically similar consonants is very restricted. Experiment Three also incorporates the passive strategy in order to observe the effect of acoustic similarity in a task where the gating or amplification of critical items is not possible. Two control conditions are included to provide a standard by which to compare the effect of categorized sets. In one of these conditions, all nine of the stimulus items are acoustically similar; in the other, only items with little acoustic similarity (random words) are used. The only other difference in design between Experiment Three and others which have involved categorized information is that a group of subjects heard only one type of stimulus material. This should have little effect upon the results aside from giving subjects who are presented with separately categorized critical and non-critical items the opportunity to derive maximum benefit from the informational differences.

Methodology

Stimulus Items: 360 words were selected from the Thorndike and Lorge (1944) A (frequency of occurrence 50-99/ 1,000,000) and AA lists. 180 words (acoustic pool) were chosen because they could be divided into 20 lists of nine acoustically similar words (e. g., hair, chair, care, etc.). The other 180 words (random pool) were carefully chosen because of their relative lack of acoustic similarity to one another and to the words in the acoustic pool. The random and acoustic pools each consisted of 120 monosyllabic AA words, one disyllabic AA word, 58 monosyllabic A words and one disyllabic A word.

From the two word pools 20 lists each, of four types of stimulus material, were prepared.

1) Material R--random words in all nine positions. Lists were prepared by sampling without replacement from the random pool.

2) Material AAS--all nine words in each list are acoustically similar. (These lists appear in Appendix I.)

3) Material NC--random words in critical positions; acoustically similar words in non-critical positions. These lists were formed by integrating materials R and AAS. Thus, list one consisted of the items in the second, fourth sixth and eighth positions from list one of material R and the items in the first, third, fifth, seventh and ninth positions of list one in material AAS and so forth for the 20 lists.

4) Material C--acoustically similar words in critical positions and random words in non-critical positions. These lists were also composed by integrating the lists of material R with the lists of material AAS. For list one, the words in the second, fourth, sixth and eighth positions were from list one in material AAS and the words in the first, third, fifth seventh and ninth positions were from list one in material R.

Subjects: 32 (16 male, 16 female) first and second year psychology undergraduates.

Design and Procedure: Eight experimental tapes were prepared, two for each type of material. Each tape consisted of four blocks of five trials each. On Tape One, for each material, blocks one and four were recorded at 1.33 seconds/item and blocks two and three at .5 seconds/item. Tape two for each material was created by transferring the material from tape one so that lists in blocks one and four were presented at .5 seconds/item and in blocks two and three at 1.33 seconds/item. (In other words, blocks one and four of tape one were blocks two and three of tape two and vice versa.)

Each tape also contained eight practice trials. Due to the difficulty in constructing eight additional lists in which all nine items are acoustically similar, no constraints on word frequency were observed in selecting the items. The eight practice trials were also divided into four blocks (two trials/block) and recorded with the same rate and block order as the experimental lists.

Four seconds of lead-in beating from a metronome preceded each list, with 20 seconds recall time separating each list. The lists were played over a Ferrograph tape recorder and subjects heard them via headsets.

Subjects were divided into four groups of eight subjects each. Subjects performed both the active and the passive strategies during the experimental session but heard only one type of stimulus material. Four subjects in each group heard tape one and four heard tape two. Subjects were assigned to strategies by blocks. Two subjects from each group used one of the following orders:

	Block 1	Block 2	Block 3	Block 4
Order 1	Active	Active	Passive	Passive
Order 2	Active	Passive	Active	Passive
Order 3	Passive	Active	Passive	Active
Order 4	Passive	Passive	Active	Active

The rate and strategy combinations that subjects were to expect for each block were clearly indicated on the answer sheets. The order in which subjects performed the strategies in the practice trials was the same as that used in the experimental trials.

Subjects were given a two-minute rest break between each block of trials. They were tested individually or in groups of up to four.

Results and Discussion

Again, responses were scored on both a strict ordered and an absolute basis. Fig. 3.5 shows the mean percent error under both ordered and absolute scoring plotted against the rate of presentation of the items for the active strategy. Fig. 3.6 displays the data obtained under the passive mode. An analysis of variance was conducted on both the absolute and ordered scoring data. The results of these analyses are shown in Table 3.4 under absolute scoring and in Table 3.5 under ordered scoring.

As expected, active performance relative to passive improves as the rate of presentation decreases (strategy x rate interaction: absolute scoring--$F = 10.61$, d.f. = 1,28, $P<.01$; ordered scoring--$F = 16.18$, $P<.01$). Additionally, active and passive performance displays the same general pattern of results with respect to the four types of material.

The focus of this investigation has been to provide data which supports the Hamilton and Hockey hypothesis that the benefit subjects derive from active extraction is independent of benefit derived from categorization of wanted and unwanted items. The results of the analyses of variance do support this hypothesis. There is a significant effect of material under both absolute ($F = 6.21$, d.f. = 3,28, $P<.01$), and ordered scoring ($F = 3.21$, $P<.05$) and the effect of material is independent of the effects of both strategy and rate.

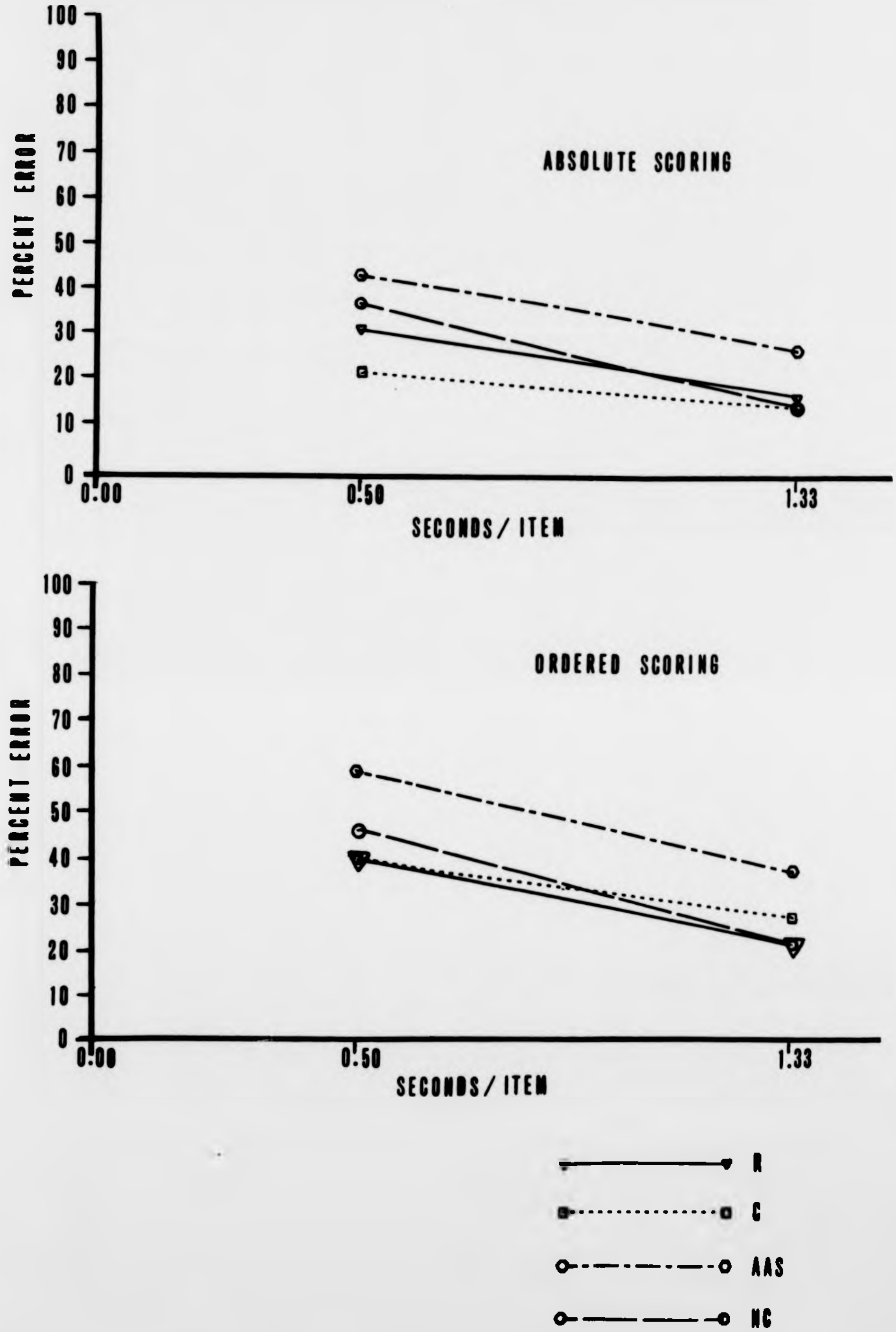

FIG. 3.5: EXPERIMENT THREE, MEAN PERCENT ERROR IN THE ACTIVE STRATEGY FOR EACH TYPE OF MATERIAL AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 8/MATERIAL).

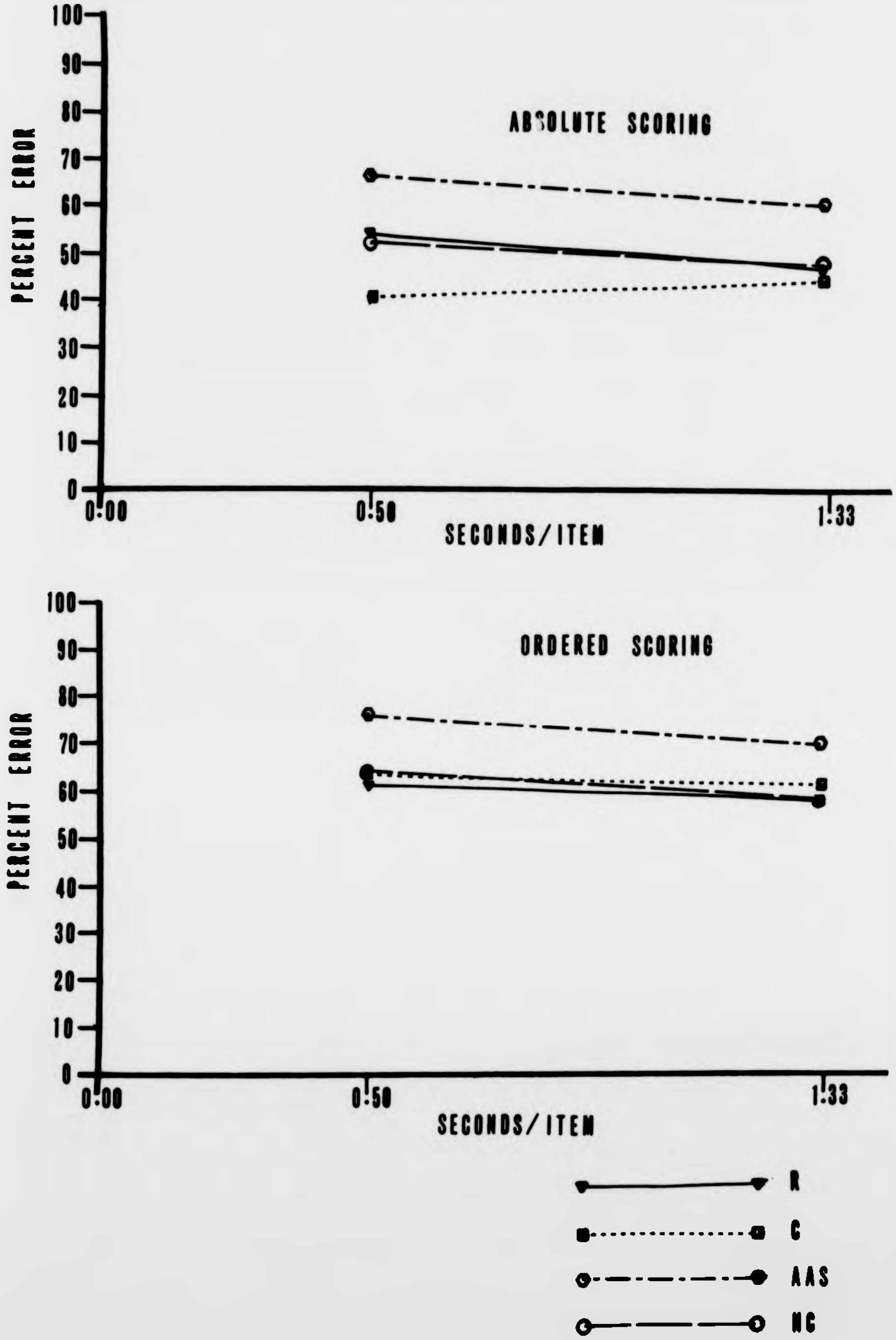

FIG. 3.6: EXPERIMENT THREE, MEAN PERCENT ERROR IN THE PASSIVE STRATEGY FOR EACH TYPE OF MATERIAL AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 8/MATERIAL).

Table 3.4: Summary of analysis of variance of data from Experiment Three under absolute scoring

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects:					
Material	240.46	3	80.15	6.21	<.01
Subjects Within Groups	361.59	28	12.91		
Within Subjects:					
Strategy	825.20	1	825.20	248.53	<.01
Material x Strategy	3.59	3	1.20	.36	N.S.
Strategy x Subjects Within Groups	92.97	28	3.32		
Rate	103.32	1	103.32	28.55	<.01
Material x Rate	23.09	3	7.70	2.13	N.S.
Rate x Subjects Within Groups	101.34	28	3.62		
Strategy x Rate	46.32	1	46.32	10.61	<.01
Material x Strategy x Rate	5.21	3	1.74	.40	N.S.
Material x Subjects Within Groups	122.22	28	4.36		
Total	1925.30	127			

Table 3.5: Summary of analysis of variance of data from Experiment Three under ordered scoring

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects:					
Material	198.94	3	66.31	3.21	<.05
Subjects Within Groups	577.56	28	20.63		
Within Subjects:					
Strategy	979.03	1	979.03	203.72	<.01
Material x Strategy	3.91	3	1.30	.27	N.S.
Strategy x Subjects Within Groups	134.56	28	4.81		
Rate	185.28	1	185.28	42.72	<.01
Material x Rate	14.78	3	4.93	1.14	N.S.
Rate x Subjects Within Groups	121.44	28	4.34		
Strategy x Rate	78.13	1	78.13	16.18	<.01
Material x Strategy x Rate	3.19	3	1.06	.22	N.S.
Material x Subjects Within Groups	135.19	28	4.83		
Total	2432.00	127			

However, observation of the pattern of results in Figs. 3.5 and 3.6 suggests that acoustic similarity may not be a totally appropriate type of material with which to test the hypothesis. The graphs of the data tend to suggest that the significant material effect is occasioned more by the difficulty of material AAS than by any benefit of acoustically grouping wanted or unwanted sets. This observation is especially pertinent to the data obtained under ordered scoring.

Hamilton and Hockey presented data which indicated that absolute scoring serves to decrease error overall. The results in Experiments One and Two were similar. However, in the present experiment when acoustic similarity groups the to-be-reported set (C) and when acoustic similarity groups all items (AAS), absolute scoring decreases error by a larger proportion than when the to-be-reported items are acoustically unrelated (R). This finding is likely to be explained by reference to the literature on acoustic similarity in tasks which are primarily concerned with the organization of items in memory and the efficiency of retrieval. For example, several studies (e. g., Wickelgren, 1965, 1966; Baddeley, 1966; Dale and Gregory, 1966; Bruce and Crowley, 1970; Posner and Konick, 1966) have shown that acoustic similarity among either a set of to-be-remembered items or among a to-be-remembered set and an interpolated task produces greater forgetting than when no acoustic similarity is present. Additionally, Conrad (1965) has argued that the low recall of acoustically similar information seen in most studies is because they have relied upon ordered recall. He presents evidence to show that acoustic similarity among items produces poor order recall but unimpaired item recall. Wickelgren (1965) has supported this finding and even suggested that item recall of acoustically similar lists is better than that of unrelated lists. While the present data do not necessarily support Wickelgren's assumption, the difficulties in retrieving order information about acoustically similar items are likely to account for the disproportionate improvement in performance across types of material when the scoring criterion is changed. Apparently, knowledge of the acoustic feature allows subjects to generate appropriate words but does not help them separate possible responses into the correct order.

Although there is no significant material x rate interaction, examination of the performance of subjects who heard material C indicates that acoustic grouping of critical items is less affected by presentation rate than the other types of material. This would tend to indicate that the acoustic feature by which to group to-be-reported items changes the signal to noise ratio of items in memory independently of the change caused by the selective treatment of items at input.

Additionally, it appears that any benefit subjects derive from active extraction efficiency is diminished because the acoustic retrieval cue is more "powerful." Thus, the only real problem which acoustic grouping retains is that of reporting items in the correct order. From the data for both materials C and AAS, it appears that active extraction provides little, if any, help with the confounding problem of order retrieval in acoustic similarity.

Acoustic similarity was selected for Experiment Three primarily because it seemed to provide a method of categorizing words and presumably could be used by subjects to distinguish wanted from unwanted sets and, hence, provide a means of testing the relationship between the effects of categorized information and active extraction. This assumption, however, was incorrect and another method of word categorization was sought. An obvious selection would be to form wanted and/or unwanted items into short sentences. However, since this would be highly likely to run into ceiling effects, this approach was rejected. Instead, semantic similarity was chosen and investigated in Experiment Four.

EXPERIMENT FOUR

Methodology

With the exception of the stimulus item, the methodology of Experiment Four paralleled the investigation of acoustic similarity in Experiment Three.

Stimulus Materials: 360 words were selected from the Thorndike and Lorge A and AA lists. 180 words (semantic pool) were selected because they could be divided into 20 lists of nine semantically related words. (These lists appear in Appendix II.) The 20 categories of words were as follows:

1. relatives
2. parts of the body
3. parts of the head
4. articles of clothing
5. colours
6. months
7. professions
8. animals
9. geographical relationships
10. qualities (e. g., good, bad)
11. countries
12. people descriptive nouns
13. sizes
14. food
15. land features
16. buildings
17. body positions and actions
18. men's names
19. raw materials
20. nationalities

Some sacrifice in apparent degree of similarity was tolerated in order to select the 20 semantically similar lists from the A and AA word lists. For instance, in the most extreme case, "individual," "creature" and "person" are all included in the category "people descriptive nouns" along with "man, woman, child, boy."

The other 180 words (random pool) were carefully selected for their relative lack of semantic similarity to one another and to any words in the semantic pool. An attempt was made to keep the number of words selected from A and AA lists and the number of syllables in the words selected from these lists as similar as possible between pools.

Thus, the four types of material are:

1) Random (R)
2) All Semantically Similar (ASS)
3) Semantically Similar in Non-Critical Positions (NC)
4) Semantically Similar in Critical Positions (C)

Results and Discussion

The analysis procedures that were used in Experiment Three were applied to the data collected. Mean percent error for each type of material is plotted against rate of presentation under both absolute and ordered scoring for the active strategy in Figure 3.7 and for the passive strategy in Figure 3.8. Summaries of the analyses of variance are presented in Table 3.6 for absolute scoring and 3.7 for ordered scoring.

Overall, using the absolute scoring criterion, the results of Experiment Four strongly support the hypothesis that the rate limitation in the active strategy is independent of the effect of the integrity of the wanted and unwanted sets. Firstly, there is clear

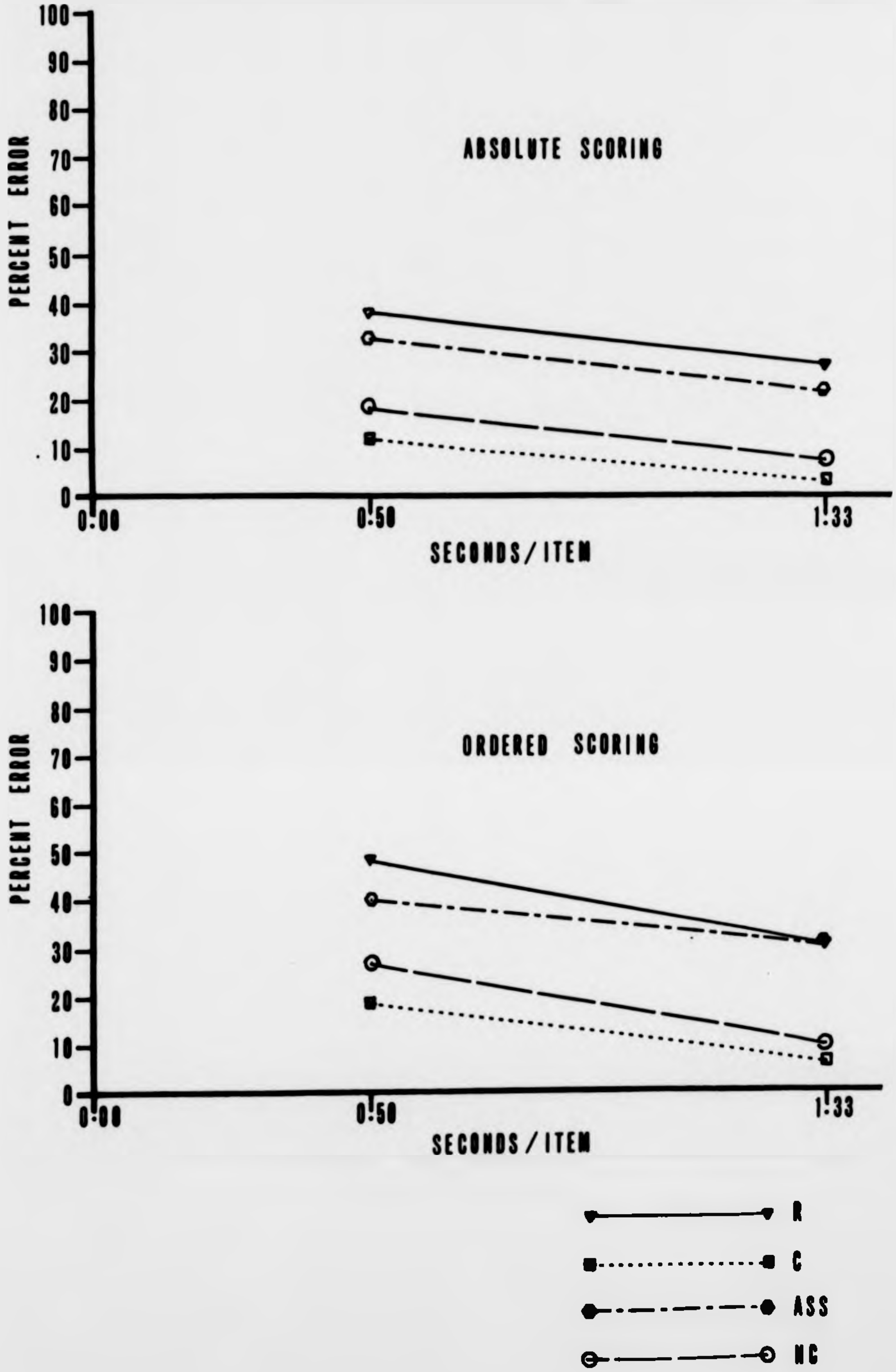

FIG. 3.7: EXPERIMENT FOUR, MEAN PERCENT ERROR IN THE ACTIVE STRATEGY FOR EACH TYPE OF MATERIAL AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 8/MATERIAL).

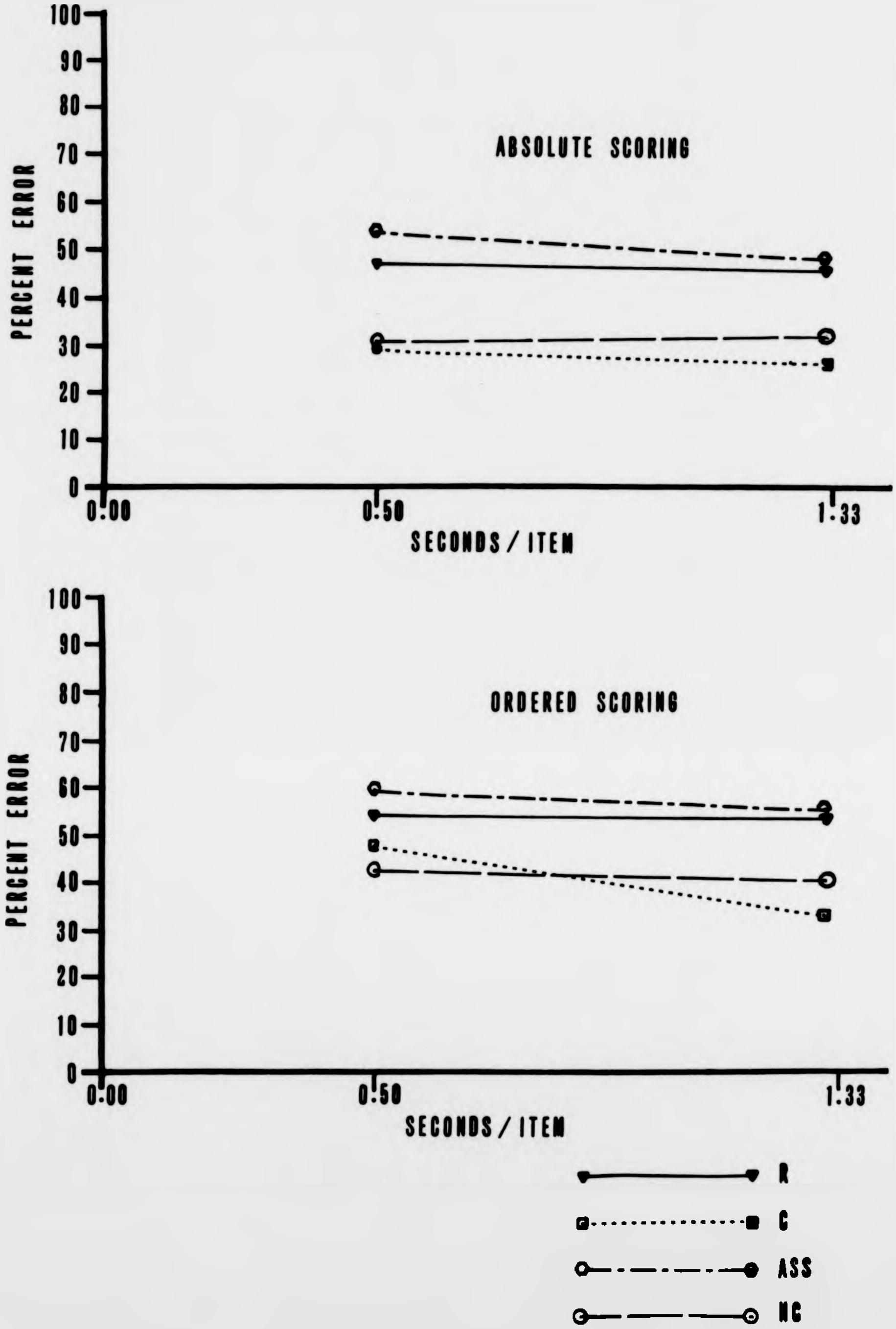

FIG. 3.8: EXPERIMENT FOUR, MEAN PERCENT ERROR IN THE PASSIVE STRATEGY FOR EACH TYPE OF MATERIAL AT TWO RATES OF PRESENTATION UNDER ABSOLUTE AND ORDERED SCORING (N = 8/MATERIAL).

Table 3.6: Summary of analysis of variance of data from Experiment Four under absolute scoring

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects:					
Material	509.28	3	169.76	9.75	<.01
Subjects Within Groups	487.69	28	17.42		
Within Subjects:					
Strategy	465.12	1	465.12	63.05	<.01
Material x Strategy	13.81	3	4.60	.62	N.S.
Strategy x Subjects Within Groups	206.56	28	7.38		
Rate	50.00	1	50.00	8.03	<.01
Material x Rate	1.06	3	.35	.06	N.S.
Rate x Subjects Within Groups	174.44	28	6.23		
Strategy x Rate	19.53	1	19.53	5.00	<.01
Material x Strategy x Rate	3.66	3	1.22	.31	N.S.
Material x Subjects Within Groups	109.31	28	3.90		
Total	2040.47	127			

Table 3.7: Summary of analysis of variance of data from Experiment Four under ordered scoring

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects:					
Material	447.09	3	149.03	6.22	<.01
Subjects Within Groups	670.47	28	23.95		
Within Subjects:					
Strategy	643.51	1	643.51	74.01	<.01
Material x Strategy	30.77	3	10.26	1.18	N.S.
Strategy x Subjects Within Groups	243.47	28	8.70		
Rate	126.01	1	126.01	12.60	<.01
Material x Rate	7.77	3	2.59	.26	N.S.
Rate x Subjects Within Groups	279.97	28	10.00		
Strategy x Rate	25.38	1	25.38	3.17	N.S.
Material x Strategy x Rate	21.15	3	7.05	.88	N.S.
Material x Subjects Within Groups	224.22	28	8.01		
Total	2719.80	127			

evidence that subjects are able to derive benefit from having critical or non-critical items grouped by semantic similarity. The two groups of subjects who heard lists C and NC, where semantic similarity grouped the critical and non-critical words respectively, produced fewer errors than did the subjects who heard lists in which all the words were either unrelated (R) or semantically similar (ASS).

Most importantly, however, the performance functions of the two groups (NC and C versus R and ASS) in the active strategy under absolute scoring are parallel. Thus, the change from the fast to the slow rate of presentation benefits each type of material equally. Furthermore, the same pattern of results is observed under absolute scoring in the passive strategy, except that there is no change in performance across rates of presentation. The analysis of variance of the absolute scoring data confirm these observations: 1) there is a significant effect of material ($F = 9.75$; d.f. = 3,28; $P<.01$); 2) the material x rate interaction is not significant; 3) the material x strategy interaction is not significant.

The results obtained under ordered scoring differ from those obtained under absolute scoring in only one critical respect: under ordered scoring, the strategy x rate interaction is not significant. All other results of the analysis of variance of the ordered data mirror those of the absolute scoring data.

The lack of a strategy x rate interaction in the ordered data is perplexing. It is clearly not due to the lack of a rate effect in the active data but rather to the substantial decrease in error from the fast to the slow rate seen in material C in the passive strategy. When the passive strategy ordered data alone is subjected to an analysis of variance (see results in Table 3.8), there is no effect of rate, nor is there a material x rate interaction. When the active ordered data is subjected to the same type of analysis (Table 3.8), there is an effect of rate ($F = 12.71$; d.f. = 1,28; $P<.01$) but the material x rate interaction is not significant. Apparently this one unusual result, while not powerful itself, is sufficient to "wash out" the expected strategy x rate interaction.

The ordered scoring passive strategy performance of subjects hearing material C is difficult to understand. Given that material C has the best performance overall under the other strategy-scoring criterion combinations, it seems that the results of material C under the ordered scoring in the passive strategy reflects difficulty with the fast rate rather than ease with the slow rate. Why this should be the case eludes interpretation in the present data and probably in this experimental design as well. However, it is not critical to the line of inquiry that has been followed in the experiments that have been reported here and will have to remain a possible focus of some future research.

It will be recalled from Experiment Three that when acoustic similarity grouped to-be-remembered items (C) and all items presented (AAS), the switch from absolute to ordered scoring resulted in greater lowering in performance than when the items were acoustically unrelated (R) or when acoustic similarity grouped the non-critical items (NC). The lack of corresponding evidence with semantic similarity clearly suggests that the difficulty with ordered recall in materials C and AAS of Experiment Three reflects difficulty peculiar to acoustic similarity rather than properties of the active extraction process.

Table 3.8: Summary of analyses of variance of both active and passive ordered data

Passive Strategy

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects					
Material	145.80	3	48.60	2.47	N.S.
Subjects Within Groups	551.06	28	19.68		
Within Subjects					
Rate	19.14	1	19.14	2.51	N.S.
Material x Rate	20.55	3	6.85	0.09	N.S.
Rate x Subjects x Groups	212.81	28	7.60		
Total	949.36	63			

Active Strategy

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects					
Material	332.06	3	110.69	8.54	<.01
Subjects Within Groups	362.87	28	12.96		
Within Subjects					
Rate	132.25	1	132.25	12.71	<.01
Material x Rate	8.37	1	2.79	0.27	N.S.
Rate x Subjects x Groups	291.37	28	10.41		
Total	1126.94	63			

One final observation should be mentioned. Thus far in this discussion of Experiment Four (with the above exception of the discussion of material C), the four types of stimulus lists have been discussed as two groups--the group in which wanted and unwanted items are from the same set (materials R and ASS) and the group in which wanted and unwanted items are from different sets (materials NC and C). This has been adequate in terms of the overall goal. However, active extraction does appear to exert some effect upon material ASS. In the active strategy for both absolute and ordered scoring, the overall performance of subjects hearing material ASS is slightly better than of those hearing material R, while in the passive strategy the converse is true. In the same context it should also be noted that, while the subjects hearing material C do perform overall slightly better than those hearing material NC in both active and passive strategies, the difference between them is less in the passive strategy.

It would appear from this that recall of semantically similar items does benefit performance in some additional way from the treatment of active extraction. One possible interpretation refers back to the Hamilton and Hockey suggestion that active extraction facilitates the constructive "analysis by synthesis" that Neisser (1967) has postulated as a basic feature of auditory attention. Under this view, it is plausible that items which share similar aspects of this analysis do reach memory store with an advantage over those where the analysis process is different. However, again, the data are insufficient for further ellaboration of this point.

REVIEW AND DISCUSSION

Two goals have guided the investigations reported in this chapter. The initial goal was to replicate the basic results obtained under the active/passive paradigm; and the second was to explore further the nature of the relationship between a concept like controlled activation and concepts like dictionary units and pigeon-holing, basic features of the interpretive models of selective attention.

Experiment One satisfied the first of these goals, reproducing the basic Hamilton and Hockey results. The primary variation in the nature of the task over the original experiment was the use of words as the stimulus items. In this replication, active performance was better than passive performance over both rates of presentation. Although it is the rate limitation in active extraction that is most critical to the theory of selection-in-time and controlled activation, it was concluded that, if words could be adequately presented at rates as fast as the rates used by Hamilton and Hockey for digits, active performance would deteriorate, at some point, to that of passive.

The second goal of this series was explored over Experiments Two, Three and Four. Hamilton and Hockey had introduced the possibility of viewing active extraction as a special case of the dichotic listening situation. Drawing on previous research, they predicted that the efficiency of active extraction should depend upon rate of presentation, but that the rate limitation should be independent of the effect generated by increasing the integrity of the wanted or unwanted item sets. The first of these assumptions has been repeatedly confirmed. The second remained complicated by an apparent ceiling effect on performance; Experiment Two primarily replicated these findings.

Experiments Three and Four pursued the same approach to the problem but varied the types of stimulus materials used in an effort to lower performance below what appears to be a level of maximal efficiency. Although these experiments possibly ran the risk of belabouring the point by searching for the "right" type of material, the results do support the hypothesis that the effect of categorized information is independent of the rate limitation in active extraction. However, whether this independence will be observed in parallel lines on graphs of untransformed data or after appropriate transformation, as Hamilton and Hockey suggested, does seem to depend upon the nature of the material. It may also depend upon individual differences among subjects. Note, for example, that Experiments One, Two and Three each had a condition in which all of the list items were random words. The same rates of presentation were used in each, yet performance in the active slow condition varied from 19% error in Experiment One to 34% error in Experiment Four (ordered scoring). Granted, this may reflect differences in the word frequencies in common language, but a large portion of this variation is still very likely to be due to individual differences in efficiency overall, in the use of the active strategy, or both.

Because of the low number of trials given each subject, a subject-by-subject comparison is not appropriate for the present data. (Chapter Five pursues individual differences in performance more systematically.) However, in terms of the present hypothesis, the effects of individual differences are not seen as damaging to the overall conclusion.

As noted earlier, the central concern of this thesis is to explore further the concept of active control and to integrate it into a model of the active control of human information processing. What, then, has been gained via the investigation of categorized information?

The overriding conclusion is that the process governing selection via active extraction occurs prior to any process which deals with selection via informational content of the items. Thus, the output of the first process serves as input to the second. This is consistent with the view of active superiority at slow rates either as a result of a negative process such as filtering, which gates unwanted items, or a positive process such as controlled activation, which serves to amplify wanted items by virtue of subjects' heightened receptivity as critical items arrive.

Two types of evidence have been critical in forming the conclusion that the effect of active extraction lies with a process which occurs prior to and independently of the process which separates wanted from unwanted items on the basis of an information cue: 1) that the rate limitation on active efficiency occurs equally across types of information and 2) that the effect of categorized information is seen in both active and passive strategies.

As discussed earlier, the first of these has not always been evident but does seem to depend upon the overriding efficiency parameters of each type of material. The second has been more consistently obvious.

There is the possibility of interactions occurring among particular types of information, order and item recall and active versus passive strategies. No full attempt has been made here to understand the relationship among these variables. Interpretation via reference to previous literature is frustrated because acoustic and semantic similarity have been investigated most frequently in the context of memory storage and retrieval and order versus item error has been most frequently investigated in the context of depth of processing, while the investigations of Hamilton and Hockey and the experiments reported here using the active/passive paradigm are intimately concerned with the selective intake of information. While these areas of investigation are certainly relevant to one another, the data presented thus far are not sufficient to provide detailed understanding of their relationships. The data provided only suggest that the special features of the retrieval processes of acoustically similar items do affect the pattern of results observed under active extraction to the point where active extraction seems to provide little benefit over and above that provided by an acoustic retrieval cue.

CHAPTER IV

Δ_m AND POSSIBLE "LIMITS" TO THE EFFECTIVENESS OF ACTIVE EXTRACTION

INTRODUCTION

Two experiments are reported in this chapter. True to the buckshot approach adopted in this research, these two experiments do not share a common focus of interest within the general topic of active extraction. Experiment Five questions whether the past reported methods of analysing the active/passive data have overlooked evidence which could force re-evaluation of the interpretation proffered thus far, and employs a signal detection analysis to determine whether one particular type of error has been made. Experiment Six, on the other hand, seeks to answer two questions: 1) Over how long a sequence can subjects maintain the type of behaviour assumed to underlie active efficiency at slow presentation rates? and 2) Can subjects use active extraction so effectively that they can essentially fill memory store with only critical items?

EXPERIMENT FIVE

Rationale For A Signal Detection Analysis

Hamilton and Hockey suggested that the result of subjects' use of controlled activation in input selection is an increase in the acquisition strength of critical relative to non-critical items. By the output stage, the greater acquisition strength has been translated into a stronger status in memory. In essence, active extraction increases the discriminability of the critical relative to the non-critical items in memory store. Conceptualizing the nature of the differences produced in memory store between active and passive strategies as one of greater discriminability in the active strategy bears strong resemblence to the type of hypotheses tested via signal detection analysis. That is, if one equates the non-critical items with the noise distribution, and the critical items with the signal plus noise distribution, active extraction seems to produce a shift in d'. A signal detection analysis of active/passive data therefore should yield a significant increase in d' active over d' passive if the original hypothesis is correct.

When the two distributions are conceptualized as above, a shift in d' is a prediction which is fairly easily made. A logical basis for the alternative prediction of active extraction causing only a shift in β is more difficult to explain in the light of the previous research.

In passive operation, when both critical and non-critical items are from the same informational category, d' is a function of subjects' ability to discriminate in memory store whether an item occurred in an even or odd numbered position in the sequence. A shift in β would imply that active extraction induces subjects to adopt a more lax criterion by which to evaluate whether an item occurred in an even or odd numbered positon in the sequence and hence, should produce a high proportion of non-critical intrusions.

It is somewhat difficult to integrate a shift in β with the rate dependency of the active strategy. Both active and passive strategies should be equally affected at the slow rate. Furthermore, as Hamilton and Hockey demonstrated in their Experiment 6, it is not enough to explain why a shift in β is rate dependent, but one would also have to justify its dependence upon a regular slow rate of presentation.

Thus, not only does active efficiency appear intuitively to affect *d'*, but the previously reported body of research about the properties of active extraction appears to negate the possibility that it is alternatively a shift in β only. A signal detection type analysis in the active/passive paradigm is likely, therefore, to lead only to the theoretically self-evident. However, the analysis is worth conducting in order to satisfy the reader that active extraction does produce a significant shift in *d'* relative to passive performance.

The precedent for applying signal detection analysis to tasks involving a substantial memory component was set by Egan (1958) and its usefulness further developed by that author as well as others. While the theoretical issues these investigations addressed (Kintsch, 1970, reviews the history) were different from those of central concern in the active/passive discussion, they have served as a guide in the design of Experiment Five.

In these "dedicated" memory experiments, a recognition rather than a recall paradigm is traditionally used. A recognition paradigm presents the advantages of 1) testing the overall strength of items in memory without interference from the difficulties associated with retrieval in a recall paradigm, and 2) ensuring that each list positon can be accurately tested. Thus, a recognition paradigm is used in this experiment. Additionally, a confidence rating (initially used by Egan, Greenberg and Schulman, 1959) is used to simulate changes in subjects' criterion, without changing the task instructions.

<u>Methodology</u>

<u>Stimulus Material:</u> 18 consonants (all those in the alphabet except G, V, and B) were used as the stimulus items in Experiment Five.

720 lists of 9 consonants each were prepared. The complete consonant set was repeated every two lists, although randomized within every two lists. The lists were recorded at 1 second/item, preceded by four seconds lead-in beating from a mechanical metronome. The last list item was followed, in rhythm, by an electronic tone followed by one of the nine consonants from the list (probe).

The lists were arranged into 20 blocks of 36 lists each. Within each block the consonant appearing in each list position, first through ninth, was used as the probe four times.

Subjects: 12 (9 male, 3 female) fourth year psychology undergraduates and post-graduate students. Each subject was highly experienced in memory and attention tasks. All subjects were paid for their participation.

Design and Procedure: Subjects were tested in two groups of six subjects each. Each group was tested for one hour per day on five consecutive days. Group A was tested between 1 p.m. and 2 p.m. and Group B between 2 p.m. and 3 p.m.

Each session consisted of 144 trials, or four blocks of 36 trials each. Subjects performed both the active and passive strategies two blocks of trials of each strategy in each session). The report procedure was adapted to suit a recognition paradigm. The subjects' task was to decide initially whether the probe item corresponded to a critical or a non-critical item. If the probe was judged a member of the critical set, subjects recorded the position that item occupied in the list on prepared answer sheets. If the probe was judged a non-critical item they simply placed a tick mark in the response box for that trial. Finally, subjects were asked to rate their confidence in the accuracy of their response on a 1 to 5 scale, where "1" corresponded to a complete guess and "5" to complete certainty. Each number in the scale was printed on the response sheet along with a heading which indicated the "value" of the "1" and "5" ratings. Subjects, therefore, were required to circle the number corresponding to their rating. Care was taken in requesting that subjects try to use the complete scale to represent their certainty across trials.

In the present experiment, unlike Experiments One through Four, the definition of the critical set was varied, primarily in order to assist subjects in adhering to the passive strategy when required. On one-half of the passive trials within each block the critical items were designated as the first, third, fifth, seventh and ninth item from the list, and on the other one-half the criticals were the second, fourth, sixth and eighth. On each passive trial, the critical set was not revealed until after the list had been presented. At the end of each list, coincidental with the tone preceeding the probe, a card displaying the critical set (i.e., 1-3-5-7-9 or 2-4-6-8) was revealed. Within each passive block each intra-list probe position was tested twice when the critical set was the first, third, fifth, seventh, ninth and twice when second, fourth, sixth, eighth.

Correspondingly, in active trials both definitions of critical set were tested. However, only one critical set was tested per block of trials. Of course, the subjects were fully aware of the designated critical set for each block.

The ordering of blocks within and across sessions for each group followed a modified ABBA design as indicated below:

Group A

Session 1	Session 2	Session 3	Session 4	Session 5
Active (1-9)	Passive	Active (1-9)	Passive	Active (1-9)
Passive	Active (2-8)	Passive	Active (2-8)	Passive
Passive	Active (1-9)	Passive	Active (1-9)	Passive
Active (2-8)	Passive	Active (2-8)	Passive	Active (2-8)

Group B

Session 1	Session 2	Session 3	Session 4	Session 5
Passive	Active (1-9)	Passive	Active (2-8)	Passive
Active (2-8)	Passive	Active (1-9)	Passive	Active (1-9)
Active (1-9)	Passive	Active (2-8)	Passive	Active (2-8)
Passive	Active (2-8)	Passive	Active (1-9)	Passive

Subjects were instructed in the use of both strategies in a manner similar to that employed in each of the previous experiments. Testing did not begin until each subject expressed complete understanding of the task requirements.

The first session was treated purely as practice and results were not analysed. Similarly, each day's session began with 18 practice trials. Five seconds of recall/response time was provided between trials. Between blocks subjects were allowed as much rest-time as they desired.

Results And Discussion

For the purposes of the signal detection analysis, results were collapsed across critical sets (1st, 3rd, 5th, 7th, 9th, and 2nd, 4th, 6th, 8th) and scored on an absolute basis. A "hit" was defined as correct identification of a critical item, a "miss" as failure to identify a critical item, a "false alarm" as identification of a non-critical item as critical, and a "correct rejection" as correct identification of a non-critical item. Table 4.1 shows the mean percent of each type of response for both active and passive performance.

The data in Table 4.1 clearly supports the hypothesis that active extraction affects d'. The false alarm rate in active performance is so low that it seems that only greater discriminability of critical items can account for these results. A signal detection analysis was undertaken, nevertheless, to provide sufficient statistical evidence to satisfy the reader of the validity of this view.

In order to calculate d', the percent hits and false alarms were determined for each subject at each confidence rating. As fairly typically occurs, some subjects produced virtually no false positives, leaving some confidence ratings totally devoid of this type of error. Each subject failed to use at least one of the confidence ratings for false alarms in the active strategy. Therefore, the data for each subject was examined with a view to collapsing confidence intervals in a manner which maximized the number of subjects whose data could be used in the analysis as well as the number of confidence intervals available. The optimum strategy was to combine ratings 2 and 3, reducing the number of points for plotting the ROC curve to three (i.e., ratings 5; 5+4; 5+4+3+2). Four subjects committed false alarms at each

Table 4.1: Mean percent hits, misses, false alarms and correct rejections under absolute scoring in both active and passive strategies. (N = 12; 100% = 1728.)

TYPE OF RESPONSE	ACTIVE	PASSIVE
Hits	94.27	82.35
Misses	5.73	17.65
False Alarms	4.40	14.35
Correct Rejections	95.60	85.65

of confidence ratings 2+3, 4 and 5. Thus, inferences about d' in the active and passive strategies were made from the data of these four subjects only. The mean percent hits, misses, false alarms, and correct rejections for these four subjects is shown in Table 4.2.

In determining d' for the active and passive strategies, the data was averaged across subjects. Averaging was done by first transforming the probability scores associated with the confidence intervals 5, 5+4, and 5+4+3+2, for both hits and false alarms on a z-scale and then calculating the algebraic mean for the group for each of these intervals.

d', or technically Δ_m, was calculated by plotting the active and passive ROC curves (straightline fit was determined via observation) for the group data and reading Δ_m as the value of z- false alarms where the curve passes through z- hits = 0. The ROC curve for the group data for both the active and passive strategies is plotted in Figure 4.1. As seen in this figure, Δ_m- active is equal to 2.75 and Δ_m-passive is equal to 1.55.

Since this "eye-ball" technique is subject to some observer error, the mean Δ_m for the group was verified by plotting the active and passive ROC curves, reading Δ_m for each subject, and then calculating the algebraic mean of the individual Δ_m's. This method produced a group Δ_m-active of 2.8 and a group Δ_m-passive of 1.5.

Figure 4.2 shows the active and passive ROC curves for each subject. The value of Δ_m active and passive is noted for each subject. Δ_m-passive is less than Δ_m-active for each of the subjects.

Table 4.2: Mean percent hits, misses, false alarms and correct rejections for the four subjects from Experiment Five whose data was used in the signal detection analysis.

TYPE OF RESPONSE	ACTIVE	PASSIVE
Hits	90.11	78.12
Misses	9.89	21.88
False Alarms	9.03	25.00
Correct Rejections	90.97	75.00

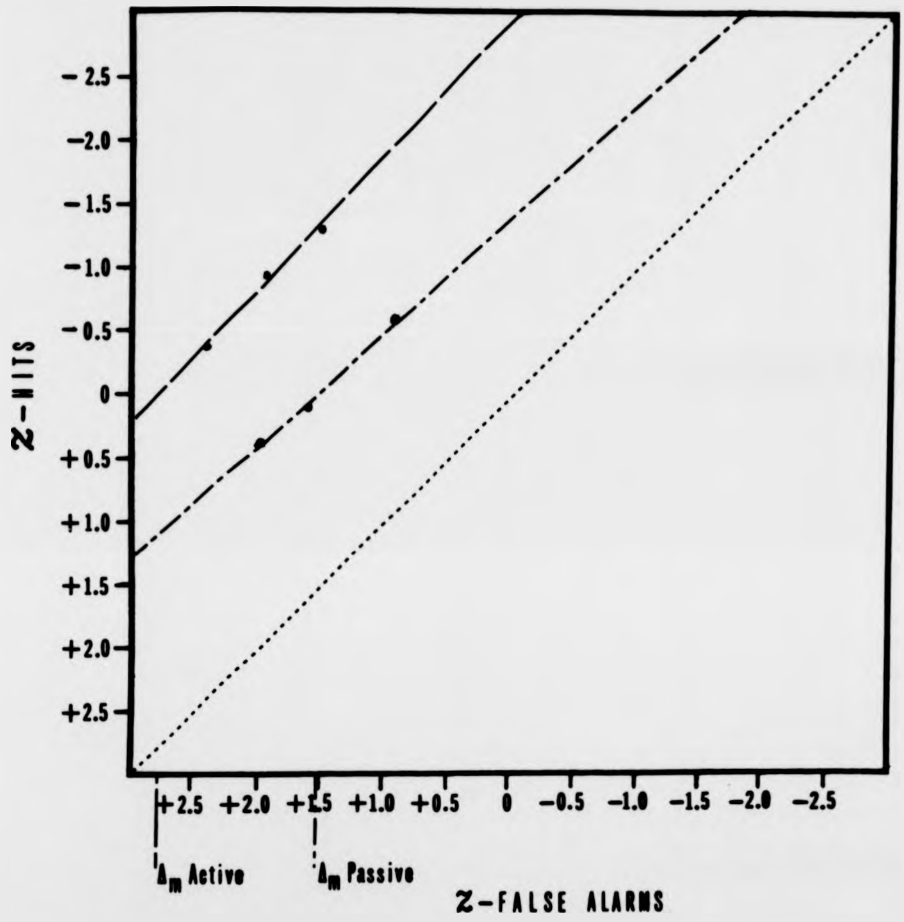

FIG. 4.1: EXPERIMENT FIVE, MEAN ROC CURVES FOR ACTIVE AND PASSIVE PERFORMANCE FOR FOUR SUBJECTS.

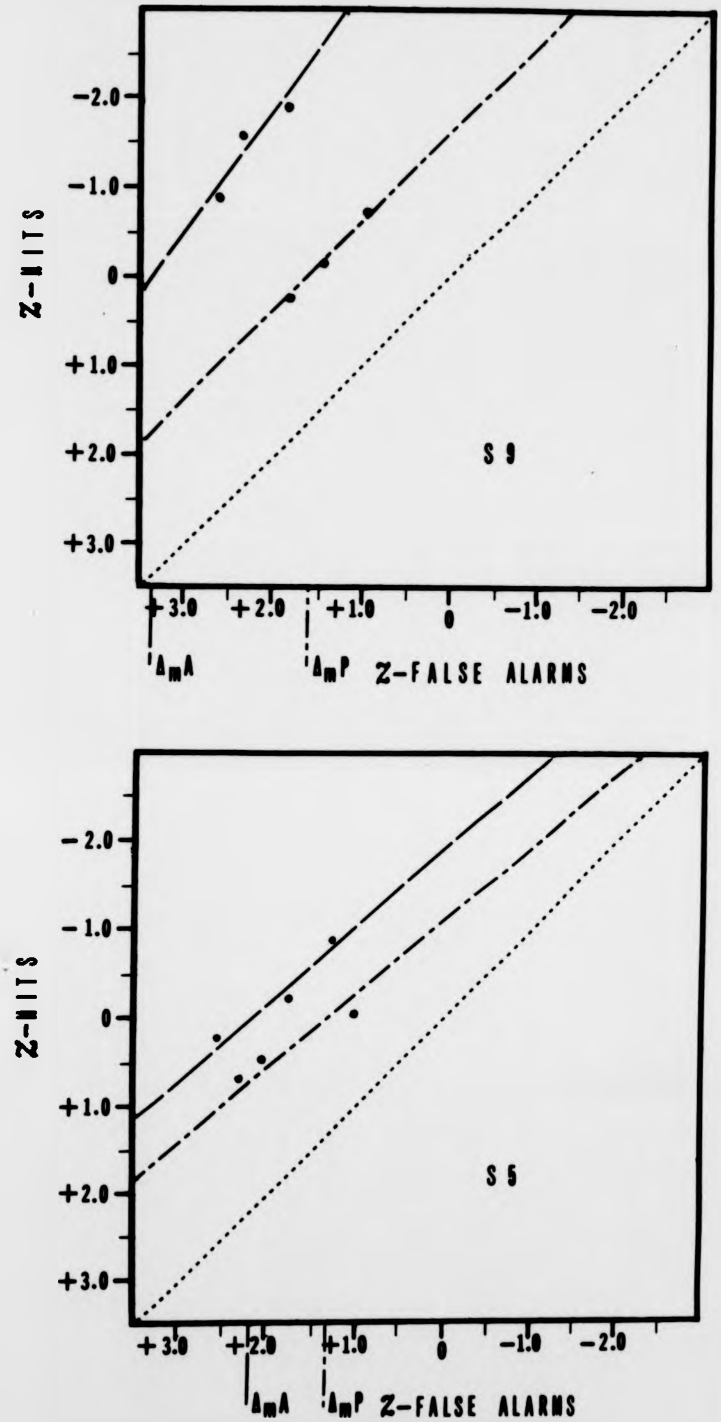

FIG. 4.2: EXPERIMENT FIVE, INDIVIDUAL ROC CURVES FOR ACTIVE AND PASSIVE PERFORMANCE FOR EACH OF THE FOUR SUBJECTS.

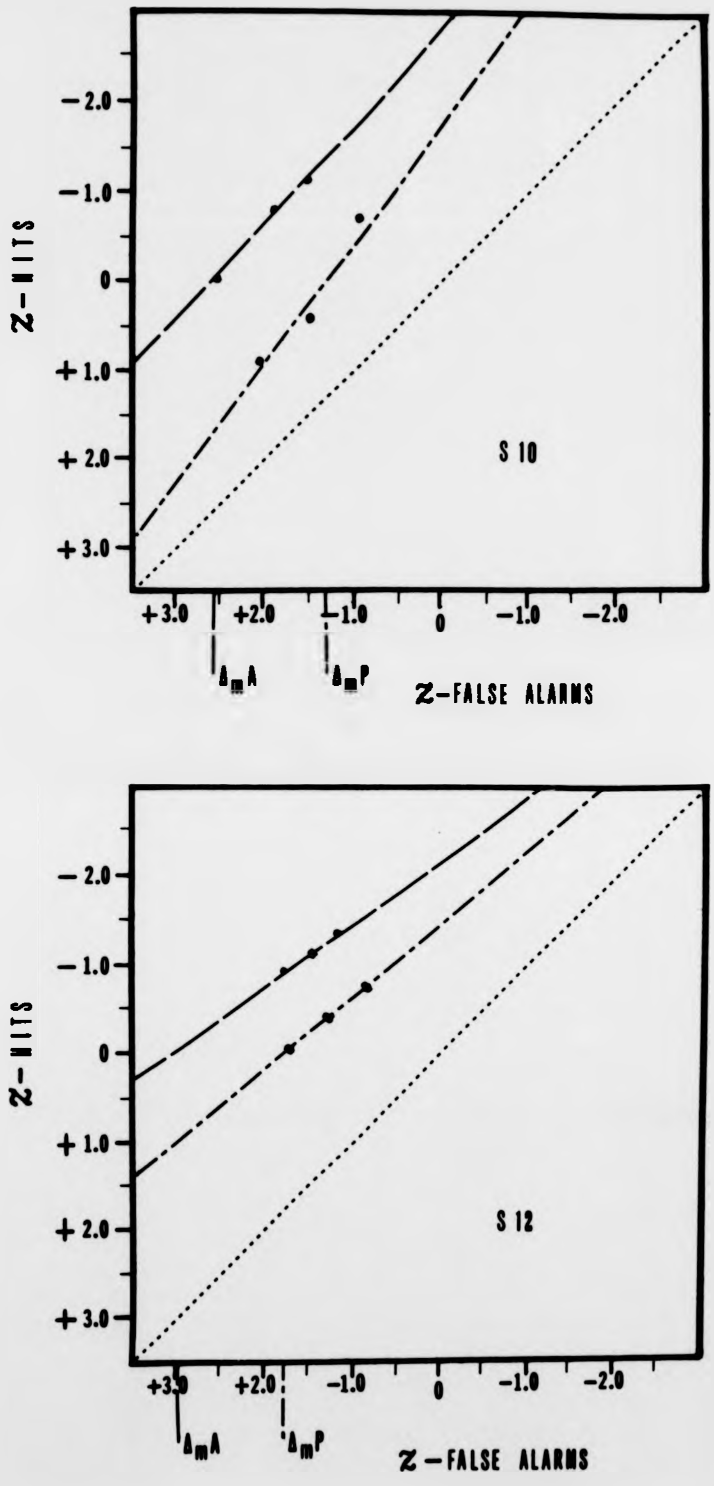

FIG. 4.2: (CONTINUED)

These findings clearly support the assumption that active extraction is appropriately characterized as a shift in d' rather than β. As noted earlier, this finding probably does little to further overall understanding of the controlled activation process. It's contribution to this research is, therefore, regarded as statistical confirmation of the interpretation of the effect in memory produced by active extraction that has been promoted in the previous research.

EXPERIMENT SIX

Rationale For Testing The Limits Of Active Strategy Efficiency

As noted in the introduction to this chapter, Experiment Six seeks to address two of the questions unanswered in the research thus far. As Hamilton and Hockey suggested, controlled activation, the process assumed to underlie active strategy superiority, seems to be closely related to the sort of process believed to occur in the fore-period of a reaction time task. (Some of the literature relevant to this latter process was introduced in Chapter II.) The parameters governing efficiency in both the active/passive paradigm and the reaction time task are similar. Both processes, for example, require time to reach an optimal state. This is seen in the reaction time studies (Posner and Boies, 1971; Bertelson, 1967) as faster reaction times when the foreperiod is at least .2 seconds, and in the active/passive paradigm by the rate dependency of active performance. Similarly, both processes are dependent upon subjects having the opportunity to predict (within reasonable limits) the time of arrival of the stimulus. In the reaction time studies this is evident in the general importance of the warning signal, and in the active/passive paradigm by subjects' poor performance when the stimulus items are presented at irregular time intervals (Hamilton and Hockey, Experiment 6).

Finally, another similarity between the two processes is their apparent independence from other types of attention or attentional processes. The evidence for this latter point comes from independence of the preparation and encoding functions (Posner and Boies) in the reaction time studies and the independence of rate and type of stimulus material in the active strategy (Chapter III, Experiment Four).

The major facility Hamilton and Hockey have attributed to "controlled activation" but which has not been described as a property of the process involved in the reaction time studies, is the abilty to produce preparations over an extended sequence. In the case of all of the active/passive experiments reported thus far, this extended sequence requires production of four preparations -- one to correspond with each of the critical items (2nd, 4th, 6th, 8th).

Relative to the context of the reaction time studies, where only one "preparation" is required, the production of four preparations does constitute an extended sequence. Having justified that four is possible however, the question arises as to how long the subject can maintain the behaviour. One possible method of investigating this point is to measure performance over an even longer sequence. If subjects' ability to time their preparations to receive stimuli is limited, breaks down, or otherwise falls out of sequence with the designated critical items, then at some point report of critical items among subjects performing the active strategy should be no greater than among subjects performing the passive strategy.

The second question which Experiment Six seeks to address is how effective can active extraction be? As Hamilton and Hockey noted, other theories of the selective intake of information have emphasized how man economizes on stimulus loading by selecting some inputs at the expense of others. Some of the relevant literature on how this economy is achieved was reviewed in Chapter I. The general conclusion of that review was that two types of mechanisms, operating by different types of selection, seem to exist. Following Broadbent's taxonomy, one of these is described as a filtering mechanism which operates primarily on the basis of a physical cue and quite successfully gates unwanted information. The other is described as a pigeon-holing mechanism which operates primarily on the basis of an informational cue and is less successful than the filter. Pigeon-holing is thus regarded as attenuating rather than gating the unwanted message. Both mechanisms are assumed to be successful because they diminish the amount of the unwanted message, relative to the wanted message, which gains access to the limited capacity portion of the information processing system.

Investigations concerning both of these mechanisms, however, have frequently employed an experimental task in which the subject is presented with more information than he can successfully pass through the limited capacity system at one time, effectively forcing the subject to select among inputs in order to meet the demands of the task.

One could argue that performance in the active slow condition, when tested over a nine item sequence, does not present a very difficult task. In a nine item sequence recall is tested over a four critical item range. If the old rule-of-thumb (Miller, 1956) is correct and applicable to critical item recall, then subjects should be able to recall four items easily. (Indeed, in most of the experiments reported previously subjects were operating at or near apparent ceiling levels for the task).

This raises the question of whether an increase in list length is accompanied by a corresponding increase in the number of critical items subjects recall when using active operation. Increasing list length will at some point certainly run into the limits of memory capacity. Therefore, in order to examine how effective active extraction can be, it is necessary to establish what truly effective performance would be. A possible way to test this is to increase list length so that there are more to-be-remembered items, and then compare subjects' active performance with the performance of subjects who were presented only with the critical items.

Naturally, in order to ask this question of the data it must first be established that subjects can produce the preparations over a period of time at least as long as the time required to present the stimulus lists. Experiment Six, therefore, seeks to attain two goals. The initial goal is to determine whether subjects have the ability to employ active extraction over sequences in excess of nine items and to begin to establish how far in excess of nine items subjects can produce the underlying timed preparations. The second goal is to examine how the economy in memory loading which active extraction achieves compares with the efficiency of recall when no non-critical items are present.

In Experiment Six, list length was increased substantially. The active/passive performance of subjects was compared over lists of 17, 25, 33 and 41 words. Additionally, active extraction performance was compared to a control condition in which, in essence, only critical items were presented.

Methodology

Stimulus Material: 984 monosyllabic and disyllabic words were selected at random from the Thorndike and Lorge (1944) lists of A and AA words and were randomly drawn (without replacement) and arranged onto 24 lists of 41 words each. These lists were recorded on tape at a rate of 1 second/item. Each list was preceded by four seconds of lead-in beating from an electronic metronome. This master tape was used to compose four of the eight tapes used in the experimental sessions.

The eight experimental tapes consisted of two sets of four tapes each. The two sets were the "non-critical/critical" and the "critical." The four tapes within each set differed in the length of lists.

1) Non-Critical/Critical: The non-critical/critical set consisted of the master tape (24 lists of 41 words each), and three additional tapes, one each of 33, 25, and 17 list length duration. The three shorter list length tapes were composed simply by re-recording the master, blanking out items occurring after the requisite number in each list. This technique ensured that each tape consisted not only of the same inter-list and intra-list item order, but that pronounciation of each item remained constant across all tapes.

One of the conditions in the experimental design which used the non-critical/critical tape set was conducted at a later date than the others and used non-British subjects. Thus, a duplicate of the non-critical/critical set was prepared to suit the prevailing "accent." Use of this second non-critical/critical set is noted in the design and procedure.

2) Critical Set: The critical set also consisted of four tapes, one tape each for list lengths 8, 12, 16, and 20. These tapes were prepared by transferring the even numbered items from the master tape. The odd numbered items and all items beyond the requisite list length were blanked out on each tape. The end result was lists in which the items were essentially presented as one item every two seconds.

Subjects: Subjects were 72 University of Stirling first and second year psychology undergraduates and 24 introductory psychology students at Macalester College, St. Paul, Minnesota. The 72 Stirling subjects were divided into eight groups, four groups of six subjects each and four groups of twelve. The Macalester subjects were divided into four groups of six subjects each.

Design and Procedure: The design included 12 experimental blocks -- four list lengths in each of three conditions. The three conditions were:

1) Passive strategy
2) Active strategy
3) Critical item presentation

The active and passive conditions differed in the familiar way. In the active condition subjects were asked to listen for only the even numbered items in the lists, while in the passive strategy they were asked to listen to all items with equal attention. In both conditions subjects were instructed to write down only the even numbered items from each list.

Although subjects performed only one of the two strategies during testing, they were instructed in the use of both. They were encouraged to adopt the assigned strategy throughout, despite any benefit they may perceive in one over the other.

In the critical item presentation condition, subjects were instructed simply to record each item recalled.

Four list lengths were presented in each condition, one list length per block. In the active and passive conditions the list lengths were 41, 33, 25, and 17 words, while in the critical item presentation condition the list lengths were 20, 16, 12, and 8 words. (It will be recalled from the description of the stimulus materials that the to-be-recalled items were the same for each list length across conditions.)

Subjects in the passive and active conditions heard the non-critical/critical tape while subjects in the critical item presentation condition heard the critical tape.

The Stirling groups were assigned randomly to the active and the critical item presentation conditions, while the Macalester subjects were used only in the passive condition. The second master tape described earlier was used only for the Macalester subjects.

Subjects performed only one condition at one list length throughout a session. The four twelve-subject groups performed the active strategy. The eight other condition/list length blocks each had six-subject groups. Subjects were tested as a group (either six or twelve).

Each session consisted of four practice trials and 20 test trials. Recall time between lists was 30 seconds in the active and passive 41 and 33 list length and the critical item presentation 20 and 16 list length groups. In the remaining groups recall time between lists was 20 seconds.

Subjects were given a couple of minutes rest-break between each group of five trials.

Results and Discussion

Before one can examine the efficiency of active extraction relative to the condition in which only the critical items are presented it is necessary to determine whether subjects have the facility to produce the preparations involved in the active process over sequences as long as those tested (i.e., 17, 25, 33, and 41 words). Therefore, discussion of the results is confined initially to the first question raised in this experiment.

Over how long a sequence can subjects produce preparations?: Performance as measured by the mean number of critical items recalled per list (absolute scoring) for each list length is shown for both the active and passive strategies in Table 4.3. The mean number of critical items recalled under active extraction is greater than in passive operation for each list length. The difference between active and passive mean performance was tested for each list length using a *t*-test. This difference is significant (P at least $< .05$) for each comparison.

In the active strategy, the mean number of critical items recalled remains almost constant at near four per list. In the passive strategy there is some indication that the number recalled increases as a function of list length, at least over the two extremes (17 words and 41 words) tested here. The consistency of number recalled in the active strategy suggests that four items is the maximum memory load under the present conditions and that subjects operate at this level irrespective of list length.

Table 4.3: Mean number of critical items recalled per list for each list length in both the active and passive strategies in Experiment Six. (N = 6 in each passive group. N = 12 in each active group.)

LIST LENGTH	PASSIVE	ACTIVE
17 Words (8 critical items)	2.28	4.08
25 Words (12 critical items)	2.49	3.84
33 Words (16 critical items)	2.37	3.72
41 Words (20 critical items)	2.82	3.97

At this level of analysis, the data do suggest that subjects are able to produce the timed preparations of active extraction over lists considerably longer than the nine item sequences used in all the research reported previously. Before drawing this conclusion, however, it may be prudent to examine one possible confounding effect. It is possible that the critical items recalled in each list fall entirely within the primacy and recency regions of the serial position curve and, hence, that the apparent active superiority is merely a function of the interaction of the effect of the controlled activation process with those processes governing the primacy and recency effects rather than of subjects' ability to produce the timed preparations of controlled activation over the extended sequence. One way of examining these data apart from possible primacy/recency effects is to examine performance over the middle region of the lists.

Following this line, subjects' response sheets were rescored, by critical item position in the lists. Examination of the number of items recalled in each position indicates that the primacy region, on average, covers the first four critical items and that the recency region covers the last four critical items of the list, irrespective of list length. (The raw data from which this observation was made appear in Appendix III.) Therefore, it is recall of the critical items intervening between the first and last critical item quadruplets which are of interest.

As an aid to viewing the data, all critical items were grouped into successive segments of four items each. The mean number of critical items recalled per four item segment, or quadruplet, is shown in Table 4.4 for both the active and passive strategies at list lengths

Table 4.4: Mean number of critical items recalled per quadruplet for list lengths 25, 33 and 41 words in both active and passive strategies. (N = 6 in each passive group. N = 12 in each active group.)

LIST LENGTH	PASSIVE	Active
25 Words		
Primacy quadruplet	0.72	1.22
2nd quadruplet	0.25	0.74
Recency quadruplet	1.52	1.88
33 Words		
Primacy quadruplet	0.76	0.83
2nd quadruplet	0.15	0.49
3rd quadruplet	0.17	0.64
Recency quadruplet	1.29	1.76
41 Words		
Primacy quadruplet	1.27	1.17
2nd quadruplet	0.04	0.43
3rd quadruplet	0.05	0.42
4th quadruplet	0.05	0.35
Recency quadruplet	1.41	1.60

25, 33, and 41 words. (The shortest list length is excluded because the eight critical items of a list of 17 words all fall within the operational definition of the primacy and recency quadruplets.)

In all three list lengths, the mean number of words recalled per intervening quadruplet for each list length in the active strategy is greater than in the passive strategy. Comparisons were made of active versus passive performance for each intervening quadruplet of each list length. All comparisons were significant (P at greatest < .05). The most critical finding, however, is that in each successive intervening quadruplet of list lengths 33 and 41 in the active strategy, the mean number of items recalled remains fairly constant, as well as high (relative to the passive). This clearly suggest that subjects are able to selectively treat the critical items throughout a list as long as 33 or 41 words. In terms of the theory of controlled activation, therefore, it seems reasonable to assume that subjects are able to exercise control over sequences considerably in excess of nine items.

In the lists of 41 words, there is a slight but progressive decline in the mean number of items recalled from the second to the fourth quadruplet. While this may be indicative of decreasing control over production of the timed prepartions as the sequence continues, the data from list length 33 appear to contradict this point. Recall is slightly greater in the third than in the second quadruplet of the 33 word lists. Therefore, while it does seem reasonable to conclude that subjects are able to continue to selectively treat the items which appear as late as the 13th, 14th, 15th, and 16th critical items in a list, the possibility of deterioration within, but especially beyond this point must be considered. Rather, at this time, it is concluded that the use of controlled activation to selectively treat critical items in the active extraction task is not limited to sequences of nine items, and probably extends at least up to the 33-41 item range, if not beyond.

How effective can active extraction be?: Three assumptions were made in the design of Experiment Six: 1) Increasing the number of critical items to be recalled increases the difficulty of the active extraction task. 2) If subjects are performing as well as they need to rather, than as well as they can, when the number of critical items to be recalled is four, then increasing list length should result in recall of more than four critical items per list. 3) Given the limits of memory span, the criticals only condition indicates the highest level of performance which could be expected at each list length using active extraction.

It was noted earlier in the discussion of the results of Experiment Six that the mean number of critical items recalled per list in active extraction is near (or just under) four items, irrespective of list length. Table 4.5 shows the mean number of items recalled per list in the active strategy under absolute scoring for comparison with recall in the criticals only condition. While mean recall under active extraction is roughly four critical items per list, in the free recall situation subjects recall roughly seven items.

In response to the question which opened this discussion, it appears that active extraction can effectively secure roughly four items for recall. Although recall of the non-critical items was not tested, it seems reasonable to assume that the interleaved non-critical items account for the remaining three "chunks" (Miller's term) of available memory store. The task instructions specifically requested

Table 4.5: Mean number of critical items recalled per list per subject in both the active strategy and in the criticals only condition for each list length under absolute scoring. (N = 12 in each active group. N = 6 in each criticals only group.)

(List Length)	ACTIVE	(List Length)	CRITICALS ONLY
(17 words)	4.08	(8 words)	5.93
(25 words)	3.84	(12 words)	7.63
(33 words)	3.72	(16 words)	7.26
(41 words)	3.97	(20 words)	7.36

that subjects try to prevent non-critical intrusions in their report. (They were asked to record an item only it they felt "reasonably" confident it belonged to the critical set.) Subjects' attempts to keep the false positive rate low, therefore, prevents validation of this assumption via comparison of total list recall in the active strategy with recall in the criticals only condition.

Some non-critical intrusions did occur, however. Table 4.6 shows the mean number of all items recalled per list in both active and passive strategies. In both strategies, addition of non-critical intrusions increases the mean number of items recalled by .6-.8 items per list over the means shown in Table 4.5. This data provides some evidence to support the assumption that if subjects were not specifically enjoined to prevent intrusions, total list recall may more closely approximate recall in the criticals only condition.

The failure of subjects to increase the number of items recalled per list as list length increases suggests that the number of critical items recalled per list is not a sensitive measure of the effectiveness of active extraction, rather effectiveness must be measured relative to passive performance. Active extraction, therefore, does not seem to "economize" on stimulus loading as effectively as the type of economy achieved under the interpretive models of attention.

In terms of the alternative positive and negative views of the nature of the effect of active extraction this conclusion more directly supports the interpretation of the selective treatment at intake as adding something extra to the critical items rather than as attenuating the non-critical. It should be noted, however, that it is possible to assume that the limit on critical item recall simply

Table 4.6: Mean number of all list items recalled per list for each list length in both active and passive strategies. (N = 6 in each passive group. N = 12 in each active group.)

(List Length)	ACTIVE	PASSIVE
(17 words)	4.97	3.32
(25 words)	4.64	3.04
(33 words)	4.51	3.13
(41 words)	4.61	2.93

reflects the ineffectiveness of the attentuating process rather than negates its existence.

Given that economy in memory load achieved by active extraction is apparent only when compared to passive non-selectivity and that active extraction does not achieve optimal economy in memory storage (as indicated by active performance relative to recall in the criticals only condition), one may question the value of active listening strategies. However, it should be noted that the experimental context in which active listening has been investigated is an artificial one. It has used critical item recall as a means of observing the active listening strategy and some of the parameters governing its efficiency; but this context places great emphasis upon how well active listening enables subjects to reproduce every other item from a long sequence of unrelated items. If, as suggested in the introduction to this research, the sort of process underlying active extraction is more fundamentally related to how the organism concentrates attention upon a task, then the real value or function of active listening is more likely to be how the organism activates appropriate aspects of information interpreting routines stored in a sort of long-term operational store. In other words, similar to the sort of process Martin (1972) suggested, relate more to how the organism isolates streams of thought, than to how items are prevented from occupying some of the "space" in the system devoted to short-term storage.

CHAPTER V

PHYSIOLOGICAL EVIDENCE OF CONTROLLED ACTIVATION

INTRODUCTION

Throughout the preceding discussions, active strategy efficiency at slow rates of presentation has been described as due to the benefits subjects derive from a modulation in alertness. It has been assumed that modulation in alertness is achieved through controlled modulation in activation state. Furthermore, the rate dependency of active extraction has been explained as due to the time required to achieve these state changes.

These assumptions concerning active extraction and indeed the validity of the whole concept of active control of activation state require further substantiation by relating active strategy efficiency to physiological activity. The experiments reported in this chapter are directed toward that end.

The difficulties inherent in actually observing physiological state changes have been documented in the literature. They may be summarized as follows:

1. The concept of activation state, as opposed to activation level, suggests that any single physiological measure may or may not reflect state changes depending upon the nature of the required activity.

2. The nature of the relationship between activation state and task state suggests that the magnitude of the physiological change away from a normal alert state is a function of the difference between desired state and actual state.

3. Traditional measures of physiological activity, especially EEG, frequently suffer from complexities of administration and analysis. Those physiological indicies which are easy to observe seem to be readily influenced by a number of variables, while those which are difficult to observe simply require a great deal of sophistication to record and analyze.

Taken together, these factors warn that choice of the physiological index must be fairly cautious one in order to be able to observe modulation in activation state.

Choice of the physiological index used in the experiments reported here was guided by the heart rate literature, reviewed in Chapter I. As noted then, the direction of change in heart rate seems to distinguish two types of activity in which the organism may engage. Cardiac deceleration typically occurs when the organism is in a general alert state of observing the environment while cardiac acceleration occurs when the organism begins to manipulate the information.

Libby, Lacey, and Lacey (1973) have shown that cardiac deceleration occurs when subjects observe pictures, and that the amount of deceleration correlates with the degree of interest in the pictures. While Lacey (1967) has suggested that cardiac deceleration plays a causal role in attentional control, this has been disputed by both Obrist et al. (1969, 1970) and Elliott (1969, 1972). Both argue that cardiac deceleration is evidence of the inhibition of movement which is merely conducive to a state of alerted intake. The general finding remains, however, that cardiac deceleration quite reliably occurs in situations of attentive observation of the environment.

Similarly, Lacey (1967) has argued that cardiac acceleration plays a causal role in environmental rejection. The alternative interpretation, however, is that cardiac acceleration occurs as the result of a tendency to verbalization and increased muscular activity when the subject prepares to respond (Obrist).

As with cardiac deceleration, the precise nature of the role which cardiac acceleration plays is not especially critical. What is important however, is that it corresponds to a situation in which intake of information is expected to be less efficient.

Hamilton, Hockey and Rejman (1977) have discussed how important it is to understand the nature of the task components in order to be able to predict reliably how activation state will influence performance. A particular activation state may be conducive to efficient performance in one task but not in another. Further to this, they describe the subject's state selection as dependent upon the information processing behaviour to which the system is biased. When behaviours compete, the state appropriate to the dominant behaviour should be observed.

Campos and Johnson (1967) have provided what appears to be an example of how this type of competition is reflected in physiological activity. They observed cardiac acceleration in a situation in which the subject was required to intake information and at the same time prepare a response. In the active extraction process, no such competition between behaviours is inherent. The task instructions require the subject to alternately listen for the critical items and try to ignore the non-critical items at input. If subjects are able to, and do, use modulation in activation state to control these activities, then a phasic modulation in heart rate should extend through the sequence, with cardiac deceleration occuring prior to the critical items. In the passive strategy, where subjects are asked to employ the same listening strategy throughout the sequence, cycling of heart rate should not occur.

"Choice" of subjects was a somewhat speculative affair. The rationale was as follows: Several studies have shown that introverts and extraverts differ in observed level of performance. Broadbent (1963) and Bakan, Belton, and Toth (1963), for example, have found the vigilance decrement occurring after some time at work, to be greater among extraverts than introverts. Corcoran (1965) and Eysenck (1967) have explained these results as indicating that extraverts are chronically less aroused than introverts, and that the generally higher level of arousal of introverts causes their performance to be more efficient quite frequently.

This interpretation is in close agreement with the unidimensional concept of arousal. In Chapter I, the predictive failures of the unidimensional concept in the stress literature and in the OR literature were reviewed. It was concluded that these results support an activation state hypothesis. The introvert-extravert literature possess some predictive failures of the same type. Broadbent (1971), for example, has cited results which indicate that extraverts appear to be under-aroused in some task situations, but not in all.

If one must adhere to a unidimensional concept these results appear to contradict those cited earlier, whereas the activation state-task state hypothesis encompasses both. Thus far then, we <u>may</u> expect to observe different levels of performance among introverts and extraverts in the active/passive task.

The stress literature provides further guidance on the expected nature and direction of those differences. Davies and Hockey (1966) and Davies, Hockey, and Taylor (1969) found extraverts to benefit more than introverts from the change in activation state produced by noise. In a similar vein, Corcoran found extraverts to suffer more from the changes in activation state produced by the generally dearousing sleep-deprivation. While these results may be explained in terms of beneficial and detrimental changes in activation state and the Yerkes-Dodson law, another interpretation is possible. Introverts may inherently have less space for change in activation state than do extraverts.

While the Yerkes-Dodson law would explain the better performance of extraverts under noise conditions, in some tasks, as the result of introverts being forced beyond optimal arousal level into the region of a detrimental increase, the alternative interpretation suggests that extraverts can shift state more readily, and consequently reap the benefits of noise more easily. This interpretation has received some support in the literature. It bears close resemblence to Wilder's law of intial values (discussed in Maher, 1966, p.89).

Wilder hypothesized that the lower the initial value of the functioning of a physiological system, the higher will be its response to stimulation, except in cases of extremely high levels of stimulation where a reversal of effect may be found. Broen (1968) has reviewed studies that support this principle: Gunderson (1957) found schizophrenics to exhibit high levels of basal autonomic activation, while Angyal, Freeman, and Hoskins (1940) found schizophrenic reactivity to stressful conditions to be low. Reynolds (1962) compared schizophrenic and normal subjects' physiological activation under both normal and stress conditions. Although the normal subjects registered lower basal levels than schizophrenics, their reaction to stress conditions was greater. Similarly, Zahn (1964) studied chronic schizophrenic and normal subjects in five conditions varying in task demand. The normals' reactivity tended to vary with demand, while the schizophrenics', although exhibiting a higher basal level, varied comparatively less.

Finally, among introverts and extraverts, Corcoran (1965) found the physiological reaction to both noise and sleep deprivation to be greater for extaverts than introverts. Extrapolating to the active/passive task, then, we may expect to observe the following pattern of results:

1. Introverts are likely to perform better in the passive strategy than extraverts because introverts are by nature in a generally more beneficial state of activation.

2. The opportunity to control the task through modulation in activation state will benefit extraverts more than introverts, because extraverts possess greater scope for manipulation of activation state. Thus, extraverts should be able to perform the active strategy as well as, if not better than, introverts.

3. Finally, extraverts are more likely to provide the physiological evidence of activation state manipulations in the active strategy.

Experiments Seven and Eight were conducted to test these hypotheses. Experiment Seven was concerned solely with exploring the pattern of results obtained from introverts and extraverts using the traditional paradigm. At the same time, it provided the opportunity to locate and recruit introvert and extravert subjects and more importantly to familiarize them with the active/passive task in advance of the experiment in which heart rate was monitored (Experiment Eight).

EXPERIMENT SEVEN

Methodology

Stimulus Material: 120 lists of nine consonants each were prepared by sampling without replacement from a group of 18 consonants (all consonants except B, G, V). 60 lists were recorded at the rate of .5 seconds/item and 60 lists at 1 second/item. Six seconds lead-in beating preceeded each list.

Subjects: 22 (11 introverts, 11 extraverts) psychology undergraduates were selected from the first-year course. The method of selection was as follows: Form A of the Eysenck Personality Inventory (Eysenck and Eysenck, 1965) was administered to all students attending a lecture. Of those tested, 216 properly completed the form. The mean extraversion score for this groups was 12.26, with a variance of 18.54, and a standard deviation of 4.31. An arbitrary point of approximately one standard deviation above the mean (score 16) was selected, and students with scores at or above this cut-off were classified as extraverts. Students approximately one or more standard deviations below the mean (score 8 or lower) were classified as introverts. Of the 78 students classified as belonging to these two groups, 40 students were randomly selected and invited to participate in the experiment. 36 (19 introverts, 17 extraverts) actually participated in the experimental session. 14 of these were excluded from the final analysis for reasons stated in the results section.

Design and Procedure: 100 lists (50 of each rate of presentation) were selected as experimental trials, the remaining 20 (10 of each rate) were used as practice trials. The experimental trials were divided into four blocks of 25 trials each (two blocks of each rate of presentation). Subjects were divided into two groups. One group heard the blocks of trials in the order fast rate, slow rate, slow rate, fast rate, while the other group heard them in order slow, fast, fast, slow. Within each group one-half of the subjects adopted the active strategy for blocks one and three and the passive strategy for blocks two and four. For the other one-half of the subjects in each group the converse was true. An attempt was made to keep the number of introverts and extraverts performing each strategy-rate ordering as equal as possible. The strategy-rate ordering of the 20 practice lists (4 blocks of 5 trials each) was the same as in the experimental lists for each group.

20 seconds recall time separated each list. Subjects were given a one minute rest break between blocks one and two and blocks three and four, and a three minute break between blocks two and three. All subjects were tested between 5 and 6 p.m. and in groups of six to eight.

At the end of the session Form B of the Eysenck Personality Inventory was administered to all those in attendance. On Form B of the E.P.I. there was a general tendency for scores to be higher than on Form A (mean 14.00, variance 33.93, standard deviation 5.82). 14 subjects were excluded from the analysis of results. Three extraverts were dropped because their scores on Form B of the E.P.I. were lower than the cut-off point selected for Form A. Four introverts were dropped because their scores on Form B were higher than the cut-off point. One subject claimed to have had "memory training," one misunderstood instructions, and one was not native English speaking. These three subjects were also excluded from analysis. This brought the total number of subjects remaining in each group to 11.

Results and Discussion

Responses were scored on a strict ordered basis. Mean percent error is plotted against rate of presentation in Figure 5.1 for both introverts and extraverts in the active and passive strategies. An analysis of variance was conducted on the data. A summary of this analysis is presented in Table 5.1.

The overall results paralleled those reported earlier. Performance in the active strategy improved with the decrease in rate of presentation of the items, while performance in the passive strategy did not (strategy x rate interaction, $F = 20.33$; d.f. = 1,20; $P<.01$). Introverts and extraverts did not differ in achieved level of performance in the two strategies (introvert-extravert x strategy interaction, $F = 3.25$; d.f. = 1,20; critical value of F at .05 level = 4.35). However, a tendency for extraverts to benefit more than introverts from the change from passive to active selection was observed, consistent with the view that extraverts possess greater space for beneficial activation state changes than do introverts. It was thought possible, therefore, that analysis of the data on some criteria other than those represented by Figure 5.1 might isolate the locus of an introversion-extraversion difference. Since the difference in observed level of

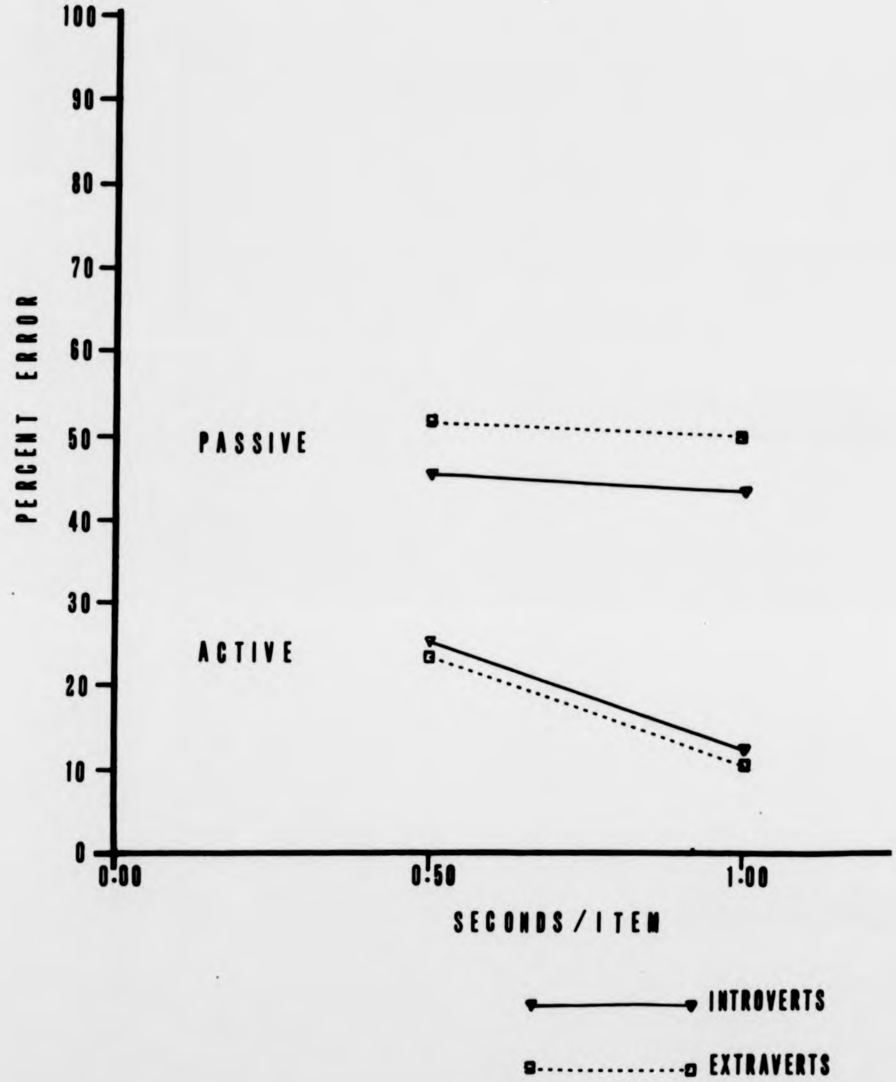

FIG. 5.1: EXPERIMENT SEVEN, MEAN PERCENT ERROR FOR INTROVERTS AND EXTRAVERTS IN THE ACTIVE AND PASSIVE STRATEGIES AT TWO RATES OF PRESENTATION (N = 11/GROUP).

Table 5.1: Summary of analysis of variance of data from Experiment Seven.

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects					
Introversion-Extraversion	122.91	1	122.91	0.40	N.S.
Subjects Within Groups	6199.05	20	309.95		
Within Subjects					
Strategy	19322.91	1	19322.91	170.59	<.01
Introversion-Extraversion x Strategy	368.18	1	368.18	3.25	N.S.
Strategy x Subjects Within Groups	2265.41	20	113.27		
Rate	1163.64	1	1163.64	16.85	<.01
Introversion-Extraversion x Rate	0.00	1	0.00	0.00	N.S.
Rate x Subjects Within Groups	1380.86	20	69.04		
Strategy x Rate	632.91	1	632.91	20.33	<.01
Introversion-Extraversion x Strategy x Rate	2.91	1	2.91	0.09	N.S.
Strategy x Rate x Subjects Within Groups	622.68	20	31.13		
Total	32081.45	87			

performance between the two groups remained the same irrespective of rate of presentation, rate is not likely to be a key determinant. Percent error for each group, therefore, was averaged across rate in both active and passive strategies.

Responses were rescored to determine percent error for each critical item on the assumption that the difference between introvert and extravert performance is unlikely to extend over the recency region of the serial position curve. A typical curve was obtained for the performance of both groups of subjects. These curves are presented in Figure 5.2 for the active and passive strategies averaged across rate. Introverts and extraverts recalled the eighth item of the list with equal frequency, while over the first three critical items, introverts recalled more items than extraverts in the passive strategy and fewer in the active strategy.

In view of this finding, an analysis of variance was conducted on the data from the second, fourth, and sixth positions of the curves in Figure 5.2. A summary of this analysis is presented in Table 5.2. As would be expected, the effects of strategy ($F = 171.15$; d.f.= 1,20; $P<.01$), and position ($F = 108.73$; d.f. = 2,40; $P<.01$), and the strategy x position interaction ($F = 15.20$; d.f. = 2,40; $P<.01$) are highly significant. More relevant to this discussion, the introversion-extraversion x strategy interaction is also significant at the .05 level ($F = 4.45$; d.f. = 1,20).

Thus, when scored on these criteria, introverts and extraverts do seem to cope with the active and passive tasks at differing levels of efficiency. From the graphs of the data in Figures 5.1 and 5.2, it appears that the bulk of the difference lies in the better

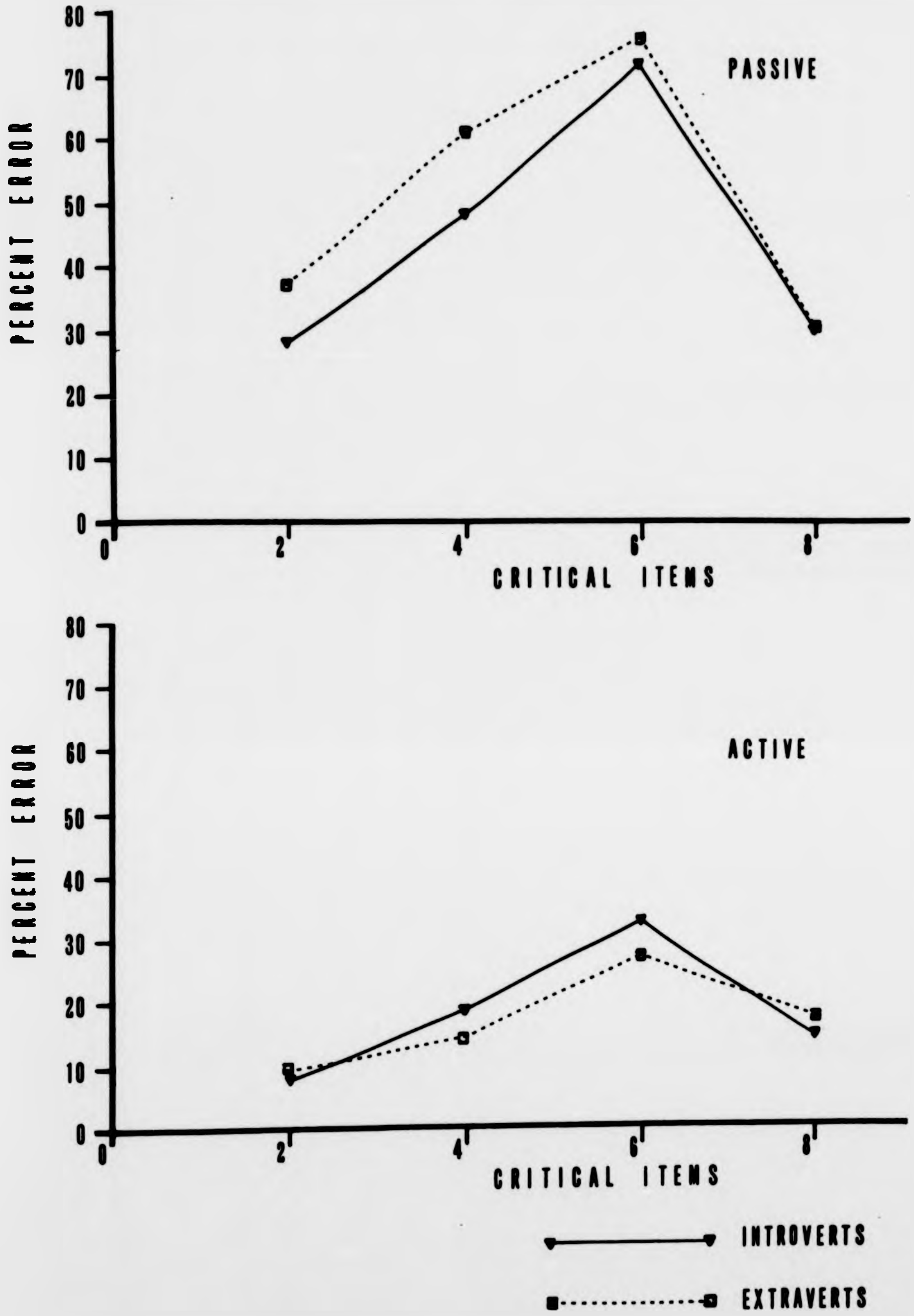

FIG. 5.2: EXPERIMENT SEVEN, MEAN PERCENT ERROR FOR INTROVERTS AND EXTRAVERTS AT EACH CRITICAL ITEM POSITION IN THE ACTIVE AND PASSIVE STRATEGIES, AVERAGED ACROSS RATE.

Table 5.2: Summary of analysis of variance of data from Experiment Seven, over the first three positions of the serial position curve and with fast and slow rates added together.

SOURCE OF VARIATION	S.S.	d.f.	M.S.	F	P
Between Subjects					
Introversion-Extraversion	58.67	1	58.67	0.83	N.S.
Subjects Within Groups	3000.24	20	154.01		
Within Subjects					
Strategy	10299.67	1	10299.67	171.15	<.01
Introversion-Extraversion x Strategy	267.76	1	267.76	4.45	<.05
Strategy x Subjects Within Groups	1203.58	20	60.18		
Position (2,4,6)	5492.56	2	2746.28	108.73	<.01
Introversion-Extraversion x Position	53.47	2	26.73	1.06	N.S.
Position x Subjects Within Groups	1010.30	40	25.26		
Strategy x Position	572.38	2	286.19	15.20	<.01
Introversion-Extraversion x Strategy x Position	33.29	2	16.64	0.88	N.S.
Strategy x Position x Subjects Within Groups	753.33	40	18.83		
Total	22825.24	131			

performance of introverts in the passive strategy. While extraverts perform the active strategy better than introverts, this difference is not as great as in the passive. However, the expectation expressed earlier appears to have been borne out. Extraverts benefit more than introverts from the opportunity to control the task through the phasic alternation in activation state allowed in the active strategy. Given these results, there is further justification for expecting to observe the actual physiological state cycling more readily in the extravert than in the introvert group. Experiment Eight was designed primarily to provide an environment in which to record heart rate while introvert and extravert subjects perform the active and passive strategies. Since it has been argued consistently that the time-course of subjects' preparations to receive stimuli forms the basis of the active strategy rate dependency, only the slow rate of presentation is employed in this experiment.

EXPERIMENT EIGHT

Methodology

Stimulus Material: 70 stimulus lists were prepared using the procedure stated in Experiment Two. All 70 lists were recorded at the rate of 2 seconds/item.

Subjects: 15 (7 introverts, 8 extraverts) psychology undergraduates. The 22 subjects whose results were analyzed in Experiment Seven were invited to participate in the present study. 18 (8 introverts, 10 extraverts) subjects agreed to participate. By the time this experiment was conducted six of the subjects were no longer enrolled in a psychology course. These subjects were paid for their participation.

Three subjects (1 introvert, 2 extraverts) were dropped from the analysis for reasons stated in the results section.

Apparatus: Subjects' heart rate was measured using a Devices Type 4522 instantaneous heart rate meter, which produces a DC voltage proportional to the inverse of the elapsed time between the two previous beats and is accurate to $\pm 2\%$. Output was stored on one channel of an FM tape recorder. The recording system consisted of a Ferrograph Stereo Audio Frequency recorder operating with a Lam Electronics FM adaptor to produce low-frequency response (bandwidth DC - 180 Hz, signal/noise ratio 44 db). Stimulus lists were stored on the second channel of the tape recorder.

Design and Procedure: Subjects performed both the active and passive strategies during the experimental session. 60 experimental trials were divided into four blocks of 15 trials each. One-half of the subjects in each group performed the active strategy in blocks one and four and the passive strategy in blocks two and three while the other one-half of the subjects followed the reverse order. 20 seconds recall time separated each list. Subjects were given a one minute rest break between blocks one and two and blocks three and four and a three minute break between blocks two and three. 10 practice trials, five active and five passive, preceded the experimental trials.

Subjects were tested individually at either 2:00 p.m. or 3:30 p.m. One-half of the subjects from each group were tested at the earlier time and one-half at the later time.

After each subject had been connected to the physiological recording apparatus he was instructed in the use of both strategies. Although the purpose of the equipment was explained in order to put the subject as much at ease as possible, the working hypothesis was not discussed.

Tape-recorded heart rate/stimulus lists were played to a PDP-11 computer via an analogue to digital converter. A computer program was written which sampled the analogue data every .5 seconds and digitized the data for subsequent rescaling and printout. The lead-in beating preceding each stimulus list acted as a signal to the computer to begin sampling the heart rate channel every .5 seconds beginning .5 seconds after the last metronome beat. Both the heart rate channel and the stimulus list channel were sampled for the duration of each trial (36 samples) and the resulting digitized values were stored on tape. The data was subsequently printed out as sequences of 36 heart rate values.

Some points in the output data showed unrealistically high heart rate readings. These occurrences appeared to be due to subjects coughing or disturbing the position of the electrodes temporarily. There was no pattern in the occurrence of this problem and it was treated most frequently by simply removing the unrealistic readings from the data. However, in the case of three subjects (1 introvert, 2 extraverts) the problem was so acute that these subjects were excluded from further analysis, leaving a total of 15 subjects (7 introverts, 8 extraverts).

Results and Discussion

The output data for each subject was divided into three categories, passive, active and active correct (active strategy lists in which the subjects made no errors). Each of the 36 heart rate samples was averaged across lists within these three categories to determine average heart rate at each sample point. A mean heart rate for each category was then calculated by averaging across the 36 sample points. Finally, percent deviation from this mean heart rate was calculated for each of the 36 points within each category. (Appendix IV shows this data for each individual.) Mean percent heart rate deviation for both extraverts and introverts was determined by averaging across subjects within each group and within each category. These scores were plotted against time of occurrence of each list item in Figure 5.3 for the extravert group and in Figure 5.4 for the introvert group.

The pattern of extravert heart rate deceleration and acceleration displays many of the features of the controlled activation process, and of its role in the active/passive paradigm, which have been described and/or explored in the previous discussions. In both the active and active correct list categories there is a clear pattern of heart rate deceleration beginnning about one second before each critical item and reaching peak deceleration just after critical item occurrence. Each deceleration is followed by cardiac accelerations which reach peak amplitudes in the immediate vicinity of the non-critical items. This pattern of physiological state change corresponds exactly to that predicted if subjects are capable of voluntarily changing activation state to meet anticipated task demand. The decelerations occur at the point in time at which efficient information intake will best serve performance. Similarly, the cardiac accelerations occur at the points in time in which efficient information intake will be most damaging to overall performance.

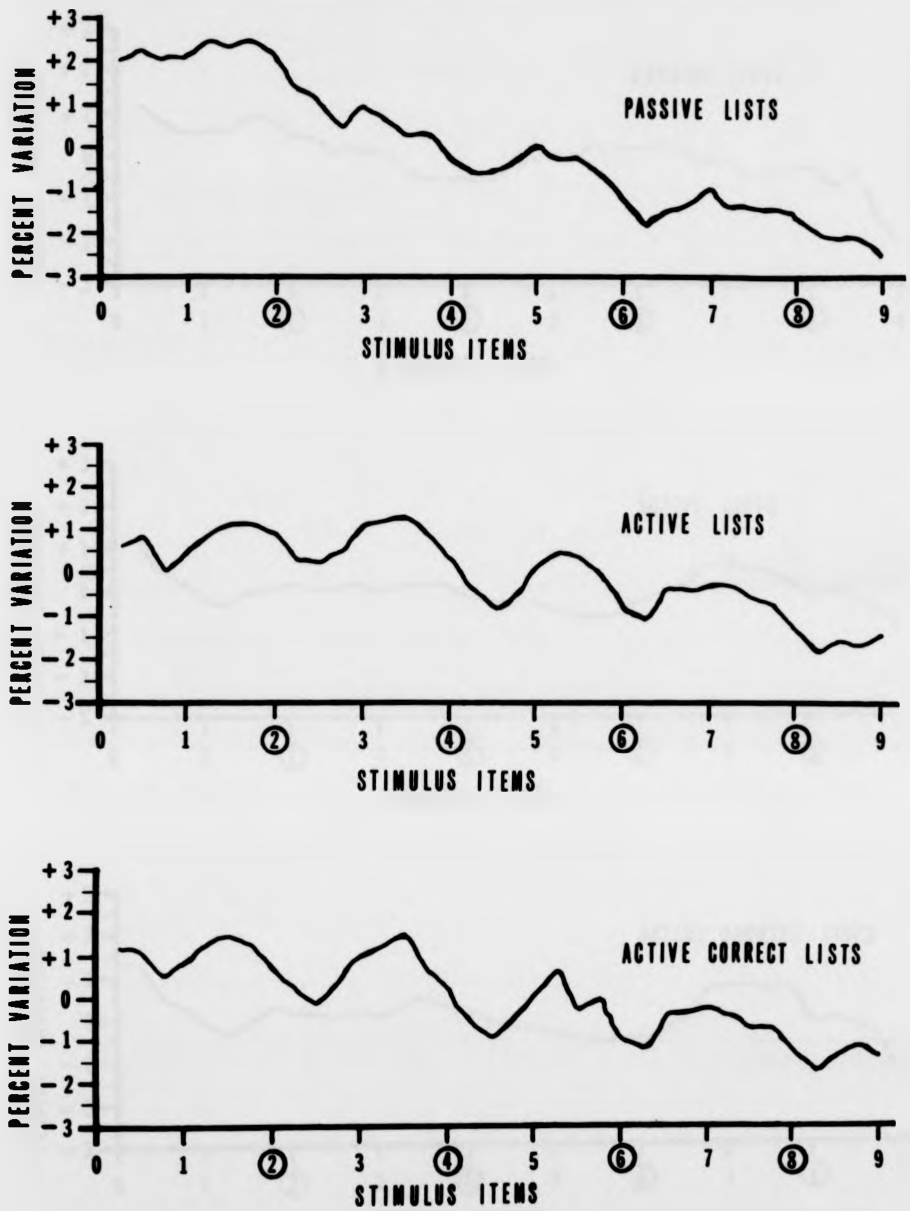

FIG. 5.3: EXPERIMENT EIGHT, MEAN PERCENT VARIATION FROM AVERAGE HEART RATE FOR EXTRAVERTS ON PASSIVE, ACTIVE, AND ACTIVE CORRECT LISTS (N = 8).

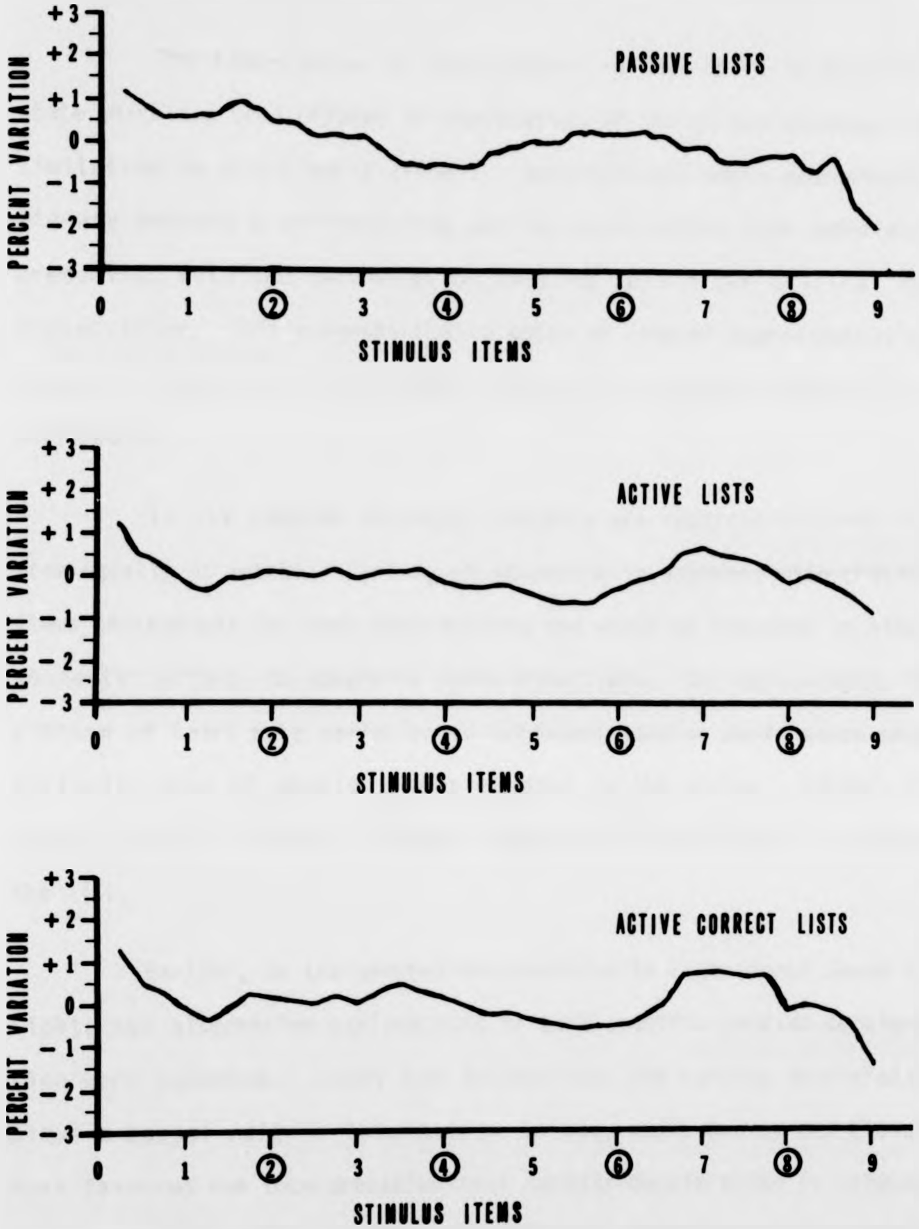

FIG. 5.4: EXPERIMENT EIGHT, MEAN PERCENT VARIATION FROM AVERAGE HEART RATE FOR INTROVERTS ON PASSIVE, ACTIVE, AND ACTIVE CORRECT LISTS (N = 7).

The time-course of development of the shift in activation state which has been offered in explanation of the active strategy rate limitation is also clearly evident. Decelerations begin approximately mid-way between a critical item and the non-critical item immediately preceding, with the deceleration peaking just after critical item presentation. This suggests that a space of time of approximately one second is required for the state change to be maximally beneficial to performance.

In the passive strategy, subjects are required to treat each item equally at intake. Cycling of attention in sequence with critical items contradicts the task instructions and would be expected to hinder subjects' efforts to adhere to these directions. Correspondingly, the pattern of heart rate variation in extravert passive performance shows virtually none of phasic shifts evident in the active. Rather, the passive curve in Figure 5.3 shows a progressive deceleration throughout the list.

Earlier, in the general introduction to Experiments Seven and Eight, two alternative explanations of task specific cardiac deceleration were reported. Lacey has argued that the cardiac deceleration plays a causal role in information intake, while Obrist and Elliott have favoured the interpretation that cardiac deceleration is evidence of a general inhibitory tendency which is conducive not only to environmental intake but to other tasks as well. Kahneman (1973) has described this inhibitory state as one of two or three general states which correspond to generalized alertness. The second pattern he describes as one of general sympathetic dominance which corresponds with effort toward response.

The inhibitory pattern, thus may be conducive to passive performance overall. As the load in memory store increases, the inhibition of motor activity serves to help the subject "hold on" to the task in hand.

Kahneman essentially regards the allocation of effort in information processing as task-driven. Effort investment, as measured through physiological state change is essentially homeostatic. As the task progresses the discrepancy between task demand and current investment is monitored, and as the discrepancy increases, additional resources are allocated to keep pace with the task. The passive strategy seems to provide evidence of how change in activation state is task-driven. As the number of items in store increases, heart-rate decreases.

The overriding goal of this research, however, has been to demonstrate that the allocation of effort can also drive the task. The extravert heart rate variation curve provides evidence to support this hypothesis. The activation state change in the active strategy occurs in anticipation of the presentation of the critical items, effectively biasing the system toward efficient processing of those items.

It is interesting to note that some evidence of both types of control appear in the active strategy data. The curves of extravert heart rate variation in the active strategy (Figure 5.3) show the phasic shift in sequence with the critical items, superimposed upon a general cardiac deceleration through the entire list, similar to that seen in the passive strategy. On the one hand, the cycling of heart rate indicates how subjects predict the need for effort investment and use their facility for control of state to ensure that critical items enter the system when it is in an optimum state for the task. On the other hand, the general deceleration throughout the list shows how the system progressively shifts state to cope with the increased demand of memory storage.

Thus far in this discussion of the results of Experiment Eight, the introvert cardiac variation has been neglected. The pattern of cardiac activity among introverts (Figure 5.4) is different from that of extraverts. In the two active categories none of the cycling of heart rate in phase with critical items is apparent. While there is some tendency toward general deceleration throughout the list this tendency is:

1. smaller in scope than among extraverts both in the active, as well as, the passive strategy; and

2. confined primarily to a drop in rate at the beginning and end of the list, with the middle of the list, especially over items two through six in the active categories, showing virtually no change.

This lack of phasic acceleration and deceleration in the active categories is not construed as damaging to the interpretation of extravert heart rate activity, nor indeed to the overall goal. As noted in the discussion of the rationale for selection of subjects, the introvert group was expected to show at most, less evidence of control through state modulation than the extraverts. Evidence was reviewed which suggested that introverts are less reactive to stress-induced state change, and it was hypothesized that they possess less space for voluntary change in state.

This argument does not pre-suppose that introverts are incapable of using the same general tactics to secure active performance as extraverts use, but rather that introvert facility for state change is restricted and not as readily subject to observation on the index chosen in Experiment Eight as is extravert activity.

An additional initial hypothesis was that the general "normal" activation state of introverts is more conducive to task efficiency overall. Therefore, it can be assumed that introverts "require" less state change to achieve efficiency. This would again argue that introverts should yield less evidence of state modulation in the active task.

A final possible contributor to the general pattern of the introvert heart rate curves should be explored. There is some evidence (Bakan, Belton, and Toth, 1963) that introverts can achieve the same degree of benefit from noise induced changes in activation that extraverts derive, but that they reach peak at a later point in time. While this is, in the first place, consistent with the view that introverts possess lower reactivity, it could also suggest that their time-course for optimal state change is considerably longer than the time allowed in active extraction.

While each and all of these explanations is possible, the introvert active performance (including the rate dependency) seen in Experiment Seven is here taken as sufficient evidence that introverts are employing the same general tactics as extraverts in coping with the active extraction task, but are less efficient or effective in using them.

Before further exploring the relevance of the results of Experiment Eight in the broader context of the control of information processing, one further observation should be recorded. While the graphs of Figure 5.3 show the mean percent heart rate variation for the extravert group, the active curves are more characteristic of some of that group than of others. This suggests the possibility that within the extravert group there is really a subset which possess all (or maybe some) of the activation-arousal characteristics which correlate with the personality inventory by which the two groups are categorized. Again, this finding is not construed as critical to interpretation of the results of Experiment Eight. It does, however, provide interesting possibilities for further exploration of the introvert-extravert classification, as well as research on individual differences in the control of activation state.

Thus far, this research has been aimed at demonstrating that optimization of state is a viable strategy in coping with task demand. It has been a goal to demonstrate that state change can control the information processing task by biasing the system to most efficiently process only the information which is required for good performance. Demonstration of this facility has hinged upon a task in which alternation between two opposing states best serves efficiency. Perhaps the more frequently encountered situation, however, is one in which some elements of the task demand, or tend to force, the organism into one state while concurrent demands are best met through a state which has a conflicting configuration in activation space.

If control of activation state is to be regarded as a viable strategy in the control of information processing on a broader scale than the active extraction task, then it is critical to be able to assume that the organism can also balance opposing demands.

There are many examples of experimental situations in which conflict occurs between the state to which the subject is "driven" and the state which would most benefit performance. The stress literature is filled with such cases. In these tasks there is frequently apparent failure of the subject to essentially override the state induced by the stressor in order to achieve or maintain the state most conducive to the task. However, some examples of subjects' ability to apparently override a detrimental state produced by a stressor in order to maintain efficiency are documented (Wilkinson, 1964, is among the most dramatic).

In other non-stress cases, there is apparent conflict between the state associated with one type of activity and the state associated with another type of activity required by the same task. In these situations evidence of subjects' ability to inhibit one state in favour of another is also available. Kahneman (1973) has reviewed two examples in relation to the variants of high arousal which he delineates. On the one hand, Elliott (1969) has shown parasympathetic dominance when verbalization should be sufficient to cause sympathetic dominance. On the other hand, Campos and Johnson (1967) have shown a reverse effect when attention to an external stimulus is required during verbalization. These studies would tend to indicate that subjects are able to use the controlled activation process to maintain state even when other activities in which the system engages would normally tend to require another state.

Experiment Nine, the final study reported in this research, was devised to provide further supporting evidence of this facility.

EXPERIMENT NINE

Conflict was set-up between the state associated with sympathetic dominance, which characteristically includes heart rate acceleration, by instructing subjects to verbalize during a task which would benefit from a parasympathetic pattern (heart rate deceleration). In this latter element of the task, subjects were required to maintain several items in memory store.

The task is adapted from the closed system thinking task Hamilton *et al*. (1977). Subjects were instructed to transform a series of consonants by adding four consonants to each in the series. The transformations were performed one at a time and subjects verbalized as they worked through the simple transform. At the same time, they were required to hold each transformed item in memory so that they could report the entire string as a group at the end of the task.

For comparison a second task was incorporated in which the only demand placed on subjects was to verbalize the transformation. No report of the final new series was required.

Methodology

Stimulus Materials: 30, 3" x 5" index cards on which were printed four random consonants.

Subjects: The 18 (8 introvert, 10 extravert) subjects who participated in Experiment Eight were invited to participate in the present task. As in Experiment Eight, those subjects no longer enrolled in introductory psychology were paid for their participation.

Design and Procedure: The experimental design was a simple one, adapted from Hamilton, Hockey, and Rejman (1977) as noted above. Subjects were shown each of the stimulus cards in turn. They were asked to perform a +4 transformation, adding four letters on to each consonant on the card. For the first 10 trials (No-store), subjects were asked to verbalize each transformation. Thus, for the sequence T L W F subjects would say "T U V W X--L M N O P--W X Y Z A--F G H I J." On the last two trials (Store-4), subjects were asked to verbalize the same transformation, but to store the transform for report of the entire sequence at the end. Thus, for the sequence T L W F subjects would say "T U V W X--L M N O P--W X Y Z A--F G H I J--X P A J." In the Store-4 condition subjects were instructed to be certain they were able to reproduce all four of the transformed letters before attempting to report any of them. They were told that they could covertly rehearse the transformed consonants in store before proceeding to the next transformation and before final report.

Before the 30 experimental trials subjects were given as many practice trials as they required. Subjects were self-paced when actually working on a transformation throughout the session. For the most part, subjects took a few moments rest break between each list, occasionally resting for longer periods in the Store-4 condition.

Subjects were tested individually at 2, 3, or 4 p.m. The testing times were as evenly distributed as possible among the two subject groups.

Throughout the session, subjects heart rate was monitored and recorded using the same apparatus described in Experiment Eight. Progress through each transformation was indicated by an electronic marker on the 2nd channel of the tape. The experimenter depressed a foot switch when the subject began and stopped verbalizing each transformation in both conditions, and again when the subject began report of the final transformed sequence.

Recorded heart rate was transformed in the same manner as in the previous experiment, using computer sampling every .5 seconds.

Results and Discussion

Heart rate data for only those trials in which subjects successfully completed the transformation were analysed. In the No-store condition, extraverts performed 79% of the transformations correctly while for the introverts this figure was 81%. In the Store-4 condition, extraverts were correct on 71% of the trials and introverts on 81%.

Since subjects worked at their own pace and since this pace varied considerably both within and across subjects, it is impossible to meaningfully display average heart rate variation for the two groups by showing each of the .5 second samples. Instead, heart rate output was broken into seven sections for the No-store condition and nine sections for the Store-4 condition. For the No-store condition these seven sections were:

1. 1st transformation (T_1).
2. Time between 1st and 2nd transformation.
3. 2nd transformation (T_2).
4. Time between 2nd and 3rd transformation.
5. 3rd transformation (T_3).
6. Time between 3rd and 4th transformation.
7. 4th transformation (T_4).

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on the 2nd channel of the tape. The experimenter depressed a foot switch when the subject began and stopped verbalizing each transformation in both conditions, and again when the subject began report of the final transformed sequence.

Recorded heart rate was transformed in the same manner as in the previous experiment, using computer sampling every .5 seconds.

Results and Discussion

Heart rate data for only those trials in which subjects successfully completed the transformation were analysed. In the No-store condition, extraverts performed 79% of the transformations correctly while for the introverts this figure was 81%. In the Store-4 condition, extraverts were correct on 71% of the trials and introverts on 81%.

Since subjects worked at their own pace and since this pace varied considerably both within and across subjects, it is impossible to meaningfully display average heart rate variation for the two groups by showing each of the .5 second samples. Instead, heart rate output was broken into seven sections for the No-store condition and nine sections for the Store-4 condition. For the No-store condition these seven sections were:

1. 1st transformation (T_1).
2. Time between 1st and 2nd transformation.
3. 2nd transformation (T_2).
4. Time between 2nd and 3rd transformation.
5. 3rd transformation (T_3).
6. Time between 3rd and 4th transformation.
7. 4th transformation (T_4).

For the Store-4 condition the same seven samples were used and the eighth consisted of the time between fourth transformation and the final report, and the ninth consisted of the final report of transformed four-consonant sequence.

The averaging procedure was as follows:

1. Heart rate for each of the .5 second computer samples was averaged within each section for the No-store and Store-4 conditions.

2. Mean heart rate for each subject was calculated by averaging across the seven sections for the No-store condition and the nine sections of the Store-4 condition.

3. Percent variation from this mean heart rate was calculated for each section of the two conditions for each subject. (The individual subject data is shown in Appendix V.)

4. Finally, mean percent variation for each section of each condition was calculated by averaging across subjects within the introvert and extravert groups.

This mean percent variation from average heart rate is shown for each section of the No-store condition for both introverts and extraverts in Figure 5.5 and for the Store-4 condition in Figure 5.6.

In the No-store condition, both introvert and extravert heart rate variation patterns reflect alternation in state, which is consistent with task demand. Heart rate increases during verbalization

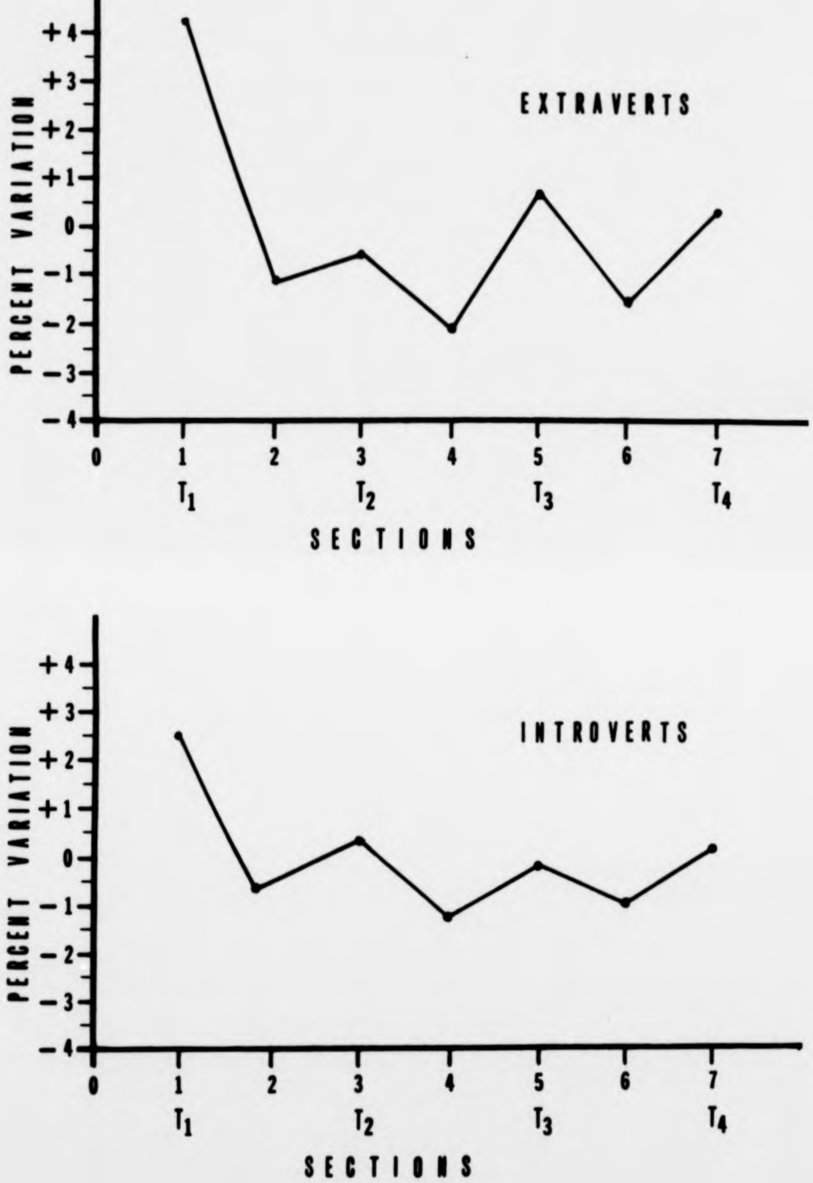

FIG. 5.5: EXPERIMENT NINE, MEAN PERCENT VARIATION FROM AVERAGE HEART RATE FOR EACH SECTION OF THE NO-STORE CONDITION FOR INTROVERTS (N = 8) AND EXTRAVERTS (N = 10).

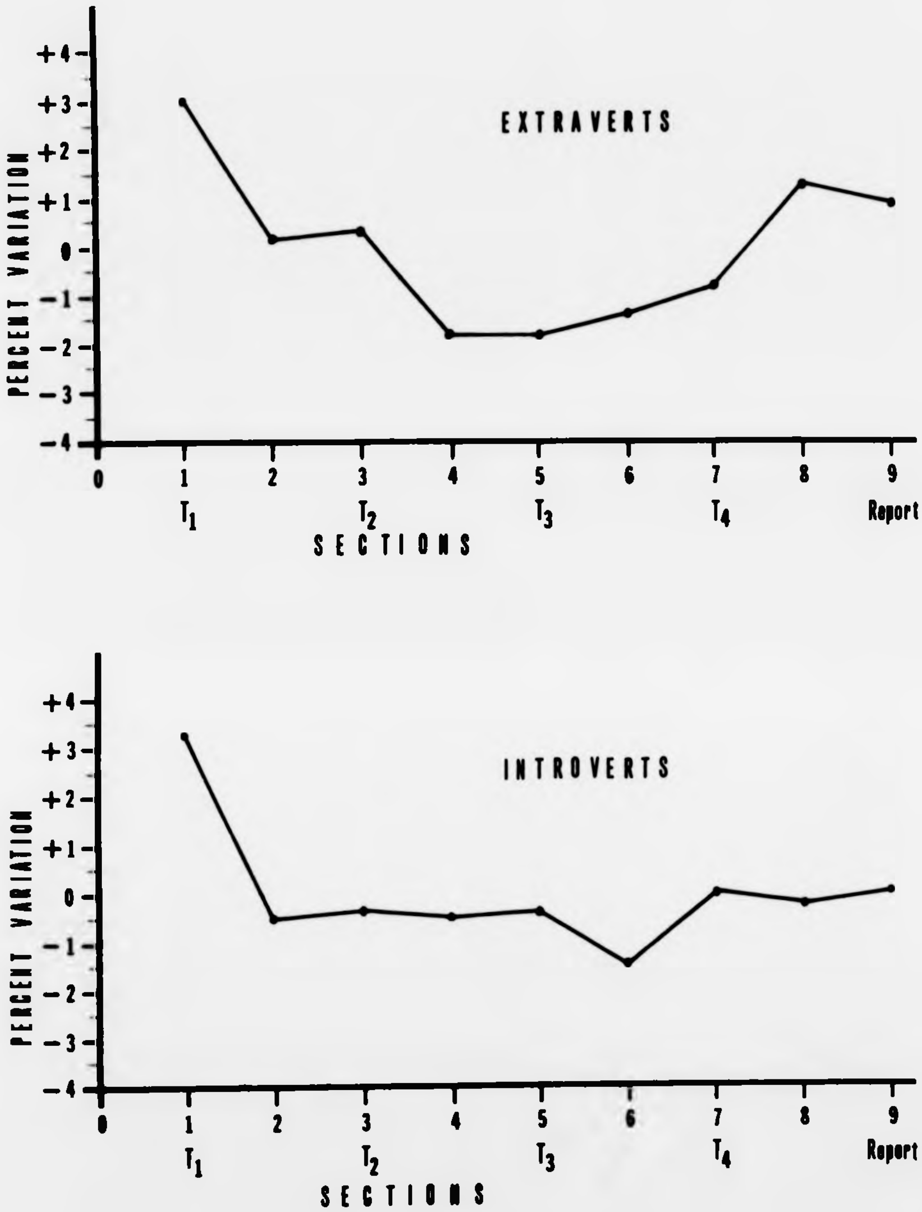

FIG. 5.6: EXPERIMENT NINE, MEAN PERCENT VARIATION FROM AVERAGE HEART RATE FOR EACH SECTION OF THE STORE-4 CONDITION FOR INTROVERTS (N = 10) AND EXTRAVERTS (N = 8).

(points T_1-T_4 in Figure 5.5), but decelerates in the intermediate points. In the No-store condition the intermediate points were brief -- only a few seconds -- and were characterized by subjects looking intently at the card to isolate the starting point for the next transformation. This is consistent with the type of activity associated with cardiac deceleration. When they began verbalizing the transformation, however, heart rate accelerates, presumably due to the return to normal sympathetic dominance produced by the motor activity involved.

Consonant with the introvert-extravert differences observed in Experiment Eight, it is interesting to note that the variation in heart rate is generally less in the introvert group. Again this suggests that introverts are either restricted in ability to move within activation space, or require less state change to achieve "acceptable" levels of performance. The fact that introvert accelerations during verbalization are less pronounced tends to support the former interpretation more than the latter, given that it has been assumed that heart rate acceleration here is caused by the motor activity rather than that the acceleration assists verbalization.

In the Store-4 condition a different pattern of heart rate variation is evident. Although heart rate is greatest at the initial verbalization of the transformation (T_1), there is virtually no increase accompanying the subsequent verbalizations during which the subject must actively maintain items in memory store. At these intermediate points of the Store-4 condition subjects were engaged in essentially two activities, covert rehearsal of the items in store, followed by looking at the next item in the sequence. (The period of time spent in each intermediate stage was considerably longer than in the No-store condition, and increased as the number of items in store increased, an indication of the greater degree of effort required by the Store-4 task.)

While heart rate deceleration is assumed to accompany alerted intake of external stimulation, heart rate decelerations in the Store-4 condition in the intermediate sections argue that deceleration is appropriate to alerted intake or observation of internal stimulation as well. The lack of acceleration during verbalizations therefore, indicates that subjects are indeed able to inhibit a state which would be detrimental to their hold upon this internalized information, and consequently upon their ability to report all four transformed items at the end of the sequence.

As observed in the No-store condition, introvert heart rate variation is again less pronounced than extravert. In the extravert group there is a fairly sizable acceleration occuring in Section 8 and through the report (Figure 5.6). This would appear to represent the general effort toward response. This is supported by the observation that subjects frequently spent less time in Section 8. They appeared to rehearse the previous three transformations during Section 6, perform the fourth transformation and then quickly give the final report. This seemed as if subjects were grabbing the initial items out of an "internal" echoic memory, the last item out of a true echoic memory, and then stringing them together for final report.

Both Experiments Eight and Nine have attempted to provide a physiological demonstration of controlled activation. In Experiment Eight the focus was on how the controlled activation process enables subjects to achieve active control of information processing. Experiment Nine was more concerned with how controlled activation allows the subject to maintain control of an information processing task when other task variables cause a tendency for activation state to modulate into an opposing state. Both of these demonstrations provide insight into the nature of the role which controlled activation plays in information processing. Therefore, discussion of both of these experiments is resumed in Chapter Six, which seeks to explore how the controlled activation process may reflect upon future models of the human information processing system.

CHAPTER VI

POSSIBLE IMPLICATIONS FOR FUTURE MODELS OF THE HUMAN INFORMATION PROCESSING SYSTEM

REVIEW

The introduction to this research reviewed two fundamentally different approaches to selective attention. It noted that although theories of involuntary and voluntary attention have both been concerned with how stimuli come to occupy consciousness they have stressed different means by which selection is achieved. The involuntary models have been developed through research on the OR. Within this reserach, two lines of inquiry have dominated. On the one hand, attempts have been made to categorize properties of stimuli which elicit the OR, while on the other, research has concentrated on describing the functional significance of the physiological manifestations of the response.

Berlyne (1960) described the stimuli which elicit the OR as possessing the "collative" properties of novelty, complexity and conflict-generating power. Kahneman (1973), however, has redefined these stimuli in terms of their processing requirement. He regards stimuli which are capable of eliciting the OR as those which inherently require full processing; and he further regards the information processing system as inherently biased to deal with these stimuli at the expense of other activities.

To some researchers, Berlyne included, the physiological manifestations of the OR have represented a generalized response of the system which increases overall efficiency in dealing with the alerting stimulus. This interpretation has been consistent with a unidimensional concept of arousal. Sokolov (1960), however, concerned with the lack of significant correlation among various indicies of the physiological response, has tended to view the response as composed of a loosely organized set of physiological reactions, each functioning to increase a specific aspect of system efficiency. Kahneman (1973) notes that these various reactions occur together because they are adaptive in dealing with several kinds of stimuli, rather than because they are linked together and incapable of occuring in isolation.

The topics of interest within voluntary attention have been quite different. A major goal of this body of research has been to describe the flow of information through an information processing system to response. The resulting models have been primarily structural in nature, and have dealt with characteristics of the individual information interpretive mechanisms, the inter-relationship among mechanisms, and the parameters governing the efficiency of the flow of information through the system.

Thus, there has been a lack of commonality between the issues of research in involuntary and voluntary attention. While voluntary attention has been concerned with the nature of the information interpreting routines applied to stimuli received by the system, research on involuntary attention has not. Similarly, while research on involuntary attention has been concerned with the functional significance of the physiological manifestations of the OR, for many years research on voluntary attention has only been concerned with how these variables interact with the interpretive routines. This interaction has been enshrined in the Yerkes-Dodson law and the unidimensional concept of arousal.

Recent years have seen significant efforts to bridge the gap between the divergent views of the human information processing system that these two types of research promote. The work presented in the preceding pages has been aimed at narrowing that gap further. It has fostered the view of the intensive resources of attention as an integral part of the human information processing system, and most specifically, the view of the intensive resources as subject to voluntary control in a manner similar to the interpretive resources of the system. This final discussion, therefore, seeks to explore how the results of the research presented here should reflect upon future speculation regarding the nature of control of human information processing activities.

Chapter I sketched a very brief and incomplete review of some of the research which has been conducted under the heading of voluntary attention. That review did not, nor did it attempt to, do justice to the level of understanding of the interpretive resources of information processing that that work has achieved. It noted, instead, that in terms of the goal of the research presented in this thesis, it is more critical to understand some of the conclusions that were formed.

The most significant of these is the view that man is capable of allocating his interpretive resources with considerable freedom and in anticipation of task requirements. Moray (1978), for example, portrays man as a strategic planner, capable of organizing his interpretive resources into coherent sequences of behaviour that bring about the goals that he sets in the most efficient way. In this view, man is clearly able to anticipate the demand for interpretive resources that the task imposes, and is able to deploy his resources in a manner befitting that demand. The exploration of controlled activation presented in the preceeding pages seeks to establish a case for viewing the intensive resources of the system as subject to control in a similar way.

Eventually, it must be possible to construct a detailed, integrated model of the human information processing system which allows for this type of control of the intensive resources. While the data currently available is not sufficient to warrant development of a integrated model of this type, the results of the nine experiments presented earlier do suggest what several of the features or characteristics of such a model may be. These will be discussed in this final chapter. However, two models of the human information processing system, or aspects of that system, which specifically integrate both types of resource have appeared in the literature to date. These are Kahneman's (1973) theory of mental effort and the Hamilton, Hockey, and Rejman (1977) control model of activation state-task state. Both of these have been reviewed in the preceeding pages, but a more extensive treatment of each is warranted at this time -- Kahneman's model because it has provided, at the same time, the most extensive model of the general class to which the controlled activation process belongs and because it does not accommodate controlled activation; and the Hamilton, *et al*. model because it outlines the basic features needed in a model which can accommodate controlled activation.

KAHNEMAN'S THEORY OF MENTAL EFFORT

Kahneman's (1973) theory of mental effort is significant because it is the first model which ascribes a role in the control of information processing to physiological activity. Additionally, one of the basic principles of his model is in direct contradiction to the research goals presented in this thesis. Kahneman regards his model as a capacity model. As noted in Chapter I, the idea of man as limited in his capacity to process information is one of the basic premises of the application of communication theory to human systems which has survived the years, despite the fact that the definition of capacity as the rate of information transmission through the system has been severely diminished in importance.

In general, it seems that capacity is some kind of a pool of "energy" available for constructing, accessing, and executing information processing routines. While some theorists tend to regard each information processing mechanism as having its own capacity limit (e.g. Sanders, 1977), for the most part capacity has been treated as an input to information processing activities which can be allocated to many different aspects of the system. Kahneman treats capacity in this aspecific way. He regards capacity or attention as intimately related to arousal, noting that increases in arousal serve to increase the capacity available for information processing activities. While there have been various attempts to measure the capacity invested in a task (Sanders, 1979, reviews and organizes some of this literature), Kahneman argues that capacity can be measured by moment to moment fluctuation in physiological activity.

Kahneman notes that most information processing activities require an investment of capacity, or effort, and that there is a standard investment of capacity to meet this demand. After Neisser (1967), he states that at least the early stages of perceptual analysis do not require capacity. However, Shiffrin and Schneider (1977), and Schneider and Shiffrin (1977), have recently provided a fairly comprehensive discussion of tasks which apparently require little and no capacity and how they come to be that way. They have made a distinction between controlled and automatic processing. In essense, controlled processing requires capacity, mental effort, or attention, while automatic processing does not.

Kahneman maintains that capacity is allocated to tasks with considerable freedom, according to the momentary intentions (such as the task goals) and enduring dispositions (such as, attending to the alerting stimulus of the OR) of the system. When the tasks in which man is engaged do not require all of the available capacity, spare capacity is invested in a passive monitoring of the environment. However, when a task requires more than its standard allocation, spare capacity can be diverted from perceptual monitoring and invested in the task. Similarly, if the capacity demands of one task exceeds its standard investment, as well as the available spare capacity (if any), capacity can be diverted to it from a secondary task, but at the expense of performance in that secondary task. Kahneman has provided quite an extensive review of the literature of task interference. He has interpreted this literature, at least partially, in terms of his capacity model. This is in contrast to the "structural bottleneck" interpretation which has been common in studies of voluntary attention for many years. Although Kahneman regards the structural models as valuable, his interest has been in showing that a capacity interpretation can account for a number of the findings on task interference.

Kahneman was concerned with the observation that man cannot invest as much effort in a simple task as he can in a difficult task (Kahneman, Peavler, and Onuska, 1968) and from this concluded that only through experience with a task can man determine that the standard investment of capacity is insufficient to meet task demand. In other words, the system is highly dependent upon feedback on the accuracy of its own output. Once the demand has been evaluated as being in excess of the capacity available within the system, capacity can be increased to meet the demand by increasing arousal.

Thus, moment to moment fluctuations in physiological activity reflect the demands of the tasks in which man is engaged. However, certain factors which affect arousal affect available capacity more indirectly. For example, Kahneman (after Easterbrook, 1959) regards the arousal increase produced by loud noise as primarily causing change in the policy by which capacity is allocated, and regards fatigue and low arousal as affecting the accuracy with which task demand is evaluated. These, in turn, result in insufficient change in arousal and/or allocation policy to meet the demand.

Kahneman does not subscribe to the unidimensional concept of arousal, although this is not totally apparent in the model described above. However, he notes that an arousal concept must be able to account for evidence of directional fractionation and situational stereotypy (Lacey, Kagan, Lacey, and Moss, 1963; Lacey, 1967; Libby, Lacey, and Lacey, 1973), and thus, must be described on more than one dimension and must be subject to both task-specific and inter-index variation.

Kahneman uses the term "pattern" of autonomic activity and notes that various indices of arousal are not coupled, but rather that they vary with greater independence than a unidimensional concept of arousal can explain. Although Kahneman did not attempt to catalogue task-specific autonomic patterns systematically, through reference to the heart rate literature, he did describe what he termed two task-specific variants of high arousal. Chapter V provided physiological evidence which supports the existence of both of these states, and they were introduced at that time as:

1) A state of motor inhibition which facilitates information intake and is characterized by cardiac deceleration.

2) A state of response readiness which facilitates responding and is characterized by cardiac acceleration.

Kahneman hypothesized the existence of a third state of relaxed acceptance of environmental stimulation, but noted that it was unclear whether this state needed to be distinguished from the first. To date, there has been no further evidence to confirm nor disprove its existence.

However, Pribram and McGuinness (1975) have tended to concur with Kahneman's inhibitory and response readiness states. They have provided evidence to elaborate two physiological control systems which they term the "activation" and "arousal" systems. They further present a classification of information processing tasks according to whether and when each system is involved. This classification relates to Kahneman's in that arousal is akin to the inhibitory state and activation to the response state. Pribram and McGuinness also elaborate a third system which coordinates the arousal and activation systems. This third system they say requires "effort." (Their use of the term, therefore, is different from Kahneman's in the sense that Kahneman equates attention, arousal, activation and effort.) Pribram and McGuinness further locate control of each of these systems within particular brain structures. The control circuits of the arousal system they locate in the amygdala, of the activation system in the basal ganglia of the forebrain, and of the coordinating system in the hippocampus.

To the extent that Kahneman's model implicates autonomic system change in control of information processing activities and to the extent that it suggests that the increased capacity resulting from autonomic change is subject to voluntary allocation among information processing activities, Kahneman's model parallels the implications of this research on controlled activation. However, to the extent that Kahneman's model portrays arousal as task-driven or as totally dependent upon feedback on the discrepancy between capacity and demand, it is unable to fully accommodate controlled activation. The controlled activation process is accommodated more easily within the views of Hamilton, et al. (1977) discussed in the next section.

Although Kahneman drew away from the unidimensional concept of arousal, and supported description of arousal on at least two primary dimensions, as noted before, his model does not capitalize upon this information. Kahneman's interest in the physiological manifestations of attention was primarily in isolating a single index of autonomic activity which can reliably reflect, on a moment to moment basis, the amount of effort invested in the task. He regards pupillary dilation as particularly useful in this respect (e.g., Kahneman and Beatty, 1966, 1967), although more recent research (Mulder, 1980) has shown measures of sinusarrythmia to be particularly powerful. Thus, Kahneman searched for a non-task-specific index of autonomic activity while clearly noting that task-specific patterns exist. Hamilton, et al. (1977) on the other hand, were more directly concerned with how these task-specific changes reflect upon cognitive function.

THE ACTIVATION STATE - TASK STATE CONTROL HIERARCHY

As reviewed in Chapter One, Hamilton, et al. (1977) are responsible for the reformulation of the arousal-information processing relationship in terms of activation state-task state. Through a series of experiments they were able to demonstrate that the pattern of results seen in a complex task performed under noise stress reflects the pattern expected from knowledge of the effect of noise upon each component individually. From these results they argued that change in activation state serves to increase the bias toward one or a class of competing component processes, which in turn reflects upon the selection of competing information sources or outputs.

Hamilton, et al. portray this influence for the state produced by noise in terms of the control hierarchy of Figure 6.2. They describe some of the principles of its operation as:

1) The priming or potentiation of the interpretive resources can occur at the same time as the state change at the left of the hierarchy. Posner and Boies (1971) have shown this clearly in the independence of the encoding and preparation functions in their reaction time studies.

2) "The degree of bias to any element at a given level reflects on the potential of its competitors" (p. 481). To illustrate this point, Hamilton, et al. cite Ninio and Kahneman (1973) who have shown that subjects are able to detect animal names occuring on brief dichotically presented lists with either high efficiency on one list, or with equal but lower efficiency on both lists.

3) To the extent that two competing tasks share common elements, both will benefit to the degree that the state change increases bias toward those elements. Hamilton, et al. have clearly demonstrated this principle in an adaptation of the active/passive listening task. At the same time as peforming one of the two listening strategies, subjects were required to monitor a second information source for the random occurrence of a tone. Detections in this secondary task, as measured by mean *d'*, increased in the vicinity of the critical items, when the subject shifts into a state appropriate to maximal receptivity (as indicated by cardiac deceleration in the extravert data of Experiment Eight). In passive listening, where state change cannot optimize performance because all items must be fully processed, detections remain at about the same level throughout the nine-item sequence.

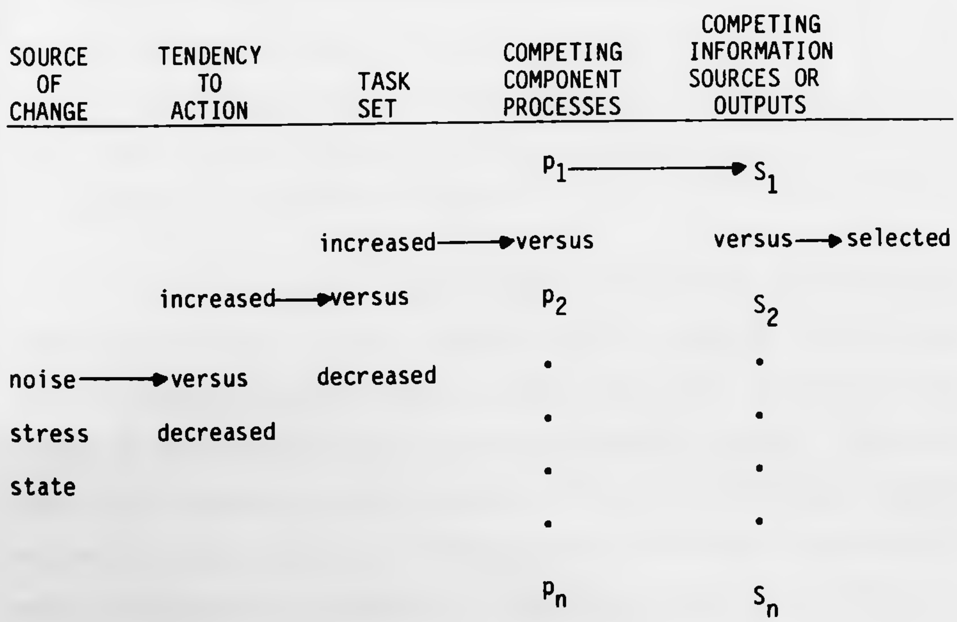

Figure 6.1: Control system hierarchy for the state produced by noise stress, from Hamilton, Hockey and Rejman, 1977 (p. 481).

Consonant with the views of Kahneman (1973) and the work of Pribram and McGuinness (1975), Hamilton _et al_. note that "activation state...is likely to be defined by variation on at least two major dimensions" (p. 480). The degree of precision they attempt in their description of how state change reflects on output through the hierarchy of Figure 6.1, as well as in their other discussions, reflects these primary dimensions. However, they state that efficiency of performance on various types of cognitive function is likely to relate to different points within the space defined by these two dimensions. The activation state of the organism, therefore, must be defined by the magnitude as well as the direction of change away from some neutral or normal state. Hamilton, _et al_. have essentially pulled apart the section of Kahneman's model which deals with arousal and the allocation policy, showing how stress-induced state change sets (at least to some extent) the policy by which capacity is allocated, by increasing the relative efficiency of wanted behaviours. In this respect they have been able to begin to answer questions which have arisen in the stress literature (e.g., Why do different stressors show different patterns of effect upon the same task? Why do some stressors serve to increase or decrease level of task performance while others do not?).

They have indeed suggested that stress should be defined in terms of the degree to which optimum state for the task differs from the state produced by the stressor, rather than simply in terms of the change in physiological activity produced by the stressor. But they have also shown how it should be possible to view non-stress induced activation state change, to a large degree, as reflecting the policy which the organism has adopted. They have noted, as did Näätänen

(1970) that the efficiency of behaviour is determined, in part at least, by the appropriateness of the state.

Hamilton, et al. went on to speculate upon the basic elements of a model for the voluntary control of activation state change which, again, takes conceptual elements of Kahneman's model to another level of generalization, but also leaves open the possibility of a predictive state change such as seen in the data presented in this thesis. They describe two primary features, a mechanism which selects the state desired to meet current processing goals (system monitor), and a state acquisition operation to execute the state change which the system monitor selects. By reference to the two known primary dimensions of activation state, Hamilton, et al. predict the following as characteristics of the operation of these features:

1) Both inputs and outputs can occur while the system is in any state, but the efficiency of handling either will depend upon the distance between actual state and optimal state for that activity.

2) The system monitor evaluates current state of the system in relationship to ongoing processing goals, and where mismatch between state and processing goals occurs, issues a command for a state change that will help capture currently wanted behaviour. Where input does not map directly onto output, the system will shift to a state appropriate to stimulus reception and categorization, and where categorized input does not map directly onto output, the system will shift to a state appropriate to output selection and response.

3) The state change inherent to the OR in this scheme represents the permanent bias of the monitor to issue a command for state change in response to novel events, although Hamilton, et al. offer the interesting suggestion that these novel events could be internally as well as externally generated.

4) Finally, they note after Pribram and McGuinness that the actual state acquisition process requires effort.

In most critical respects, the models of Kahneman and of Hamilton, et al. are similar. Both attach considerable significance to the role of the intensive aspects of behaviour in controlling information processing activities. While Kahneman's model treats activation state change as increasing an aspecific pool of capacity for information processing tasks, the Hamilton, et al. model seeks to come to grips with the goal-directedness apparent in particular patterns of state change by devising a scheme to allocate the influence of a given state through the system to response. In this respect the Hamilton, et al. model comes closer to the level of precision needed to account for the current data on controlled activation.

Both the Kahneman and Hamilton, et al. models allow for control over activation state. Kahneman portrays state change as the organism's efforts to deal with what has happened to him, and specfically warns against assuming that voluntary state change can occur as a result of what the organism thinks is going to happen to him. Hamilton, et al., on the other hand, recognize voluntariness of activation state, both to help capture wanted behaviours and to maintain currently wanted behaviours, such as in an attempt to resist induced state change or override states which are detremental to current processing goals. The system they describe, therefore, comes much closer to incorporating the view expressed in this thesis than does Kahneman's.

The remaining sections of this discussion explore how the results of the experiments presented in the preceding chapters may be reflected in the development of future models of the information processing system. The first section reviews the results which help justify the claim that state change can serve as part of the organism's plan for dealing with the future. The second section is concerned with the parameters governing the efficiency of use of controlled activation to meet anticipated demands, and what these parameters imply for the situations in which controlled activation is likely to prove a viable strategy in the control of cognitive operations. The final section is concerned with what the results of the experiments presented in this thesis imply concerning the control system in human processing.

JUSTIFICATION FOR ACTIVE CONTROL

It was a primary intention in the experiments of Hamilton and Hockey (1974) and of this author to:

1) Devise an experimental paradigm which allows opportunity for subjects to employ a controlled activation process, based upon guidance available from previous research.

2) Demonstrate that the results achieved under these conditions are amenable to interpretation as due to a controlled activation process, both by showing that the data have characteristics which previous research would lead one to expect, and by demonstrating that alternative interpretations of the results are inadequate.

3) Provide physiological evidence of a controlled activation process.

These goals have been addressed at various points within the previous chapters, and the rationale for accepting that a controlled activation process exists has been described. Therefore, this section is offered primarily as a review of how the research developed, the hypotheses which were tested, and the key findings which justify the existence of controlled activation as a means for achieving active control of information processing activities.

In order to provide the opportunity for subjects to be able to use controlled activation to take active control of the task, and to be able to observe this process, previous research has indicated that the task should provide:

1) An activity for which a task-specific activation state change, as measured by the direction of change on at least one index of physiological activity, is known (e.g., Lacey, 1967).

2) Time for state change to develop sufficiently to become a viable strategy for coping with anticipated demand (e.g., Posner and Boies, 1971).

3) An indication of the point in time at which state change should reach maximal amplitude (Tecce, 1972).

Additionally, there are the implicit assumptions that:

1) The task should not incorporate concurrent activities for which competing activation states are known.

2) The overall experimental design should incorporate a control task in which state selection is highly unlikely to serve as viable strategy for controlling information processing.

As described in the methodology section (Chapter III), the active/passive paradigm satisfies these needs in the following respects:

1) Several studies have indicated that cardiac deceleration occurs during alerted intake of information (e.g., Lacey, 1967). The active strategy required subjects to select designated inputs from a sequence.

2) A rate of presentation of list items slow enough for state change to develop (at least .5 sec., Posner and Boies, 1971) was incorporated.

3) The rate of presentation of the items was regular and subjects were given advance warning (via lead-in beats) of what that rate would be.

4) Cardiac acceleration is frequently observed when subjects are actively engaged in preparing and executing a response (e.g., Campos and Johnson, 1967). In the active/passive paradigm competition between stimulus reception and responding was kept to a minimum by:

   a) presenting a stream of items and not requiring overt response until the list was completed, and

   b) encouraging subjects not to rehearse presented items.

5) In the active strategy subjects were encouraged to listen only for the critical items, while in the passive strategy they were asked to treat all items with equal attention during input.

Having thus arranged a set of conditions which, as dictated by previous research, should tend to provide optimum opportunity for subjects to relegate primary control of the task to a controlled activation process, the results of the research should be expected to indicate the following:

1) Active extraction is superior to passive, but the efficiency of performance in the active strategy is rate dependent.

2) Active efficiency is not dependent upon the time required to process stimuli nor the effects of the informational content of the items presented, but is dependent upon the time of arrival of critical items. Thus, the locus of the effect of controlled activation is in the input stage.

3) Provided that the sequence of state changes appropriate to the selective listening task is amenable to observation, then physiological monitoring should indicate cycling of state with cardiac deceleration prior to the arrival of critical items.

The results of the various experiments conducted by Hamilton and Hockey (1974), reported in Chapter II, and those reported in Chapters III through V, have tended to confirm these expectations. Active extraction as measured by percent recall of critical items was shown to be superior to passive. This superiority was explained as representing the greater acquisition strength of critical relative to non-critical items which occurs due to subjects' shifting into a state of maximum receptivity before critical items arrive. By the stage of ouput, the greater acquisition strength of critical items has been translated into greater ease in discriminating of those items in memory store. (Experiment Six showed greater mean Δ_m-active than mean Δ_m-passive).

Active efficiency was shown to be rate dependent, while passive performance was not. In all but one (Experiment Four) of the experiments which employed the basic active/passive paradigm (as described in the methodology section of Chapter III) there was a significant strategy x rate interaction. Hamilton and Hockey (1974) showed that this rate limitation is not due to the time required to process (identify, categorize, store) stimuli within the system, but due to the time taken to prepare to receive them. They further demonstrated that preparation to receive stimuli is not a function of subjects being able to predict position in sequence of wanted items, but rather a function of opportunity to predict time of arrival of wanted items, by showing that active stragey performance deteriorates under irregular timing.

Similarly, Experiment Four indicated that this effect is independent of any benefit subjects derive from the opportunity to use characteristics of the informational content of the items to select ouptputs from the perceptual analyzers. From these results it was concluded that in the active slow condition, by the time critical list items enter the perceptual analyzers, a controlled activation process has already placed the system in a state conducive to critical item reception.

Finally, the extravert heart rate variation curve during active extraction (Experiment Eight) shows the predicted cardiac deceleration prior to the time of arrival of each critical item.

PARAMETERS GOVERNING THE USE OF CONTROLLED ACTIVATION

The above results have been interpreted as demonstrating that man has the ability to use the intensive resources of the information processing system to achieve a higher level of control than the task-driven, error-correction type of control which Kahneman (1973) regards as the limit of man's ability to voluntarily employ state change to aid cognitive function. In essence, these findings imply that man is able, at least where efficient intake of information is required, to predict when the work is going to get tough and is able to deploy his intensive resources in anticipation of this demand, in order ultimately, to help reach his processing goals. This type of control has been termed "active control" and the process by which it is achieved has been termed "controlled activation."

The results presented in this thesis, as well as in other sources, however, tend to indicate that man's ability to use the controlled activation process is limited by two basic types of factors: the predictability of his environment (external and internal), and the functional constraints upon his physiological system. These factors would seem to limit the types of situations in which controlled activation will provide a useful strategy for dealing with information processing tasks.

Kelley (1968), in his discussion of manual and automatic control, notes that for control to rise above simple error-correction, man must have an explicit representation of the task. Failure to adopt an appropriate task set, whether due to motivational variables or inefficient processing of the information needed to form that set due to fatigue or other factors, certainly prevents the possibility of using controlled activation to capture desired behaviours or maintain those that are currently wanted.

In the active extraction task, the time at which each successive operation is required was highly predictable, due to the regular presentation rate. Hamilton and Hockey (1974) found that active extraction is impaired when items are presented irregularly in time, and Tecce (1972) found longer reaction times when the foreperiod of the CNV studies was of unpredictable duration. These data, however, should not be interpreted as indicating that only precise temporal predictability is suitable for controlled activation. The deficit in active extraction under irregular presentation must be attributed, to some degree, to there being insufficient time between some stimuli for state change to develop. In fact, Tecce (1972) demonstrated that subjects show a different type of CNV, (one which rises to peak amplitude more slowly) when the onset of the imperative stimulus is less certain, than when time of onset is known precisely.

In everyday life, it is much more probable that man uses his knowledge of the sequential ordering of information and of relative timing to determine when various activities are required. The literature of human skills (e.g. Poulton, 1966; Welford, 1968), for example, shows that as man gains experience with a complex task, his behaviour appears to shift from that of an intermittent servo-mechanism to that of an adaptive and predictive controller. In a similar manner, Hamilton (1969) has shown that as man gains experience with diffrerent signal probabilities in multi-source monitoring tasks he is able to use his acquired knowledge of the relative probabilities of a signal occurring on each source to adopt a monitoring strategy. In a more everyday example, consider the situation of going to hear a lecture or to sit in on a seminar. One prepares to listen attentively when the speaker rises, clears his throat, and the room becomes quiet. Similarly, the man with the lottery ticket, mentioned in Chapter II, uses his knowledge of what the radio announcer is currently saying to predict the point in time at which he wishes to attend most fully. Martin (1972), in an example which bears clear relationship to application of controlled activation in the active extraction task, notes how man uses his knowledge of the hierarchical structure of speech and attends most fully during periods of low redundancy (in an informational sense) and devotes his attention to processing previous inputs during periods of high redundancy.

Most of the research presented in this thesis has concentrated on the use of controlled activation to help isolate desired inputs. The examples given above have focused on the same, where the anticipaton of time of arrival of these inputs is at least relatively predictable. Hamilton and Hockey (1974) have noted that a controlled activation process could serve to facilitate internalized thought as well. For controlled activation to be a viable strategy for coping with other aspects of task demand, information transformation, reduction, storage, response selection, etc., the relative timing and demand of these aspects of the task must be predictable as well.

Kahneman has interpreted evidence of physiological state change (pupillary dilation) in tasks where these more "internalized" activities are being performed as indicating that state change occurs only after the capacity supplied has proved insufficient to meet the demand (Kahneman, Beatty and Pollack, 1967; Kahneman, 1970). With data like these, where state change begins after a few moments at work, it becomes much more difficult to recognize the active or predictive use of state change.

The hypothesis which is offered here is that the state change _is_ a controlled activation process, an example of the situation where subjects use controlled activation process to maintain currently wanted behaviours, and hence progressively change state as their conception of the task indicates that maintaining that behaviour will become more difficult. The results of Experiment Nine may be a case in point. When no storage of transformed items is required, subjects move to a state appropriate to the verbalization of each transform. When, however, they must store each transformed item for future output, subjects maintain the state through the verbalization, possibly in anticipation of the difficulty of holding items in store. Campos and Johnson (1967) have found similar results in a different task.

The time-course of state change in controlled activation is likely to rather severely limit its applicability in the control of information processing tasks. As has been noted earlier, the time required for state change appears to be quite long, given the rate at which the interpretive resources are frequently required to, and do, shift among different types of function. Both the behavioural data gained in reaction time tasks (Posner and Boies, 1971; Klein and Kerr, 1974) and the evidence of CNV latency (Tecce, 1972) gained in a similar task, suggest that the time course of state change when subjects are awaiting a stimulus which requires immediate motor response is in the .4-.6 second range.

Observations from the current data suggest that optimum state change takes about twice this long when subjects must cycle preparations to receive stimuli (for later recall) through time. Hamilton and Hockey (1974) and Experiment Two (Chapter III) found close to error-free letter/digit recall at 1 second/item. Similarly, the active strategy extravert heart rate variation curves of Figure 5.3 showed that each separate cardiac deceleration and acceleration phase required about one second.

Thus, the time required to reach optimum state seems to be shorter for a task requiring immediate motor response following detection of a target stimulus, for example, than for a task requiring alternation between stimulus rejection and intake of items for later recall. A possible explanation of this difference in latency is that the magnitude of change required in the latter task is greater than in the former, and therefore takes longer to achieve. The rationale for this interpretation is as follows: Firstly, within both tasks performance improves up to the point that optimum state is achieved. Tecce (1972) found fastest reaction times when the largest amplitude CNVs were recorded. Similarly, Hamilton and Hockey (1974) and Experiment Two (Chapter III) both showed that performance improves as the rate of presentation decreases to 1 second/item. Both of these findings imply that within the task, magitude of state change determines the time required to reach optimum state.

Secondly, the state changes governing efficiency in both tasks have been regarded as producing an alert state conducive to information intake, and therefore are highly likely to be variations of state within the same major dimension of activation space (Hamilton, _et al._, 1977). Indeed, Lacey and Lacey (1970) have associated increased CNV amplitude with decreased heart rate. The state change of the CNV task requires subjects to move from some midpoint on this dimension.

However, if one accepts that cardiac acceleration occurs at points in time where stimulus rejection is a good strategy to adopt (Lacey, 1967, promotes this view although the reason for cardiac acceleration is disputed by, Obrist, et al., 1969, and Elliott, 1972), then the extraction task seems to require subjects to pass through this midpoint to points on opposite sides of it with each cycle. Thus, the change required from maximum amplitude in one direction to reach maximum amplitude in the other is greater than to reach maximum amplitude from a neutral start.

The active strategy extravert heart rate variation curves of Figure 5.3 clearly show cardiac accelerations and decelerations, but superimposed upon this pattern is a progressive cardiac deceleration. Therefore, to accommodate the interpretation that magnitude of change required accounts for the difference in optimum time-course one would have to assume that the midpoint progessively shifts throughout the sequence.

In Experiments One, Three and Four, words were used as the stimulus items, and only two rates of presentation (.5 and 1.33 seconds/item) were employed. At the slower rate, performance did not attain as high a level as with letters/digits (except when subjects were able to use a semantic cue in retrieval). Following the magnitude argument developed above, it may be possible to assume that words have a higher processing requirement and the state change required is larger than for letters/digits. However, it seems equally reasonable, if not preferable, to assume that word recall is more negatively affected by other factors, such as memory storage and retrieval problems than are letters/digits and that these difficulties cannot be overcome by a better input strategy (greater state change). Experiment Three has indicated that controlled activation does not help subjects overcome all the problems inherent to acoustic similarity, for example, and Experiment Six indicates that active extraction does not result in increased memory span to the level attained when no non-critical items are presented.

For the present it will be assumed that optimum state change in the active extraction task is independent of material type and is reached in about one second. However, it will also be assumed that the magnitude of the state change required determines the time it takes for state change to reach optimum amplitude.

In summary, the present data imply that man's ability to use controlled activation is time dependent. The larger the change in state that is required to optimize performance, the greater the amount of time (preview of the task demand) subjects require to achieve that state.

The length of time required to achieve state change clearly indicates that controlled activation will provide a viable strategy for dealing with a task only in situations where it takes some period of time to complete each stage of the processing. In Chapter I it was stated that controlled activation may be akin to concentration in an everyday sense. If this is the case, then the type of tasks in which controlled activation will be useful will be those which require concentration. This certainly excludes tasks which Schneider and Shiffrin (1977) have termed automatic, but also excludes tasks in which low levels of attention are required. Situations of this type are where stimulus-response links are inherently strong (the acoustic similarity among to-be-remembered items in Experiment Three may be such a case) or have been made strong through practice, and behaviour is essentially habitual. Driving a car is probably a good example of the latter, although one could argue that controlled activation processes probably helped develop this skill, and may be called into play when more difficult aspects of the task are imminent.

Subjects' ability to use controlled activation also appears to be limited by their degree of mobility within activation space. In the discussion of the results of Experiment Eight, three interpretations of the findings that introvert passive performance is slightly better than extravert, and that introverts do not show heart rate cycling were offered. These were:

1) Introverts are more restricted in the magnitude of movement within activation space that they can achieve.

2) Introverts require longer time to develop state change.

3) Introverts do not need to use state change to control the task as much as extraverts do.

From the data currently available it is not possible to totally determine which, if any, of these interpretations is correct. However, for the purposes of this discussion it will be assumed that the data of Experiments Eight and Nine indicate some mix of these views. On the basis of the finding that introvert passive performance is somewhat better than extravert, it will be assumed that introverts are inherently in an activation state more conducive to general efficiency than are extraverts. This view has been common in the literature (e.g. Eysenck, 1967). On the basis of the introverts' active stragey rate dependecy it is further suggested that introverts do attempt to use a controlled activation process in the extraction task. However, both the failure of introverts to show the heart rate cycling of extraverts, and the generally lower level of change in the heart rate variation data of introverts in Experiment Nine is interpreted as indicating that introverts are more restricted in their range of movement within activation space. As noted in Chapter V, this view has also received some support in the literature.

The possibility that certain individuals may be more restricted in the range of movement which they can achieve within activation space than others does hold obvious implications for there to be individual differences in ability to use controlled activation. Whether or not subjects adopt different methods or strategies for dealing with a task as a result of these possible restrictions is certainly unclear, but may be a useful hypothesis with which to approach the study of individual differences in behavioural efficiency.

Despite what appears to be restrictions upon the range of mobility within activation space, at least for some subjects, man does not appear to be severely limited in the number of state changes he can produce through time. Experiment Six suggests that subjects can and do use controlled activation during input sequences of at least as long as half a minute. Certainly, this ability is critical if controlled activation is going to serve any useful role in the control of ongoing activities.

The possibility of a restriction in the range of movement within activation space raises the question of whether a suitably motivated subject can voluntarily achieve the activation state produced by noise, for example, in order to achieve the same pattern of results obtained under noise. Certainly, a major difficulty in proceeding to investigate this point as the present time is a lack of information concerning the effects of stressors on various types of cognitive function and of the physiological states produced by those stressors. Hockey (1979) has suggested an overall research approach that would begin to catalogue these relationships.

IN CONTROL OF CONTROLLED ACTIVATION

At noted in the section of this discussion which reviewed the Hamilton, et al. activation state-task state control model, those authors described how it is possible to conceptualize the effect of activation state change upon the interpretive resources of the system through a control hierarchy, where the output of one stage of the system serves to increase the relative stregth of competing behaviours at the next level of the hierarchy. The structural models of the information processing system deal with the passage of information through the hierarchy of mechanisms within that system (e.g. Triesman, 1969) and provide a corresponding basis for assuming the differential priming of the competing behaviours at different points within that scheme. The structural models, however, look at the transmission of information once the system is set. The Hamilton, et al. control hierarchy, on the other hand, seeks to portray how the programming of the hardware of the mind/body-software/hardware distinction serves to increases the relative efficiency of different aspects of the software.

The research of Hamilton and Hockey (1974) and the research presented in this thesis have been concerned with how man makes use of his knowledge of the structure of his environment to form a preconception of what the demands of the task he faces are, and then programs the hardware of the information processing in a way that will help bring about his processing goals. This conception of the control of the system turns away from the view presented by Kahneman (1973) in that it portrays man as a planner, capable of deploying his intensive resources in anticipation of demand, rather than as using his intensive resources to reduce the increasing discrepancy between capacity and demand. Other parts of this thesis have been concerned with justifying this view, with evaluating how a controlled activation process adapted for dealing with the selective intake of environmental stimulation reflects upon the output of the control process, with speculating upon the functional significance of controlled activation in the broader scheme of the ongoing control of conscious activity. Certainly, the evidence is insufficient to completely justify the full ramifications of some of the positions adopted. But, as noted at the outset, the approach to this research has been of a shotgun nature, with no single line of inquiry taken through to the point where assertions could be made in complete confidence, for the sake of exploring what may lie down other avenues of approach.

One of the avenues which the collective results seem to have opened is the opportunity to begin to formulate a control model of a system whose output is activation state change. Hamilton, et al. (1977) sketched a brief scheme of a system which consisted of basically two elements, a system monitor charged with the responsibility of using the command for state change, once task demand specified the direction of change required, and the effector system (Executive) which executed that command. The existence of a effector system of this type does not seem to need justification at the hands of a behavioural psychologist, for it must be the responsibility of the physiologist to continue the line of inquiry opened by Pribram and McGuinness (1975). However, the sequence of operations which results in the system monitor issuing the command for activation state change to occur does, at this point, seem amenable to description in terms of a control system which performs the following functions:

1. Monitors the current activation state of the system.

2. Determines desired state needed to achieve processing goals.

3. Evaluates discrepancy between current and desired state.

4. Determines the time at which state change should occur.

5. Issues a command for state change at the time appropriate to meet demand.

There appear to be many "things" needed to fill in such a model. For the time being there are many questions and few answers, for example:

1. What is the form of the information which allows the system to monitor current state? One must assume the existence of some kind of feedback loop from the effector system.

2. Where does the information concerning what a desired state is come from? Is it a learned process? -- (in which case we should expect to find evidence that indicates that children have less facility over state selection than adults.) Can experience and learning, for example, explain the shorter attention span of children?

3. What are the representations of the controlled variable which allow comparison of desired state to actual state?

4. What is the nature of the link between the software of the information processing system which provides for task instructions and other indicators of the way in which information, or indeed information processing sequences are structured to be turned into input to a system which determines the time at which state change should be effected?

5. Once the command for state change has been issued, can that plan be executed basically open-loop, or is feedback on the progress of executing that command needed? Can the command be fine-tuned if feedback is available?

6. To what extent, if any, can we conceptualize the state change issued in the OR, for example, as one of a collection of stored programs of state change which are automatically activated by specific types of novel events?

Finally, at various points in the preceeding pages, it has been suggested that a controlled activation process serves as a fundamental process by which man concentrates his attention. It has been argued that that process indicates that man has a significant degree of volition in the control of his intensive resources. Yet, the type of system, probably with intricate feedback and feedforward loops that has been hinted above, is obviously quite mechanized itself. The most critical question, therefore, is where, in the model of the human information processing system, does the ultimate level of control lie? Is there an ultimate level, or are we simply looking at an infinite regression in the locus of control through a series of hierarchical control systems, each with complex interactions within and among each other?

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APPENDICES

APPENDIX I

Experiment Three, All Acoustically Similar Stimulus Lists

1. right quite sight light fight height bright spite might
2. came game name blame same claim shame frame flame
3. base face place case grace pace trace race space
4. date great late straight rate state wait gate hate
5. hear near dear tear clear mere fear rear cheer
6. pair hair care dare chair wear fair share bear
7. sweet heat meat treat greet beat seat street sheet
8. wing spring sing thing bring ring string king swing
9. rain pain train chain plain grain brain main strain
10. break make take lake bake cake shake wake sake
11. dead said read head thread bed instead spread led
12. ride side tried guide wide cried pride hide inside
13. mine fine sign nine dine line pine wine shine
14. mill bill fill hill kill still will till ill
15. nail sale fail mail rail pale trail scale tail
16. know grow show glow slow blow throw flow snow
17. pie buy lie sky high sigh dry fly cry
18. pour more door four shore roar store score floor
19. pray way day gray pay stay may play gay
20. drew blue true flew knew threw grew shoe two

APPENDIX II

Experiment Four, All Semantically Similar Stimulus Lists

1. father mother sister brother aunt cousin friend uncle relation
2. leg arm head foot hand finger skin knee heel
3. brain tongue eye ear nose hair face teeth cheek
4. shoe coat dress hat suit tie skirt cap uniform
5. red blue green yellow white black brown pink orange
6. August April July June March December October November September
7. doctor writer minister nurse poet editor teacher artist soldier
8. cat dog horse sheep goat cow bird bee lion
9. under over below beside above around inside behind beneath
10. good favourite best grand nice better superior excellent lovely
11. China Spain Germany France England Rome Russia America London
12. man child boy woman person baby creature individual girl
13. tiny brief big large huge short small tall wide
14. potato apple bread cake chicken pie corn egg cream
15. grass hill lake plant soil rock tree sand island
16. library school church house factory castle hotel hospital station
17. run walk climb stand dance jump leap move lean
18. Jim Mark Paul Peter Richard Thomas George John William
19. glass wood paper cotton diamond coal metal wool water
20. Russian English Greek Indian American French British German Dutch

APPENDIX III

Mean percent recall of each critical item in the passive, active and criticals only conditions in Experiment Six at each list length.

(III cont.)

LIST LENGTH 17/8

Item	PASSIVE PERCENT RECALL	ACTIVE PERCENT RECALL	Item	CRITICALS ONLY PERCENT RECALL
2	30.00	59.58	1	70.83
4	14.17	55.00	2	69.17
6	5.83	36.67	3	60.00
8	10.00	42.50	4	60.83
10	10.83	36.67	5	75.00
12	25.00	41.67	6	80.00
14	44.17	47.08	7	80.83
16	88.33	88.75	8	96.67

(III cont.)

LIST LENGTH 25/12

Item	PASSIVE PERCENT RECALL	ACTIVE PERCENT RECALL	Item	CRITICALS ONLY PERCENT RECALL
2	36.67	43.33	1	57.50
4	15.00	33.33	2	50.83
6	7.50	23.75	3	45.00
8	12.50	22.08	4	44.17
10	2.50	17.50	5	39.17
12	4.17	13.33	6	39.17
14	9.17	20.42	7	65.83
16	9.17	22.50	8	72.50
18	8.33	23.33	9	75.83
20	17.50	34.17	10	85.00
22	39.17	49.17	11	89.17
24	87.50	81.25	12	95.83

(III cont.)

LIST LENGTH 33/16

Item	PASSIVE PERCENT RECALL	ACTIVE PERCENT RECALL	Item	CRITICALS ONLY PERCENT RECALL
2	31.67	28.75	1	49.17
4	24.17	23.75	2	44.17
6	11.67	17.08	3	31.67
8	8.33	13.33	4	23.33
10	4.17	7.08	5	25.00
12	1.67	10.42	6	20.00
14	.83	11.25	7	23.33
16	13.33	20.42	8	25.83
18	2.50	16.25	9	40.00
20	3.33	17.50	10	38.33
22	3.33	14.17	11	35.00
24	13.33	16.25	12	46.67
26	5.83	15.42	13	57.50
28	7.50	25.83	14	77.50
30	32.50	41.67	15	89.17
32	82.50	93.33	16	100.00

(III cont.)

LIST LENGTH 41/20

Item	PASSIVE PERCENT RECALL	ACTIVE PERCENT RECALL	Item	CRITICALS ONLY PERCENT RECALL
2	44.16	40.00	1	53.33
4	46.67	30.42	2	40.83
6	25.00	26.25	3	31.67
8	11.67	20.42	4	24.17
10	1.67	15.42	5	17.50
12	0.00	10.00	6	17.50
14	.83	5.83	7	15.00
16	1.67	12.08	8	17.50
18	1.67	7.08	9	20.00
20	3.33	11.25	10	21.67
22	0.00	13.33	11	20.83
24	0.00	10.00	12	19.17
26	.83	5.00	13	22.50
28	1.67	10.00	14	26.67
30	1.67	8.75	15	36.67
32	1.67	11.25	16	43.33
34	5.83	20.00	17	60.00
36	15.83	22.50	18	67.50
38	34.17	33.75	19	87.50
40	84.17	83.75	20	93.33

APPENDIX IV

Percent deviation from average heart rate at each .5 second sample for each extravert and introvert subject in Experiment Eight for both passive and active strategies, and for the active lists in which the subject made no errors.

(IV cont.)

EXTRAVERT SUBJECT 1

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 80.74	ACTIVE CORRECT AVERAGE bpm= 80.67	PASSIVE AVERAGE bpm= 82.80
	1	1.51	1.51	1.30
	2	1.67	1.70	1.15
	3	1.05	1.19	2.05
1	4	1.26	1.49	1.16
	5	1.49	1.71	.76
	6	1.35	1.60	.37
	7	1.25	1.09	.50
2	8	1.67	.62	.76
	9	.25	-0.06	.63
	10	-0.04	-0.21	.28
	11	-0.47	-0.67	.34
3	12	-0.46	-0.72	.52
	13	-0.45	-0.92	.58
	14	-0.43	-0.86	.37
	15	-0.51	-0.90	-0.39
4	16	-0.58	-1.05	-0.62
	17	-1.20	-1.50	-0.89
	18	-0.77	-0.88	.41
	19	-1.09	-1.17	-0.14
5	20	-0.27	-0.20	-0.07
	21	.30	.46	.36
	22	.16	.27	.76
	23	-0.46	-0.36	.57
6	24	-0.95	-0.89	-0.17
	25	-1.47	-1.40	-0.69
	26	-1.28	-1.10	-0.62
	27	-0.92	-0.67	-0.69
7	28	-0.67	-0.41	-0.54
	29	-0.88	-0.58	-0.63
	30	-0.63	-0.36	-0.42
	31	-0.41	-0.17	-0.75
8	32	-0.07	.14	-1.10
	33	.30	.57	-1.18
	34	.56	.88	-1.04
	35	.94	1.34	-1.23
9	36	.14	.50	-1.57

(IV cont.)

EXTRAVERT SUBJECT 2

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 93.16	ACTIVE CORRECT AVERAGE bpm= 92.85	PASSIVE AVERAGE bpm= 94.12
	1	-3.34	-1.09	-2.01
	2	-1.43	-1.29	-0.47
	3	-1.49	-1.21	-0.21
1	4	-1.59	-1.15	-0.47
	5	-1.77	-1.37	-0.62
	6	-1.53	-1.43	-0.51
	7	-1.04	-1.03	-0.63
2	8	-1.35	-1.46	-0.87
	9	-1.52	-1.70	-0.79
	10	-1.37	-1.41	-0.17
	11	-1.07	-1.16	.33
3	11	-1.21	-1.27	.78
	13	-1.15	-1.15	1.24
	14	-0.94	-1.00	1.66
	15	-0.77	-0.83	1.42
4	16	-0.57	-0.50	1.27
	17	-0.21	.00	1.02
	18	.52	.74	1.29
	19	.71	.80	.93
5	20	.86	.96	.75
	21	.99	1.04	.48
	22	.97	1.01	.78
	23	.57	.55	.35
6	24	.54	.46	-1.11
	25	1.14	.96	-0.56
	26	1.76	1.50	-0.48
	27	2.01	1.62	-0.48
7	28	2.10	1.77	-0.44
	29	2.06	1.65	-0.16
	30	1.81	1.41	-0.12
	31	.93	.65	-0.46
8	32	.53	.34	-0.63
	33	.81	.52	-0.86
	34	.86	.53	-0.84
	35	1.29	1.03	-0.25
9	36	1.85	1.56	.18

(IV cont.)

EXTRAVERT SUBJECT 3

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 60.26	ACTIVE CORRECT AVERAGE bpm= 59.89	PASSIVE AVERAGE bpm= 58.00
	1	-0.15	-0.38	1.45
	2	-0.55	-0.80	2.91
	3	-1.61	-1.34	2.69
1	4	.78	.42	2.98
	5	1.11	.73	3.31
	6	2.79	2.12	2.34
	7	3.88	2.50	4.33
2	8	.43	-1.05	4.03
	9	-0.81	-2.02	2.16
	10	-4.07	-5.05	-0.64
	11	-2.44	-2.67	.64
3	12	2.21	1.37	1.48
	13	4.56	4.46	-0.40
	14	5.14	5.61	-1.59
	15	2.84	3.22	-2.02
4	16	1.03	1.40	-1.66
	17	-0.27	.42	-1.07
	18	-1.84	-1.05	-0.95
	19	-0.33	1.15	-0.29
5	20	.55	2.24	-0.55
	21	-0.33	1.42	-1.43
	22	-0.03	.10	-0.12
	23	.02	.30	-0.66
6	24	-3.04	-0.67	-0.93
	25	-3.32	-4.34	-1.59
	26	1.06	.67	-1.55
	27	-0.76	-1.24	-0.95
7	28	-1.31	-1.94	.21
	29	-0.76	-1.42	-2.19
	30	-2.59	-2.96	-3.55
	31	-1.13	-1.05	-0.55
8	32	-1.06	-1.07	.33
	33	-1.24	-0.90	-0.90
	34	1.23	2.74	-2.19
	35	-0.02	1.37	-1.79
9	36	.05	1.02	-1.48

(IV cont.)

EXTRAVERT SUBJECT 4

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 74.86	ACTIVE CORRECT AVERAGE bpm= 74.51	PASSIVE AVERAGE bpm= 74.16
	1	.13	.32	1.52
	2	.27	.86	.93
	3	.53	1.05	.09
1	4	.76	1.74	.17
	5	.81	2.38	.84
	6	.64	2.23	1.27
	7	1.08	2.56	1.51
2	8	1.02	2.12	1.11
	9	.80	1.89	.98
	10	.49	1.44	.80
	11	1.31	1.40	.65
3	12	.84	.21	.90
	13	.53	.58	1.08
	14	-0.03	-0.01	1.05
	15	.11	-0.01	1.47
4	16	-0.05	-0.85	.63
	17	-0.52	-1.46	-0.05
	18	-0.20	-1.57	-0.38
	19	-0.20	-1.50	-1.59
5	20	.15	-1.96	-1.27
	21	.36	-1.23	-0.92
	22	.48	-0.17	-0.47
	23	-0.09	-0.25	-0.74
6	24	-0.37	-0.50	-1.15
	25	-0.56	-0.71	-1.59
	26	-0.56	-0.68	-1.27
	27	.11	-0.08	-0.92
7	28	.37	.66	-0.47
	29	.67	-0.27	-0.74
	30	1.04	1.25	-0.31
	31	1.14	2.28	-0.39
8	32	-0.53	.44	-0.54
	33	-1.20	-0.38	-1.23
	34	-2.56	-1.84	-0.81
	35	-2.97	-2.20	-1.15
9	36	-3.86	-3.87	1.00

(IV cont.)

EXTRAVERT SUBJECT 5

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 75.42	ACTIVE CORRECT AVERAGE bpm= 75.35	PASSIVE AVERAGE bpm= 78.31
	1	4.16	4.59	3.66
	2	3.73	4.10	4.05
	3	2.36	2.75	3.09
1	4	2.82	3.22	3.09
	5	3.50	3.84	3.52
	6	3.42	3.65	3.84
	7	3.45	3.66	3.33
2	8	4.73	4.61	3.05
	9	4.26	3.99	2.32
	10	3.55	3.41	1.69
	11	2.96	2.81	2.36
3	12	1.80	1.57	3.26
	13	.95	.60	3.66
	14	.69	.40	2.32
	15	-0.13	-0.42	2.26
4	16	.66	.44	1.39
	17	.08	-0.15	1.03
	18	-0.78	-0.93	.11
	19	-0.98	-1.34	.92
5	20	-1.84	-2.24	.42
	21	-1.45	-1.78	-0.60
	22	-3.17	-3.41	-1.35
	23	-3.25	-3.49	-2.75
6	24	-3.70	-3.77	-3.55
	25	-3.62	-3.68	-3.36
	26	-2.56	-2.53	-2.71
	27	-2.36	-2.23	-3.61
7	28	-2.44	-2.31	-2.77
	29	-2.56	-2.34	-4.15
	30	-1.87	-1.67	-3.01
	31	-2.33	-2.19	-3.10
8	32	-2.06	-1.88	-3.26
	33	-2.23	-2.06	-3.26
	34	-1.84	-1.62	-2.68
	35	-2.21	-2.00	-3.61
9	36	-2.07	-1.82	-4.69

(IV cont.)

EXTRAVET SUBJECT 6

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 59.90	ACTIVE CORRECT AVERAGE bpm= 59.90	PASSIVE AVERAGE bpm= 58.33
	1	.62	NO	6.86
	2	2.04	ERRORS	5.69
	3	.32	IN	4.23
1	4	1.24	ACTIVE	3.22
	5	1.70	LISTS	3.00
	6	.12		1.89
	7	-0.58		2.06
2	8	.02		1.11
	9	-0.43		1.18
	10	-0.18		.84
	11	1.12		.24
3	12	1.15		.72
	13	1.14		.15
	14	1.82		-0.57
	15	1.59		.58
4	16	.22		-0.24
	17	-1.05		-1.47
	18	-1.70		-1.77
	19	-0.77		-0.93
5	20	1.80		-1.11
	21	3.62		-0.14
	22	4.89		-0.07
	23	3.69		-0.26
6	24	.45		-0.33
	25	-0.20		-1.51
	26	-1.85		-1.70
	27	-2.32		-2.06
7	28	-1.19		-1.77
	29	.57		-2.41
	30	-0.12		-2.11
	31	-0.73		-2.23
8	32	-1.70		-2.49
	33	-4.02		-2.40
	34	-4.99		-2.19
	35	-4.59		-1.51
9	36	-1.55		-2.37

(IV cont.)

EXTRAVERT SUBJECT 7

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 78.36	ACTIVE CORRECT AVERAGE bpm= 78.42	PASSIVE AVERAGE bpm= 79.88
	1	1.62	2.07	1.94
	2	.59	.99	1.95
	3	.59	.83	2.14
1	4	-0.26	.00	3.93
	5	.69	1.01	5.17
	6	.88	1.02	5.36
	7	.73	.85	5.57
2	8	.09	-0.17	5.16
	9	.27	-0.09	2.44
	10	-0.28	-0.65	1.24
	11	1.40	1.10	-0.69
3	12	2.74	2.51	-0.16
	13	2.36	2.12	-0.13
	14	1.80	1.54	-0.49
	15	.94	.79	-0.84
4	16	-0.46	-0.45	-1.53
	17	-2.12	-2.17	-2.05
	18	-2.85	-2.49	-3.12
	19	-1.95	-1.56	-2.58
5	20	.34	.27	-1.16
	21	.73	.69	-0.80
	22	.40	.34	-0.56
	23	.47	.58	.68
6	24	1.31	1.44	.33
	25	.03	.40	-0.44
	26	.63	1.02	.31
	27	1.68	2.13	.45
7	28	1.37	1.47	.75
	29	.06	.11	.31
	30	-1.51	-1.45	-0.56
	31	-0.23	-0.10	-1.13
8	32	-2.07	-2.12	-2.13
	33	-2.72	-3.21	-2.95
	34	-2.69	-3.34	-4.51
	35	-2.59	-3.21	-5.18
9	36	-1.45	-2.09	-6.66

(IV cont.)

EXTRAVERT SUBJECT 8

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 80.00	ACTIVE CORRECT AVERAGE bpm= 80.13	PASSIVE AVERAGE bpm= 78.57
	1	.68	1.56	1.84
	2	.54	.99	2.38
	3	-1.36	.05	2.53
1	4	-0.21	.21	2.84
	5	-0.01	.49	4.47
	6	1.98	2.26	4.66
	7	.45	.74	3.58
2	8	.71	.82	3.51
	9	-0.34	-0.17	2.63
	10	1.18	1.25	.39
	11	1.80	2.28	.14
3	12	2.53	3.97	1.65
	13	2.16	3.49	.92
	14	3.60	4.24	-0.08
	15	2.75	2.63	-0.24
4	16	2.61	2.03	-1.09
	17	2.11	1.17	-0.76
	18	1.18	.34	.36
	19	.94	.97	1.88
5	20	.49	.46	2.00
	21	.74	1.49	1.27
	22	-0.46	-0.67	-0.66
	23	-0.75	-1.01	-1.85
6	24	-0.99	-1.51	-2.02
	25	-0.71	-1.12	-4.17
	26	.64	.42	-2.76
	27	-0.37	-0.35	-2.27
7	28	-0.41	-0.27	-1.77
	29	-1.19	-0.94	-1.78
	30	-0.50	-1.51	-1.37
	31	-3.17	-4.12	-2.77
8	32	-3.80	-4.88	-2.35
	33	-4.06	-4.64	-3.35
	34	-2.35	-2.61	-2.95
	35	-3.10	-3.31	-2.34
9	36	-4.44	-4.77	-2.39

(IV cont.)

INTROVERT SUBJECT 1

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 92.07	ACTIVE CORRECT AVERAGE bpm= 92.07	PASSIVE AVERAGE bpm= 90.65
	1	1.37	NO	1.15
	2	.28	ERRORS	.98
	3	.87	IN	.19
1	4	.65	ACTIVE	-0.01
	5	.04	LISTS	-1.07
	6	-0.33		-0.64
	7	-1.17		-0.51
2	8	-2.01		-0.95
	9	-2.15		-1.16
	10	-2.47		-0.84
	11	-2.94		-0.09
3	12	-3.10		.02
	13	-2.70		-1.80
	14	-1.39		-2.91
	15	-1.29		-2.64
4	16	-1.15		-1.26
	17	-0.35		-0.55
	18	.98		1.24
	19	1.26		1.35
5	20	1.21		1.37
	21	1.35		1.60
	22	1.35		2.48
	23	.91		1.52
6	24	1.12		1.17
	25	1.90		1.10
	26	1.30		1.69
	27	1.77		1.01
7	28	1.12		.84
	29	-0.11		-0.08
	30	-0.30		-0.41
	31	.05		.22
8	32	.87		.43
	33	.88		-0.06
	34	1.89		-0.11
	35	2.07		-0.93
9	36	2.12		-2.18

(IV cont.)

INTROVERT SUBJECT 2

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 80.11	ACTIVE CORRECT AVERAGE bpm= 84.67	PASSIVE AVERAGE bpm= 80.20
	1	1.67	1.30	.47
	2	.90	.59	.73
	3	.90	.99	1.09
1	4	.30	1.05	.66
	5	.02	.25	1.96
	6	.71	1.28	2.78
	7	.31	3.22	3.17
2	8	.92	2.48	3.14
	9	1.96	2.43	2.43
	10	2.08	2.44	1.15
	11	1.98	2.08	.60
3	12	1.52	1.43	.46
	13	.00	-0.14	.77
	14	.10	.01	.32
	15	-0.29	-0.52	.27
4	16	-0.40	-0.56	-0.35
	17	-1.40	-1.81	-1.29
	18	-2.15	-2.59	-0.49
	19	-2.03	-2.46	-0.69
5	20	-0.91	-1.16	-0.50
	21	-1.10	-1.30	-1.12
	22	-0.14	-0.35	-1.22
	23	.00	-0.29	-1.30
6	24	-0.80	-1.56	-1.40
	25	-1.40	-1.92	-0.07
	26	-0.79	-1.15	-0.61
	27	-0.51	-0.52	-0.80
7	28	-0.04	.20	-0.93
	29	-0.16	.29	-1.69
	30	-0.02	.47	-1.26
	31	.25	-0.06	-0.80
8	32	-0.35	-0.85	-0.58
	33	-0.74	-0.85	-0.66
	34	-0.14	-0.06	-0.74
	35	-0.62	-0.54	-0.91
9	36	-1.57	-1.56	-1.64

(IV cont.)

INTROVERT SUBJCET 3

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 67.58	ACTIVE CORRECT AVERAGE bpm= 69.32	PASSIVE AVERAGE bpm= 67.57
	1	2.49	2.63	4.66
	2	2.59	2.78	4.40
	3	2.66	2.99	3.40
1	4	1.35	1.52	3.59
	5	.55	.59	3.30
	6	-0.22	.18	2.18
	7	-0.09	.13	1.28
2	8	.01	.27	.66
	9	-0.28	-0.37	-0.36
	10	-0.64	-0.75	-0.45
	11	.12	.10	-0.50
3	12	-0.41	-0.28	.14
	13	.77	1.05	.13
	14	.61	.77	.09
	15	1.30	1.67	-0.58
4	16	.89	.95	-0.39
	17	1.38	1.15	-1.00
	18	.71	.53	-1.38
	19	1.09	1.05	-1.07
5	20	-o.09	-1.13	-0.55
	21	-0.73	-0.61	-0.35
	22	-1.23	-1.05	.12
	23	-0.52	-0.38	1.10
6	24	.58	.22	1.21
	25	.81	-0.15	1.38
	26	1.05	.77	-0.20
	27	1.33	1.05	-0.92
7	28	1.35	1.39	-2.08
	29	.52	.52	-2.16
	30	-0.70	-0.50	-2.02
	31	-1.88	-1.82	-2.08
8	32	-2.50	-2.59	-1.28
	33	-1.98	-2.06	-1.30
	34	-2.77	-1.15	-2.22
	35	-3.43	-3.66	-3.10
9	36	-4.26	-4.63	-3.75

(IV cont.)

INTROVERT SUBJECT 4

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 75.36	ACTIVE CORRECT AVERAGE bpm= 76.12	PASSIVE AVERAGE bpm= 75.64
	1	1.96	1.71	-0.11
	2	1.79	1.56	.07
	3	1.69	1.27	.93
1	4	1.57	.86	1.98
	5	1.07	.29	1.77
	6	1.09	.50	1.85
	7	.53	.20	1.30
2	8	.80	.52	.47
	9	.13	.22	.63
	10	.57	.73	.39
	11	.28	.45	.56
3	12	.03	.32	.16
	13	-0.19	.08	-0.18
	14	-0.76	.85	-1.23
	15	-0.23	.26	-1.30
4	16	-0.05	.54	-0.97
	17	-0.53	-0.01	.33
	18	.29	.50	.66
	19	.49	.48	.70
5	20	.49	.19	.60
	21	-0.16	-0.57	.17
	22	-0.56	-1.14	.74
	23	-0.68	-1.26	.87
6	24	-0.38	-0.79	.64
	25	.25	-0.24	.22
	26	.53	.21	.28
	27	1.35	1.14	-0.12
7	28	.27	.32	-0.38
	29	-0.15	.01	-0.71
	30	-0.53	-0.21	-0.03
	31	-0.57	-0.20	-0.17
8	32	-1.66	-1.43	-0.81
	33	-1.34	-0.89	-1.22
	34	-2.04	-1.65	-2.75
	35	-2.23	-1.98	-2.75
9	36	-2.93	-2.63	-2.94

(IV cont.)

INTROVERT SUBJECT 5

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 70.10	ACTIVE CORRECT AVERAGE bpm= 70.15	PASSIVE AVERAGE bpm= 74.29
	1	-0.88	-0.98	-4.08
	2	-2.35	-2.47	-3.19
	3	-3.50	-3.62	-2.46
1	4	-3.44	-3.58	-1.78
	5	-3.35	-3.31	-1.29
	6	-2.82	-2.74	-1.76
	7	-2.64	-2.52	-1.57
2	8	-2.44	-2.32	-1.76
	9	-1.23	-1.24	-1.22
	10	-0.17	-0.09	-0.89
	11	1.50	1.64	-0.65
3	12	2.18	2.37	-0.40
	13	2.18	2.42	-0.48
	14	1.73	1.94	-0.92
	15	1.57	1.72	-0.78
4	16	.78	.86	-0.05
	17	.11	.23	-0.44
	18	-0.09	-0.10	.05
	19	-0.41	-0.38	.19
5	20	-0.41	-0.26	1.01
	21	-0.33	-0.16	.74
	22	.24	.30	1.01
	23	-0.09	.00	.78
6	24	.19	.07	1.28
	25	.13	.19	.93
	26	.33	.38	1.06
	27	1.60	1.77	1.60
7	28	2.23	2.45	1.37
	29	2.35	2.64	1.41
	30	2.78	2.94	1.74
	31	2.00	2.11	2.17
8	32	.83	.97	2.40
	33	.97	.11	1.74
	34	-1.10	-0.84	1.66
	35	-1.04	-0.77	1.75
9	36	-0.01	.43	.86

(IV cont.)

INTROVERT SUBJECT 6

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 79.34	ACTIVE CORRECT AVERAGE bpm= 79.21	PASSIVE AVERAGE bpm= 80.72
	1	1.93	2.41	3.47
	2	.74	1.05	3.07
	3	.08	.20	2.08
1	4	-0.81	-1.24	2.06
	5	.50	.37	2.14
	6	2.48	2.12	1.60
	7	3.08	2.99	2.27
2	8	3.10	2.87	1.60
	9	2.38	2.02	1.29
	10	.68	.16	.62
	11	.08	-0.30	.51
3	12	-0.83	-0.95	.32
	13	.05	.39	.51
	14	-0.82	-0.45	.05
	15	-0.93	-0.58	.31
4	16	-1.21	-1.01	-0.15
	17	-1.35	-1.14	-0.66
	18	-1.45	-1.43	-0.74
	19	-1.12	-0.88	-0.30
5	20	-1.29	-0.82	-0.48
	21	-1.05	-0.25	-0.38
	22	-1.74	-1.09	-0.78
	23	-1.46	-0.73	-1.31
6	24	-1.42	-1.00	-1.76
	25	-1.39	-1.02	-1.91
	26	-1.36	-0.97	-1.64
	27	.16	.39	-2.12
7	28	.35	.58	-0.98
	29	.60	.72	-0.88
	30	.50	.25	-1.34
	31	.81	.48	-1.24
8	32	.40	-0.23	-1.19
	33	.43	-0.38	-0.85
	34	.30	-0.64	-0.88
	35	-0.08	-0.77	-1.13
9	36	-0.40	-1.11	-1.00

(IV cont.)

INTROVERT SUBJECT 7

STIMULUS ITEM	SAMPLE	ACTIVE AVERAGE bpm= 85.84	ACTIVE CORRECT AVERAGE bpm= 85.93	PASSIVE AVERAGE bpm= 88.73
	1	.23	.37	1.13
	2	-0.43	-0.43	-0.20
	3	-0.55	-0.57	-1.94
1	4	-0.35	-0.35	-2.08
	5	-1.00	-1.05	-0.51
	6	-1.01	-1.05	.74
	7	-1.22	-0.93	.97
2	8	-0.59	-0.67	1.01
	9	-0.28	-0.43	1.35
	10	-0.02	-0.13	1.22
	11	.21	.08	.80
3	12	.39	.17	1.00
	13	.41	.51	.12
	14	1.08	1.22	1.18
	15	1.14	1.33	.89
4	16	.43	1.16	.26
	17	.58	.67	-0.35
	18	.05	.08	-0.51
	19	-0.84	-0.88	-0.73
5	20	-1.60	-1.73	-0.29
	21	01.96	-2.09	.02
	22	-2.26	-2.42	.38
	23	-2.09	-2.29	.70
6	24	-1.65	-1.87	.69
	25	-1.12	-1.32	.43
	26	-0.94	-0.92	.60
	27	.27	.19	.66
7	28	.48	.41	1.17
	29	.63	.67	1.10
	30	1.34	1.52	.90
	31	.93	1.13	.19
8	32	1.12	1.37	-0.51
	33	2.61	2.73	-2.38
	34	2.89	3.03	-1.83
	35	2.10	2.08	-2.83
9	36	1.16	1.09	-3.19

APPENDIX V

Percent variation from average heart rate for each extravert and introvert subject in each section of the No-store and Store-4 conditions of Experiment Nine. Rate data only for those trials in which the subject made no errors.

(V cont.)

EXTRAVERT SUBJECT 1

Section	NO-STORE CONDITION AVERAGE bpm= 85.27	Section	STORE-4 CONDITION AVERAGE bpm= 82.21
1	5.91	1	3.94
2	-0.71	2	-1.59
3	-1.53	3	1.60
4	-1.92	4	.60
5	-0.68	5	-0.32
6	-0.99	6	-1.38
7	-0.12	7	-0.84
		8	-1.90
		9	-0.10

CORRECT TRIALS = 8

CORRECT TRIALS = 5

(V cont.)

EXTRAVERT SUBJECT 2

NO-STORE CONDITION	AVERAGE bpm= 78.58	STORE-4 CONDITION	AVERAGE bpm= 74.02
Section		Section	
1	4.26	1	3.09
2	-3.04	2	-3.76
3	3.47	3	1.55
4	-1.63	4	-4.50
5	-0.66	5	.16
6	-4.40	6	-2.19
7	1.97	7	.12
		8	-2.97
		9	8.43

CORRECT TRIALS = 10

CORRECT TRIALS = 18

(V cont.)

EXTRAVERT SUBJECT 3

NO-STORE CONDITION	AVERAGE bpm= 59.78	STORE-4 CONDITION	AVERAGE bpm= 63.25
Section		Section	
1	3.23	1	1.71
2	-1.77	2	-0.43
3	-0.32	3	1.03
4	-1.67	4	-4.73
5	.85	5	5.17
6	-1.89	6	-7.47
7	1.57	7	3.38
		8	.30
		9	1.04

CORRECT TRIALS = 6

CORRECT TRIALS = 18

(V cont.)

EXTRAVERT SUBJECT 4

NO-STORE CONDITION

AVERAGE bpm= 74.76

Section	
1	7.48
2	-2.37
3	-3.68
4	-4.24
5	3.06
6	-0.75
7	.53

CORRECT TRIALS = 8

STORE-4 CONDITION

AVERAGE bpm= 77.17

Section	
1	6.79
2	-3.75
3	3.14
4	-0.58
5	1.15
6	-0.99
7	.27
8	-4.56
9	1.48

CORRECT TRIALS = 17

(V cont.)

EXTRAVERT SUBJECT 5

NO-STORE CONDITION

AVERAGE bpm= 99.40

Section	
1	-0.69
2	.09
3	1.55
4	-0.82
5	1.07
6	-2.35
7	1.15

CORRECT TRIALS = 9

STORE-4 CONDITION

AVERAGE bpm= 99.03

Section	
1	-0.97
2	2.05
3	-0.89
4	-2.32
5	-3.16
6	-0.86
7	.29
8	4.66
9	1.20

CORRECT TRIALS = 17

(V cont.)

EXTRAVERT SUBJECT 6

NO-STORE CONDITION

AVERAGE bpm= 78.86

Section	
1	1.08
2	-0.29
3	-0.22
4	-0.90
5	.53
6	.13
7	-0.36

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 79.38

Section	
1	-1.83
2	-0.34
3	-0.15
4	-1.21
5	-0.32
6	-1.17
7	-0.68
8	3.40
9	-0.01

CORRECT TRIALS = 14

(V cont.)

EXTRAVERT SUBJECT 7

NO-STORE CONDITION

AVERAGE bpm= 112.43

Section	
1	3.89
2	.25
3	-0.58
4	-0.83
5	-0.02
6	-1.13
7	-1.60

CORRECT TRIALS = 9

STORE-4 CONDITION

AVERAGE bpm= 113.49

Section	
1	4.89
2	1.04
3	-1.31
4	-1.21
5	-3.01
6	-0.88
7	-0.44
8	.04
9	.85

CORRECT TRIALS = 12

(V cont.)

EXTRAVERT SUBJECT 8

NO-STORE CONDITION

AVERAGE bpm= 79.33

Section	
1	8.27
2	.02
3	-2.32
4	-2.28
5	.13
6	-3.11
7	-0.71

CORRECT TRIALS = 9

STORE-4 CONDITION

AVERAGE bpm= 79.63

Section	
1	8.84
2	5.74
3	1.17
4	-3.97
5	-4.47
6	-4.57
7	-6.33
8	4.33
9	-0.75

CORRECT TRIALS = 11

(V cont.)

EXTRAVERT SUBJECT 9

NO-STORE CONDITION

AVERAGE bpm= 74.18

Section	
1	3.42
2	.12
3	-2.74
4	-3.85
5	.24
6	1.63
7	1.16

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 72.92

Section	
1	2.87
2	-0.87
3	.04
4	-1.39
5	-7.89
6	-0.48
7	-1.37
8	2.07
9	2.81

CORRECT TRIALS = 15

(V cont.)

EXTRAVERT SUBJECT 10

NO-STORE CONDITION

AVERAGE bpm= 75.65

Section	
1	6.71
2	-4.63
3	.58
4	-4.59
5	3.83
6	-2.55
7	.65

CORRECT TRIALS = 8

STORE-4 CONDITION

AVERAGE bpm= 75.43

Section	
1	.12
2	1.67
3	-2.03
4	-0.11
5	-3.62
6	2.29
7	-2.69
8	6.91
9	-2.48

CORRECT TRIALS = 15

(V cont)

INTROVERT SUBJECT 1

NO-STORE CONDITION

AVERAGE bpm= 79.97

Section	
1	2.55
2	-2.69
3	-3.23
4	-1.28
5	2.74
6	1.51
7	.35

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 79.87

Section	
1	4.62
2	-2.59
3	1.11
4	2.93
5	2.33
6	-0.89
7	-2.29
8	-3.79
9	-1.46

CORRECT TRIALS = 17

(V cont.)

INTROVERT SUBJECT 2

NO-STORE CONDITION

AVERAGE bpm= 80.45

Section	
1	8.53
2	8.30
3	-3.59
4	-4.25
5	-6.07
6	-1.49
7	-1.43

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 79.92

Section	
1	3.07
2	-2.69
3	-2.39
4	.18
5	4.12
6	-3.04
7	.54
8	-0.21
9	.41

CORRECT TRIALS = 11

(V cont.)

INTROVERT SUBJECT 3

NO-STORE CONDITION

AVERAGE bpm= 69.07

Section	
1	1.78
2	-1.97
3	1.69
4	-0.80
5	1.24
6	-2.52
7	.55

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 70.33

Section	
1	-0.16
2	1.65
3	-0.80
4	-0.24
5	-2.33
6	-0.27
7	-1.07
8	3.73
9	-0.51

CORRECT TRIALS = 16

(V cont.)

INTROVERT SUBJECT 4

NO-STORE CONDITION

AVERAGE bpm= 99.39

Section	
1	1.56
2	-2.10
3	2.23
4	-0.28
5	1.95
6	-2.95
7	-0.44

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 98.39

Section	
1	3.53
2	4.53
3	1.45
4	-0.64
5	-2.94
6	-2.07
7	-3.25
8	-1.98
9	1.40

CORRECT TRIALS = 14

(V cont.)

INTROVERT SUBJECT 5

NO-STORE CONDITION

AVERAGE bpm= 65.51

Section	
1	2.26
2	-2.52
3	-0.52
4	-3.10
5	3.53
6	1.24
7	-0.87

CORRECT TRIALS = 8

STORE-4 CONDITION

AVERAGE bpm= 64.62

Section	
1	5.09
2	-1.98
3	-3.48
4	-0.71
5	1.47
6	.57
7	.26
8	-1.50
9	.22

CORRECT TRIALS = 14

(V cont.)

INTROVERT SUBJECT 6

NO-STORE CONDITION Section	AVERAGE bpm= 71.73
1	2.43
2	-1.13
3	-1.44
4	-3.25
5	1.81
6	-o.63
7	2.09

CORRECT TRIALS = 9

STORE-4 CONDITION Section	AVERAGE bpm= 73.33
1	3.07
2	-3.07
3	.33
4	-1.61
5	.22
6	-3.16
7	.48
8	1.81
9	2.55

CORRECT TRIALS = 12

(V cont.)

INTROVERT SUBJECT 7

NO-STORE CONDITION	AVERAGE bpm= 94.33
Section	
1	-2.71
2	-3.92
3	3.36
4	1.90
5	3.52
6	-1.25
7	-0.88

CORRECT TRIALS = 8

STORE-4 CONDITION	AVERAGE bpm= 94.44
Section	
1	3.37
2	1.85
3	-1.02
4	-0.14
5	-4.69
6	-1.31
7	3.59
8	1.60
9	-3.28

CORRECT TRIALS = 13

(V cont.)

INTROVERT SUBJECT 8

NO-STORE CONDITION

AVERAGE bpm= 93.14

Section	
1	2.67
2	-0.78
3	1.17
4	-1.86
5	.45
6	-2.46
7	.83

CORRECT TRIALS = 10

STORE-4 CONDITION

AVERAGE bpm= 91.64

Section	
1	3.45
2	-2.71
3	1.10
4	-3.20
5	.34
6	-1.04
7	1.72
8	-0.84
9	1.15

CORRECT TRIALS = 17

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END