44798

National Library of Canada
Canadian Theses Division
Ottawa, Canada
K1A 0N4

Bibliothèque nationale du Canada
Division des thèses canadiennes

# PERMISSION TO MICROFILM — AUTORISATION DE MICROFILMER

• Please print or type — Écrire en lettres moulées ou dactylographier

Full Name of Author — Nom complet de l'auteur

RANDOLPH MICHAEL JOHN PETRUK

Date of Birth — Date de naissance

MAY 11, 1949

Country of Birth — Lieu de naissance

CANADA

Permanent Address — Résidence fixe

RR #3 FT. SASKATCHEWAN, ALBERTA

Title of Thesis — Titre de la thèse

A PROCESS INTERPRETATION OF ATTENTION

University — Université

UNIVERSITY OF ALBERTA

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

Ph. D.

Year this degree conferred — Année d'obtention de ce grade

1980

Name of Supervisor — Nom du directeur de thèse

DR. A.R. DOBBS



Date

MAY 12, 1980

Signature

Randy Petruk

NL-91 (4/77)

## NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

## THIS DISSERTATION HAS BEEN MICROFILMED EXACTLY AS RECEIVED

## AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

## LA THÈSE A ÉTÉ MICROFILMÉE TELLE QUE NOUS L'AVONS REÇUE

THE UNIVERSITY OF ALBERTA

# A PROCESS INTERPRETATION OF ATTENTION

by

© RANDOLPH MICHAEL JOHN PETRUK

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1980

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "A Process Interpretation of Attention" submitted by Randolph Michael John Petruk in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

............................................
Supervisor

............................................

............................................

............................................

............................................

............................................

............................................
External Examiner

Date Dec. 10, 1979

ABSTRACT

The attentional phenomena arising in several different methodologies are reviewed, and it is argued that selective behaviors seem to be an implicit aspect of most, if not all, cognitive processes. A theoretical orientation is advanced to account for selection across this broad range of paradigms. Basically, it is argued that selection results from the progressively focused activation of neural representations, depending on the complexity of the task demands of an experimental situation. This orientation is compared with other theories of selective attention, and is extended to account for such phenomena as consciousness, memory, and the icon. Two experiments were conducted to examine some of the major assumptions underlying this approach. The first experiment involved presenting a search set of 2, 4 or 6 letters and then a single letter probe, and required matches to be based on physical or name information. The second experiment was identical to the first study except the probe letter preceded the search set. In both experiments the pattern of errors and decision reaction times were similar and suggests that a filter cannot account for the observed effects. The implications of these and other data were discussed from the context of the theoretical orientation presented earlier.

ACKNOWLEDGEMENTS

Many people contributed to the completion of this thesis. Doctors Runquist, Di Lollo, Heth, Bisanz, Wilberg, and Treisman made many helpful suggestions in their capacity as members of the examining committee. Although they have immeasurably improved the quality of the final draft, they are in no way responsible for any deficiencies contained herein.

The data reported in the experimental section was collected carefully and efficiently by Jeff Fairless. Merrilyn Greig and Natalie Daviduk did most of the typing of the final version of the thesis.

Apart from being an academic endevour, this disertation also symbolizes my personal aspirations. I was encouraged by several individuals who seemed to understand this. Their contributions were ephemeral, intangible, and now forever, a part of me. Could I ever quantify the effect of the patience and intellectual dynamism of Allen Dobbs upon myself? I cannot; but I like to think that wherever I go his example will follow and reflect kindly upon him.

I have grown from knowing Carol Weishaar as well. Although she helped in all stages of the research, the mere statement of this seems inadequate: Together we learned to accept the absurdity of measured goals, as well as the need to reach them. This conviction, like an old friend, will never be far from me.

And finally, there was Yvonne and Adrienne Petruk.

Despite the personal cost to her, Yvonne never stood in the way of My Dream. She always helped technically and in matters of the spirit, though the dark was thick around her. As for Adrienne, she persistantly contributed graphics on all but, as yet, the final draft of this thesis. Her "ti-angles" helped put the whole project into proper perspective.

Oh yes, there was Isis, too, upon whom much depended. That I should seek to know her, passionately, in her fearful, naked beauty, seemed to be my inescapeable fate. Perhaps more than anything , I learned I never shall possess her. But like Sisyphus, I must continue trying.

Table of Contents

Page



***********

List of Tables

List of Figures

In recent years, selective attention has become an area which has drawn a great deal of research interest. This has not always been so. Despite the early recognition of the apparent importance of attention in human behavior (e.g., James, 1890), experimental psychology has only just begun to emerge from an era in which the study of such mentalistic constructs was deliberately avoided. If it is true that the "cognitive revolution" has begun (Mandler, 1975a), then examination of selective behaviors will undoubtedly become a central issue in the immediate future.

There are several reasons for this new focus, but perhaps the most basic lies in the wide range of paradigms in which selection occurs. A fundamental concern of the present paper will be to demonstrate that many of the current methodologies used to examine various issues in human memory and cognition are really selective attention paradigms. Indeed, it seems to be an inescapable conclusion that cognition cannot occur without some form of focused attention to a subset of stimulus attributes. This theme will be returned to as it is central to the present thesis.

In the next section, several areas of research that have been described as paradigms of selective attention, and others that are not usually so classified, will be reviewed. It will become apparent that selection of information occurs in each of these diverse examples. From this data base, several postulates about the structure and function of the human selective mechanism will be made. Wherever possible, it will be argued that these behaviors underlie various other diverse cognitive phenomena, such as consciousness, the icon, and forgetting. Finally, after a brief comparison of this approach with others like it, a series of studies will be described in which one aspect of the theory will be empirically evaluated.

# AN OVERVIEW OF ATTENTION PARADIGMS

The term "selective attention" has been used most frequently in the context of a few experimental paradigms in which attentional allocation can be manipulated. This approach has been shown to have conceptual utility in that it has led to the development of a standardized methodology and terminology which was lacking in previous research. However, the reliance on a few paradigms has had decided disadvantages as well. For one thing, integration with data from other "nonselective" experiments has been infrequent, even though there may be many similarities among areas. Another disadvantage is that the development of a few specific paradigms entails the assumption that the variables which can be manipulated by the design are those that are critical in attentional research. Furthermore, the terminology used may not be easily applied to other approaches, and may hinder the integration of different areas.

In considering the difficulties imposed by an over-reliance on a few paradigms, it becomes apparent that the nature of attention itself may be critically determined by the choice of design employed to investigate the phenomena. Thus, dichotic listening experiments (e.g., Broadbent, 1958), memory search tasks (e.g., Sternberg, 1966) and looking behavior (e.g., Saunders, 1963) all are purported to address attentional issues and undoubtedly do, but how these areas are related remains unclear. What seems to be missing is a conceptual framework into which all research can be fitted, including relevant areas not specifically acknowledged to be attentional in nature.

Recent work of Blumenthal (1977) has presented an opportunity to apply the principles of information processing theory to the study of selective attention. While the information processing approach is not new and has been employed previously in attentional studies (e.g., Broadbent, 1958; Cherry, 1953) it is fair to say that the issues examined in these studies were narrowly bound to the question of where in the system selection occurs. However, newer perspectives have related perception, selection, consciousness, and cognition to a common processing system. The advantage of this orientation is that it provides a format that is able to incorporate the diverse findings from other areas into the study of attentional phenomena. This processing bias can prove useful, even if it just highlights the broad spectrum of paradigms which involve selective attention. It can be demonstrated that many paradigms have different task demands but undoubtedly also require similar information processing to achieve criterion performance. An approach that employs different data bases and uses a process conception of selection may lead to the development of a fruitful and novel conceptual framework for studying these phenomena.

Before demonstrating the implicit relatedness of several different paradigms with respect to the selective processing of information, it will be necessary to discuss just what the term "processing" is assumed to entail. While there is no comprehensive set of assumptions to detail explicitly the information processing approach, several authors have used such a conception in their work on selection (e.g., Broadbent, 1958; Egeth, 1967; Haber, 1966; Keren, 1976; Neisser, 1967; Shiffrin & Schneider, 1977). The major premise is that input is sequentially analyzed throughout the cognitive domain. This analysis is assumed to involve progressive transformations of the stimulus from input to the final mental representation. In more structurally oriented theories (e.g., Atkinson & Shiffrin, 1968) different representational subsystems are assumed to be isomorphic with different transformations. Hence, iconic memory, short-term memory and long-term memory are usually considered components of the total information processing system. Moreover, stimulus manipulations can "flow" either forward or backward depending on the task demands of a situation. This flow can be terminated, rerouted or reprocessed. It is also widely assumed that the system has a limited capacity to process information. In fact, this assumption is central in theories of selection because without it there does not seem to be any reason for selective behaviors. If there are limits to the flow of information at any point in processing, then analysis of the critical aspect of input is a way in which an individual can mitigate the effects of capacity limitations. The question of where the processing bottleneck occurs has been regarded as the primary problem by researchers in this area. Erdelyi (1974) has insightfully pointed out that such a multiprocess view of cognition has been adopted by most theorists but usually along with a uniprocess mode of selection. Multiprocess accounts of selection (e.g., Moray, 1970; Neisser, 1967; Treisman, 1969), are far less common but have the advantage of allowing selection to occur at any of several points along the processing continuum. In view of the complexities of human behavior, this suggestion seems to be a plausible alternative conception of selection. The present thesis adopts the assumption that "...selectivity is pervasive throughout the cognitive continuum, from input to output..." (Erdelyi, 1974, p.12). An examination of several research areas will suffice to demonstrate the utility of this conception of selection. Not only does selection occur at different levels within particular paradigms, it occurs across paradigms as well. It will be seen that selection as differential processing of information can be inferred from an almost limitless array of procedures, including several that have not been regarded as selective attention methodologies. In the context of this thesis selection may be considered a response that limits or focuses processing of information to a subset of elements of a nominal stimulus complex.

Dichotic Listening

Historically, the first procedure widely used to investigate attention was the dichotic listening experiment. Cherry (1953) introduced the paradigm to examine how people attend to one source of information when several other sources are available in certain situations. Experimentally, he presented messages to his subjects in one of two ways. When each of two messages were superimposed and presented to both ears simultaneously, subjects could, with great difficulty, shadow (repeat) one of the messages. When one message was presented to one ear and a different message to the other, subjects could shadow one message concurrently with very little difficulty. The message on the nonattended ear, however, was "rejected" in that the subject was unable to report any of the semantic content of that channel. In fact, the only aspects of the rejected message that could be recognized was a change from male to female voice, or the insertion of a 400 cps tone. Changes in language and even reversal of normal speech were very poorly recognized.

Subsequent research using similar techniques has shown that the difficulty of shadowing a particular message can be minimized if the messages are physically distinguishable (Broadbent, 1958), and that semantic differences between channels are also a potent variable (Grey & Wedderburn, 1960; Treisman, 1964b). In the Grey and Wedderburn experiment subjects were presented words that were fractionated so that a different syllable was received by each ear, and subjects were required to shadow one ear only. They found that whole words from both ears were reported, often without the subject's awareness that they had switched into the inappropriate channel. Moray (1959) showed that the content of the rejected ear could be reported if the message was a high salience message - the subject's name, for example.

These studies deal with selective attention in the sense that they establish task demands requiring some sort of differential analysis of input information (selection), and require an active allocation of processing capacity (attention). Much of the research in this area has been addressed to structural issues - where does the selection of the appropriate input occur? Is it "early" in the system after some rudimentary analysis, or later when more detailed processing occurs?

However, this apparent concern with structural aspects of the selection system should not obscure a more basic issue: Why does processing of the nonattended channel differ, depending on the type of message input? Clearly, this indicates that systematic limitations are operative in some contexts. Whether this limitation is structural is irrelevant in a sense, because there must be a physiological reason for any behavior, or lack thereof. What is more important is that the analysis, selection, and psychological transformation of information is dependent on a number of factors, other than physical complexity of the competing messages. A message that does not affect shadowing in one context may be massively disruptive in a different situation. The empirical facts of dichotic listening studies thus lend themselves to process explanations, because different presentation parameters lead to different behaviors depending on the stimulus context. This is not to deny that structural features underlie cognitive behaviors, but rather to focus upon the manner in which stimuli are manipulated throughout the cognitive domain. In this way cognition can be regarded as a progressive series of stimulus transformations. It is the nature of these transformations that is important, not where they occur. In fact, a priori statements about where reductive encodings are assumed to occur (i.e., selection) may be misleading if they occur throughout the whole range of cognitive behaviors. This latter view is, of course, consistent with the central thesis of this paper. Dichotic listening experiments support this supposition: Selection of one input can occur at any level, depending on the distracting message. For example, a single channel can be monitored quite well if there is some physically distinguishing feature, such as the ear that receives the message. On the other hand, difficulty in monitoring occurs if messages are semantically similar (although this task can be done reasonably well in some contexts).

As we shall see, unimodal selection theories that concern themselves with where selection occurs have difficulty determining if selection is early or late, therefore admitting the plausibility of either formulation. Focusing on what variables affect the degree to which stimuli are analyzed seems to be a more fruitful avenue of research.

Looking Behavior

Another area in the selective attention tradition concerns the question of how subjects sequentially focus their attention to acquire the significant information from their environment. Two major orientations within this area are apparent.

A good deal of research has been concerned with the variables that determine spontaneous looking responses in the absence of specific task demands of a situation. In effect, the concern here is with aspects of the stimulus situation which come to control attention whenever the organism is presented a novel stimulus. Methodologically, these studies employ duration of fixation or preference of fixation as dependent measures. Selection is assumed to be related to the time spent viewing certain stimulus features, or to the stimulus features chosen from a stimulus array. Processing of stimulus attributes is therefore held to be isomorphic with, and determinable from such measures. Many such studies have indicated that novelty, complexity and significance of a stimulus in a visual field draws the attention of an observer. For example, it has been shown that children will orient to the more complex of patterns in a visual field (Fantz, 1958), and look less at a homogeneous grey patch than at a patterned shape (Fantz, 1965). Similarly, Berlyne (1958) has argued that at all stages of human development, novel and complex stimuli (those having "collative" properties) attract spontaneous attention. This suggests that epistemic motivation, uncertainty reduction, or information seeking is a major variable in determining attentional allocation.

Other research on looking behavior has centered on time duration of each visual fixation, visual acuity, and the effect of irrelevant information in the context of rather specific task demands. This differs from spontaneous looking behavior in that subjects in these paradigms are looking for something designated by the experimenter, rather than being allowed to orient upon attributes of their own choice.

An example from this orientation has been the concern with the detection of stimuli on the periphery of the visual field. Saunders (1963) has employed a detection task in which one signal was sometimes presented at the center of the visual field, and another off to the right. The subject was required to press a key indicating which signal, or combination of signals, appeared on a trial. Latencies of each response were recorded. By keeping a subject's head and eyes fixed, and by moving the right-hand stimuli from 19 to 94 degrees off center, he was able to determine that peripheral vision with the eye fixed was accurate to 30 degrees, and with the eye mobile to about 80 degrees. Moreover, latencies in responding to the signals rise dramatically at the same points. Saunders also indicated that the complexity of the stimulus is important in these tasks. Simple stimuli are detected further on the periphery and faster than are complex stimuli. In a later series of studies, Saunders showed that these increases in reaction time are not related to the time needed to move the head or eyes (these increased linearly); rather, he argued that these rises were due to some selective process. Whenever both stimuli are in the display field, both are attended and processed simultaneously, but when one stimulus is outside the displayed field (beyond 30 degrees), two selective acts are required and the response times reflect this added processing. As the peripheral stimulus approaches 80 degrees, much more time is needed because even eye movements are no longer effective in acquiring the rudimentary information necessary to tentatively recognize whether the stimulus was or was not presented.

The effect of irrelevant stimulation on the processing of relevant information is also a type of selection task. Mackworth (1965) studied visual acuity of peripheral objects using one such procedure. Specifically, she presented three letters that were 2, 6, or 10 degrees apart for 100 msec. Subjects were required to indicate if the letters were all the same or not. Near perfect responding was obtained for all angles. However, when fourteen irrelevant letters were added to the line, or if twenty lines of seventeen letters were presented along with the stimulus display, accuracy of recognition dropped to about 70 percent for stimuli 2 degrees apart to 10 percent for stimuli 6 and 10 degrees apart. When two distractors were added to the inside angle of the test letters, accuracy of recognition dropped to 80 percent. In contrast, recognition was about 40 percent if the distractors appeared outside the extreme test letters. These data indicate that as information load increased, attention to the extreme part of the stimulus field diminished. While Mackworth prefers to argue that it is visual acuity that changes, it is conceivable that selective attention is decreased as a function of load. After all, there are large differences in resolution of peripheral stimuli depending on the exact placement of the distractors, even though the test stimulus remains in the same position in each task. Although visual acuity appears to be greater for the central stimulus elements, the difficulty of processing and selecting peripheral attributes from a stimulus configuration is also implicated by these data.

Taken together, these paradigms suggest that the structure of the stimulus has a direct influence upon the nature of selection. This is, perhaps, most easily interpreted from a processing position. It is clear that the complexity of the stimulus array, the position of the stimulus, and the types of irrelevant information are important variables in selection. To regard these data as isolated phenomena obscures their fundamental relevance to selection. If we consider how these studies are related to the processing of stimulus information, the apparent dissimilarity between these paradigms is lessened. Thus, eye fields and peripheral visual acuity are undoubtedly related, as is the allocation of attention to novel stimuli and the mechanisms controlling the direction of gaze. These behaviors may be regarded as process algorithms or behavior repertoires that are engaged during information acquisition. In short, the processes employed to accumulate knowledge about the stimulus environment are an important aspect of selection.

<u>The Kulpe Task</u>

A selection task has been employed to determine if subjects can alter the quality of their perceptual experience by prior instruction to attend to specific features of a complex stimulus (Kulpe, 1904). Basically, a subject is briefly presented a multidimensional stimulus and is required to make judgments about a single dimension of variation. In the before-after design (Chapman, 1932) subjects are informed of the dimension to be judged either before presentation or after presentation. Occasionally, the experimenter would ask for a judgment on an incidental dimension after a series of judgments on the informed dimension. The rationale of this approach is that if perceptual alteration is employed, then subjects should do better on the before condition than on the after condition. Typically, subjects report the emphasized dimension more accurately than the incidental dimension. Differences between the before and after conditions have not always been reliable, and certain objections can be raised regarding the logic of such a design for evaluation of this "perceptual tuning" hypothesis (see Egeth, 1967 and Haber, 1966 for details). It is possible, for example, that the attended attribute is rehearsed more, and remembered better than the unattended attributes (Lawrence & La Berge, 1956). Haber (1964a,b) has argued that differential verbal encoding of the attributes is responsible for the effect. The emphasized dimension is encoded first, acquiring the advantage of primacy over the unattended dimensions, which may not be encoded at all because of their rapid decay from sensory memory.

This suggestion is, of course, a process explanation of an established phenomena. Although certain structural biases are entertained (such as "sensory memory"), it is clear that the terms "rehearsal", "encoding" and "decay" arise from the unstated assumption that subjects actively transform and manipulate stimulus representations, accounting for selection and the Kulpe effect.

Evidence for this latter view has been obtained by manipulating process variables. For instance, Harris and Haber (1963) trained their subjects to use one of two coding strategies. Object codes corresponded to the rules of English syntax: three green circles, two red squares, etc. Dimension codes were organized by dimensions: three, two; green, red; circle, square; etc. The critical difference between these coding strategies is that dimension coders can place an emphasized dimension first, while object coders cannot. In fact, dimension coders were more able to encode the emphasized dimension first and were benefited most by prior information about the stimulus display than were object coders. This supports the contention that encoding differences, and not perceptual tuning, underlie the Kuple effect.

Regardless of the exact mechanism responsible, it is apparent that the task requires subjects to selectively attend and process some features of a complex stimulus at input. Selection of attributes is assumed by Egeth (1967) and Haber (1966) to occur after stimulus presentation. This position also demands the assumption that attributes are independent and additive. As will become evident in the next section, selection phenomena are not only restricted to these stimuli, but to integral stimuli as well.

"Inevitable" Processing Tasks

Thus far only paradigms in which the stimuli are unintegrated have been examined, so that judgments about one dimension of a stimulus can be made independent of judgments about other dimensions. However, selection tasks have also been employed with integral stimuli; that is, stimuli in which the existence of one dimension specifies a level of another dimension (Garner, 1970). For example, a visual stimulus must have size, form, hue, saturation, and brightness. Selection of any one dimension may lead to unavoidable processing of other dimensions as well. Garner and Felfoldy (1970) have conducted an experiment to evaluate this possibility. Their subjects were given decks of cards to sort as quickly as possible on the basis of one dimension on which integral stimuli (in this case, Munsell color chips with dimensions of chroma and value) were mounted. Sorting was faster when the redundant dimension was perfectly correlated, and slower when it was orthogonal, relative to a single dimension-control deck. When nonintegral stimuli (value and chroma on two chips) were used, neither the presence of correlated or orthogonal irrelevant dimensions had any effect on sorting times. These data indicate that for integral stimuli, processing of a particular dimension is not possible without some analysis of other dimensions as well. Selection, or more correctly, lack of selection, is inferred from the differences in sorting times corresponding to dimensional relationships.

Similar studies have shown that selection can fail to occur under certain other task demands. The prefix and suffix effect is one such example (Dallett, 1964; Morton, Crowder & Prussin, 1971). The subject is orally presented seven relevant digits preceded by (prefix effect) or followed by (suffix effect) a zero. He or she is instructed to repeat all the digits but to ignore the zero. However, memory for the relevant digits is decremented by the presence of the zero. Subsequent research has shown that any speech sound similar in voice to the message creates the effect, while it is abolished by a visual zero or a nonspeech sound.

Several theoretical explanations have been advanced for the effect, and all are beyond the scope of this thesis. It is important to note however, that this paradigm is of interest because it is a clearly defined example of selection failure in a context where it would be advantageous to select. As such, it is an interesting phenomena that must be accounted for by theories of selection.

A third paradigm where selection of some undesirable attributes is inevitable is in the Stroop effect (Stroop, 1936; see Dyer, 1973 for a review). In this paradigm, subjects are presented color words printed in different colored ink, and must respond with the ink color. Thus, when a subject sees the word "green" printed in blue ink, he or she is to say "blue". The difficulty of such a task is substantial, and practice is of little benefit in mitigating the difficulty of the task (Jensen, 1965). Moreover, the effect is found with other materials: Words like "sky" and "lemon" when printed in a color different from their usually associated colors, cause interference as well (Klein, 1964). In reaction time experiments, Hintzman, Carre, Eskridge, Owens, Shaff, and Sparks (1972) and Warren (1972) have shown that there is interference if the word and color are associatively unrelated, but facilitation if they are highly associated.

Taken together, these tasks have demonstrated selection failure under certain circumstances. It appears that these paradigms result in the activation of particular expectancies in subjects (Posner & Snyder, 1975), and when these expectancies are violated, interference results. Alternately, it can be speculated that the encoding of irrelevant attributes at input requires more cognitive capacity and results in decremented performance on tasks where the redundant encoding attribute has no functional value. Facilitation occurs in those instances where the encoded irrelevant dimension is congruent with the task demands of a situation. In any case, it is apparent that selective attention in some contexts is stimulus controlled, and not modifiable by voluntary means.

This suggests that certain process algorithms are engaged automatically and are not easy to change, even in contexts in which it would be beneficial. The relationship between selection and processing is underlined by these studies as well. Failure to focus upon particular attributes at the expense of others is due to the unavoidable analysis of information in some contexts, and this leads to a failure in selection.

Split-Span Experiments

A question of long-standing interest has been to what degree can humans process information on two channels simultaneously? The answer put forth by various researchers has not been uniform. Indeed, successful division and failures of attention have been reported over a wide range of materials. What can be drawn from the various studies on attentional allocation is the degree to which the research has come to depend on an informational processing terminology and conceptual orientation. Thus, terms like "processing", "input", and "channels" are frequently employed in contexts in which the major question was the degree to which several sources of stimulation can be accurately analyzed and responded to.

Support for division of attention has been reported by Treisman and Fearnly (1971). They presented subjects with either single stimuli or simultaneous auditory stimuli consisting of nonsense syllables or a nonsense syllable and a digit. Every few trials, subjects were precued as to what digit, if any, would be presented. Upon presentation of the single or simultaneous stimuli they were to press a key, and their latency of responding was recorded. The experimenters rationalized that if subjects could successfully process items presented to each ear simultaneously, then response latencies should be lowered an equal amount by precuing both single items and pairs of items. Conversely, precuing was expected to lower the response latencies more for pairs of items than single items if the stimuli were processed serially, because each stage of processing would be facilitated. In fact, the presence of precuing lowered reaction times equally for single and simultaneous stimulus presentations, supporting the former hypothesis.

Other studies have supported the notion that simultaneous processing of information from different channels can occur (Ninio & Kahneman, 1974; Tulving & Lindsay, 1967). But other data is equally consistent with the notion that subjects, in certain situations, fail to process concurrent inputs (Broadbent, 1954; Mowbray, 1954; Poulton, 1953). In the Broadbent study, subjects were presented digits dichotically and were required to report either the order that the pairs of digits were heard, or else channel by channel. Report in the latter condition was superior to that of the former; other researchers have shown that extensive practice can mitigate the effect, although never eliminate it entirely (Moray & Jordon, 1966). These findings suggest that concurrent processing is less effective than serial read out from echoic memory in certain contexts.

Taken together, the split-span studies are consistent with three general conclusions: (1) the tasks can be done, (2) grouping of items by channels is the preferred mode of output and (3) simultaneously presented items are usually not grouped at recall (Kahneman, 1973). For the present, the primary concern is not with any specific conclusion that can be drawn from the split-span experiments, but rather with the selective processing of different inputs inherent in the task. Processing of information simultaneously from different channels suggests that selection can be avoided under some task demands. Similarly, the failure of divided attention in other contexts indicates that selective processing proceeds despite intention to avoid it in other situations. In any event, these paradigms implicate selective attention as a fundamental aspect of cognitive behaviors and an information processing orientation seems to be a useful means of extending these relationships.

<u>Search Tasks</u>

Controlled search through memory arrays is also a selection paradigm. While the term "stimulus processing" was employed as early as the last quarter of the nineteenth century in the description of introspective phenomena (e.g., Wundt, 1880), the relationship of search tasks to selective attention has not been emphasized. However, Sternberg (1966) has pointed out that a common assumption made by these theorists was that mental processes proceed in stages, and that reaction times provide a means of analyzing the component parts of such operations. Several modern researchers have begun employing a similar rationale in their study of attentional phenomena (e.g., Shiffrin & Schneider, 1977). Tasks are usually structured in a fashion that allows the use of reaction time as a dependent measure. Typically, subjects are required to decide if a presented stimulus is part of a previously learned set of stimuli. One of the processes assumed to occur after stimulus offset is a search through memory to see if the presented item is part of the designated set. Attention to some stimulus features is a fundamental requirement for the subsequent decision process. Of all the selective attention paradigms, these are most easily incorporated into a multiprocess view of selection. Because of the control over presentation times, the stability of the response data, and the simplicity of the experiments, it is very easy to apply information processing theory to this area. For this reason, a large number of selective attention experiments fall under the rubric of search tasks. Perhaps the best known paradigm has been that of Sternberg (1966). In his methodology several digits are designated as target items in the positive set, before the experiment proper begins. Single digits are then presented and subjects are required to decide if the presented item is in the positive set or not. Manual reaction times are employed as the dependent measure. The critical finding is that reaction times are a linear function of the positive set size, increasing approximately 40 msec for each item. Atkinson, Holmgren and Juola (1969) have reported similar data in an experiment in which some items were targets in a matrix of distractors. The time to decide if the target item was among the distractors was a linear function dependent on the size of the target set.

Although these, and several other studies are compatible with Sternberg's original notion that the search consisted of comparing all test items with members of the positive set exhaustively (so that all items are compared serially even if a match is made earlier), other research has shown different effects. Jonides and Glietman (1972) and Egeth, Jonides and Wall (1972) have found that presenting a digit on a background of letters was not related to the number of display items;

thus processing appears parallel. This of course differs in a fundamental way from Sternberg's data. Corballis (1975), Keren (1976), Schneider and Shiffrin (1977) have argued that these search paradigms conform to two distinct modes of processing. To use Keren's terminology (borrowed from Broadbent, 1970), they are response-set and stimulus-set selection. These distinctions will be set out in greater detail later in the paper, but for the moment, we can think of stimulus-set selection as processing that is parallel, automatic, demands little attention or effort, occurs rapidly and without subject control. In contrast, response selection requires deeper analysis, more capacity, takes longer and requires more attention. Operationally, these terms were defined by Keren in a paradigm in which three letters and three digits were presented briefly and the subject was to report which letters (or digits) were shown. In the stimulus-set condition the to-be-reported items were colored in red ink, the distractors were printed in black. The response-set condition had all the elements printed in black. Keren found evidence that the two stimulus configurations were processed differently, apparently because the relevant letters "stand out" more in the stimulus-set (where they are red) than they do in the response-set (where they are black).

In the work by Schneider and Shiffrin, differences in processing modes were demonstrated by a search task in which the presentation time of each stimulus configuration, the number of items presented, or the size of the positive set was varied. Like Keren, their research showed qualitatively distinct forms of information processing.

These tasks clearly necessitate selective processing for their successful completion. Conditions using stimulus-set characteristics seem to involve information abstraction distinctly different from that found in response-set conditions. Selection of relevant attributes can occur quickly whenever they are distinguished by an obvious physical feature, like color, in the stimulus-set paradigm. The mechanisms that control attention in these circumstances are not obvious, but it seems certain that the analysis of stimulus configurations follow particular algorithms that are directly related to the task demands imposed on the subject. In fact, several theorists have employed search tasks as the cornerstone of their accounts of attention. This is defensible on methodological grounds, but it is restrictive in that there are several other paradigms that are selective in nature. Considerations of these data in conjunction with the selective search literature may be necessary for the formulation of a global theory of attention.

<u>Paired-Associate Learning</u>

Another selection paradigm that appears particularly amenable to a process interpretation is paired-associate learning. A paired-associate task is one in which subjects are presented a stimulus and must learn to associate a particular response with it. It has been frequently observed that subjects can recall the correct response when only a portion of the stimulus configuration is presented. Underwood

(1963) was the first to discuss the phenomena and distinguish between the nominal stimulus (the entire complex physically presented), and the functional stimulus (the portion to which responding actually occurs). A typical procedure used to determine the portion of the stimulus actually involved in association formation is to present each individual component of the stimulus compound after list acquisition and ask the subject to indicate which response went with the component during learning.

It is unusual for subjects to select a portion of the nominal stimulus at random. Richardson (1972, 1976) has argued that the kind of element selected can often be described in terms of a rule. A prototypic example can be found in the work of Underwood, Ham and Ekstrand (1962). A compound stimulus consisting of words or trigrams on a colored background was paired with a single digit response. After subjects had learned the list to one perfect recitation, they were presented either the words and trigrams, or the colored backgrounds, and were required to relearn the list. The critical finding was that the group initially given trigrams on color backgrounds responded nearly perfectly to the colors alone, and very poorly to the trigrams. This suggests that the subjects were learning to associate the color to the correct response and ignoring the trigram. Moreover, this selectivity is rule-like: the use of a physically distinct stimulus attribute (color) indicates that some common process is engaged for each item on the list.

Other studies have confirmed these effects. Jenkins (1963) demonstrated that the first letter of a trigram may be employed, Cohen and Musgrave (1964) found that subjects will use the most meaningful element of a complex stimulus, and Rabinowitz and Witte (1967) showed that a single red letter in a trigram will be most likely associated with the response. Furthermore, these selection rules are transferred from list to list, independently of specific associations (Dobbs & Carlson, 1975).

Despite certain methodological problems that arise in determining what is the exact functional stimulus in a nominal complex (Postman & Greenbloom, 1967; Martin, 1971) the phenomena of selection is undeniable. What is less clear is the mechanism accounting for the effect. Since Underwood's paper (1963), the term "selective attention" has frequently been invoked as an explanatory construct. Although no theoretical statement has ever been made as to what the term means in context of paired-associate tasks, it has been vaguely regarded as a two-stage process in which some aspect of the stimulus is selected and then associated to the correct response. The actual mechanism of selection is unspecified; however, it would not appear that the process differs in any fundamental way from those examined in the discussion of other paradigms. That is, subjects are put in a situation where selection, or attention to part of the stimulus configuration, is forced by either instruction or the limitations in the system's capacity to process information. As such, the term selection appears justifiable in a phenomenological sense, but needs theoretical clarification if it is to be useful as an explanatory construct.

Depth of Processing

Perhaps the selective attention orientation that is most dependent upon processing notions is the so-called levels-of-processing paradigm (Craik & Jacoby, 1975; Craik & Lockhart, 1972; Craik & Tulving, 1975; Horton, 1977; Lockhart, Craik & Jacoby, 1976). This position holds that the analysis of stimulus information proceeds through various stages, ranging from elementary structural processing to more complex semantic analysis. Memory for a stimulus event is related to the depth to which a stimulus is analysed, with lower-order codes being less durable than those established by deeper processing. The implication that arises from this conception is that, depending on the task demands of a particular situation, different mental representations will be established. Hence, processing of information to any level can be assumed to be a selective act, because only certain interpretations of a stimulus become available after processing at one level. While there are many other aspects of the theory, it is fair to suggest that the central assumptions of this account rest on the proposition that subjects are able to selectively process information.

Evidence for such a view has come primarily from incidental learning tasks (e.g., Craik & Tulving, 1975; Hyde & Jenkins, 1969). In these studies subjects are shown a word and then are required to answer a yes/no question about the word. For example, the word "CAT" might be presented and subjects would be asked if: (1) it began with the letter "C" (structural encoding), (2) it rhymed with "BAT" (phonemic encoding) or (3) if it was a type of "ANIMAL" (semantic encoding). The critical finding is that on an unexpected recall test, subjects remember more semantic than phonemic targets, and these are better recalled than structural targets, even though the target words were equated across conditions. Furthermore, reaction time to encode the word and respond correctly reflects the same order: structural latencies are shortest, then phonemic, then semantic responses. Also, the effect is not limited only to incidental learning tasks. If subjects are told beforehand that they will be tested for recall of the targets, absolute recall will be higher, but the same relative orderings will be obtained. Recognition data mirror the same effects (Craik & Tulving, 1975).

From the perspective of selective information processing these results are impressive. They show that it is not necessarily the target that is important for recall, but rather the operations that are carried out during the encoding of the stimulus. This implicates selective processing because first, it suggests that a memory for a particular target does not consist of all possible features of the target, and second, the establishment of memories is closely related to the kind of analysis instituted during stimulus processing.

Other Selection Paradigms

Brief reference will be made to a few other processing methodologies that are basically selective attentional in nature. The word superiority (Reicher, 1969; Wheeler, 1970) literature is a case in point. In these experiments, it was shown that detection of a letter was more accurate when the letter was embedded in a word than when it was presented in isolation. This paradigm, and others like it, require a selective search of an input field, along with other processes. Although the issue addressed was whether letter perception precedes word perception, it should not obscure the fact that these procedures are viable for investigating selection phenomena from a processing point of view.

Other paradigms that are selective in nature include much of the perceptual defense and perceptual vigilance literature (e.g., Bruner & Postman, 1947; Dixon, 1971; Erdelyi, 1974). Here the concern has been with the degree to which perception was influenced by the enduring beliefs, values, goals, and needs of the organism. The data have been interpreted as indicating that a certain amount of stimulus processing takes place before conscious awareness of the stimulus field occurred. During this time the system could filter out, or censor, psychologically threatening stimuli (perceptual defense) or enhance responding to appetitive stimuli (perceptual vigilance). Several studies have examined this position (see Dixon, 1971; Erdelyi, 1974 for reviews). For the present, it will be pointed out that these paradigms employ a selection methodology: They investigate the degree to which "subliminal" stimuli come to influence behavior in different contexts. Such control is necessarily selective because not all the stimuli are processed in the same manner. Some elements may remain unconscious because of their threatening nature (although they must be processed to be censored), others may reach awareness normally, and still others may remain unprocessed entirely. There are important methodological and conceptual considerations that must be made in assessing this work, but these need not obscure the fundamental selectivity implied by the paradigm. The point to be made is that perceptual defense research and theory hinges critically on the notion of differential stimulus processing.

Work by Posner and his associates (Posner, 1969, 1978; Posner, Bois, Eichelman & Taylor, 1969; Posner & Snyder, 1975; Posner & Warren, 1972) is similar in this regard. In their studies, reaction time measures are employed to infer the nature of the code abstracted at various times after presentation of the nominal stimulus. They have argued that stimulus processing results in the formation of qualitatively distinct codes that compete for the limited processing capacity available to the subject. Depending on the task demands of the experimental situation, these codes may endure or be rather fleeting. Whatever, these studies implicate selective processing precisely because certain types of information can be derived from complex stimuli in different tasks. Selection here refers to the distinguishable codes established under different input conditions. As will be demonstrated later, these studies have considerable importance in establishing some of the basic variables involved in selection. Their application will be set forth in more detail elsewhere. For the moment it will be pointed out that these are just one of many processing paradigms useful for studying attentional phenomena.

# A THEORY OF ATTENTION

The research surveyed herein is not an exhaustive review of selection tasks by any means. In fact, it is doubtful if a meaningful taxonomy of selective attention can be made because selection occurs in so many varied contexts. The preceding review was intended to demonstrate the wide range of memory paradigms that involve differential attentional processing in some form or another. While it is possible to discuss attention using any one paradigm as a data base, it seems more desirable to consider the breadth of techniques employed to manipulate the phenomena. What becomes apparent when this is done, is the pervasive extent to which selection occurs in most, if not all, cognitive behaviors. To examine selection from any one experimental viewpoint introduces the pretheoretic assumption that the variables that can be manipulated by that methodology are responsible for selection behavior. Undoubtedly, it is true that many variables overlap across paradigms, but it is unduly gratuitous to assume that any one task can, in principle, be used to examine all the variables implicated in attentional processing. For example, informational load can be quite easily varied in search tasks but not so easily controlled in the dichotic listening experiments. Similarly, studies in spontaneous looking behavior and paired-associate learning have demonstrated what subjects select from their environment, but not how they do it.

It has certainly been most common to use a single data base to theorize about attention, and this has led to several different conceptions of selection, depending upon the empirical approach adopted. Furthermore, it can even be argued that selection behavior is not likely to be due to any single mechanism (Moray, 1970a). Proponents of this view argue that auditory stimulation is typically of longer duration than visual signals, and sequentially rather than spatially extended. Moreover, sampling times in vision are substantially longer than in audition. According to Moray, these facts suggest that even if there was a common selective system, very complex switching mechanisms would have to be envisioned to coordinate input from the different modalities into the selector.

While this approach has the attraction of allowing a more focused examination of selection in any one paradigm, it does not permit an appraisal of how these systems are interrelated. From the discussion of selection tasks presented earlier, it seems plausible that enough regularities in selection exist across paradigms to warrant consideration of a single common selection process. A global approach to attention has certain advantages that will become apparent later. The next section will outline such a theory of attention and present evidence to support it from a broad range of experimental designs. Indeed, the central argument of the present thesis is that selection, in some form or another, is an inevitable and unavoidable aspect of all cognitive behaviors. The cursory taxonomy of selection paradigms presented earlier lends itself to this interpretation: There are certainly differences in the task demands of each situation but there are some important similarities in the selection phenomena across paradigms. It is clear, for example, that selection is often influenced by the same variables in different experimental contexts. Thus, the amount of information, type of information, type of distractor material and stimulus duration are critical determinants of selection across tasks.

Selection behaviors are of manifest importance for an organism's transactions with the environment. Scarcely a task exists in which a stimulus transformation of some sort is not implicated in the execution of the required response. Such transformations are selective in that only the mental representation of those stimuli, or the learned relationships to other stimulus representations are activated in memory after stimulus onset. Furthermore, these transformations are cognitive functions in the sense that they are implicated in such processes as "attention", "consciousness", "thought", "memory", and "perception" (Blumenthal, 1977).

Overview

In the present thesis selection behaviors are viewed as a process continuum, ranging anywhere from primary, simplistic stimulus detection to higher-order, complex thought processes at the opposite extreme. Consciousness, or attention, refers to those processes that are complex in nature and demand more "effort" (Kahneman, 1973) to carry out. Short-term memory (STM) is not considered to exist as a separate entity. Rather, it is assumed to be the part of long-term memory (LTM) that is active at any one moment, as is the "icon" (Neisser, 1967) and similar phenomena.

All processes are assumed to demand some capacity. Lower-order processes appear "automatic" because the minimal analysis of the stimulus takes place quickly, and usually without any apparent attendant detriment to other processes. Higher-order, "cognitive" processing generally takes more time, demands more effort, and appears correlated with awareness. A primary assumption of the present approach is that processing of the stimulus complex is determined by the task demands of a particular situation and the previous history of organism. Use of a central "control" process or homunculus is avoided because an organism's behavior is assumed to be a function of the specific transformed input stimulus relationships. Although the orientation of the present approach is on the processing of stimulus information, some assumptions about the structure of LTM will also be made. Basically, memory is assumed to be neurologically organized into hierarchically ascending relationships. The simplest representations are structural detectors (e.g., Hubel & Wiesel, 1959). More complex relationships are represented by combinations of simplistic units to form integrated units. The way these units become integrated is by "learning" or the repetitive activation of the same units in the same context. A stable constellation or pattern of activated units is what comprises the mental representation of a stimulus event. These aspects will be discussed later in the paper, but for the moment it will be suggested that selection occurs because only a subset of the total number of possible units is activated at any time. Attentional focus results from the activation of a few higher-order units, relative to the many lower-order units activated preattentively. Thus, the present approach identifies selection, and by implication, cognition, as a consequence of algorithms that are hierarchically ordered.

The next section will detail what these algorithms are, and how they determine what is selected in a particular context. The assumptions outlined herein will be elaborated, and the implications of this conception to other memorial phenomena will also be discussed.

The Nature of Process

The distinction between states and processes is crucial in the present account. The two terms will be distinguished with respect to selection, and some operational uses of them will be noted.

"State" refers to the condition of a system at a single point in time. It is entire at any given moment. "Processes", on the other hand, occur over time and are not static or entire at any moment. This distinction is important because mental representations that are activated along a quantitative dimension will be frequently referred to. The degree of activation is a state characteristic; the means by which this activation occurs is a process. Hence, processes can only be inferred from changes in state, or to put it another way, states are always the product of processes. It is assumed that processing involves transformation of information from one state of activation to another. In the conventional literature the term "selection" has referred to both states and processes, and this has unfortunately contributed to some confusion among researchers. Although use of selection in the process sense (the act of selection) is easy to distinguish from the state usage (what is selected), the implications of these differences have not always been clear. The best example of this can be found in discussions of the capacity of STM. It has been widely assumed that STM consists of 7+2 items (Miller, 1956) or that it lasts in the order of seconds without rehearsal (Waugh & Norman, 1965). Both these notions may be correct, but they refer to different aspects of memory. In the first case, states are discussed: Only so many items can be activated at any instant in time. The second case suggests a process distinction because it is the time interval between the activated and inactivated state that is being measured. While it is not true that capacity notions are irrelevant to state descriptions, they may be misleading. As will be pointed out later, the kind of information that is active at any point in time depends upon the type of previous processing. Lower-order coding involves the establishment of many more activated units than complex analysis. Determining the number of units activated is difficult since both the qualitative and quantitative parameters of activation must be known. It is more feasible to discuss the processing aspects of capacity because this involves noting the transformation of information from one state to another. Moreover, it is usually the process limitations that are manifested in the behavioral data. In the present thesis, capacity will refer to limitations in processing which can occur during a given interval. All processes, even the seemingly "preattentive" ones (Neisser, 1967) are assumed to require some of the limited capacity. Further, it is assumed that some capacity is required to maintain a state of activation as well as establish one.

The process-state distinction has other implications as well. For example, the concept of information activation suggests that, structurally, there is a single unitary memory store consisting of different states of activation . Information in the inactive state is what has been traditionally viewed as long-term or semantic memory. The process of activation is not regarded as a transfer process. That is, information does not move to another place in memory. It is simply activated. This activation is analogous to what has been termed "primary memory" (Waugh & Norman, 1965), or the information that is immediately available at any one time. This is in direct contrast to theorists (e.g., Atkinson & Shiffrin, 1968) who have conceptualized memory as consisting of both long-term and short-term storage systems. They have assumed that during learning, information moves from short- to long-term memory. In the present account, this apparent "movement" is merely a change of information from the inactive to active state. This same reasoning can be extended to eliminate the construct of sensory or "iconic" memory (Neisser, 1967). The activation of basic, structural detectors is assumed to be nothing more than a process involving a change of informational states at lower levels. The rapid loss of information observed in sensory memory occurs because low-order analyzers become deactivated quickly from the flood of incoming information. The conception of an icon as a separate entity indirectly related to other memorial phenomena is therefore inconsistent with the current view. Since activation of units underlies the establishment of long, short, and very short-term traces, the fragmentation of memory into a set of subsystems is unwarranted. The data of Di Lollo (1979) supports this argument: Visual persistence is not a unitary phenomena, but rather the result of several different processes occurring over time. Confining iconic phenomena to any one temporal interval is purely arbitrary. Without major modification, this same rationale can be extended to question the independent existence of other subsystems of memory as well.

At this point it is important to distinguish between quantitative and qualitative differences in stimulus processing. It is currently popular to assume that information can be analyzed at different "depths" or "levels" and that these differences are qualitatively unique (e.g., Craik & Lockhart, 1972; Keren, 1976; Lockhart, Craik & Jacoby, 1976; Shiffrin & Schneider, 1977). Although the requisite criteria for depth distinctions have never been entirely clear, it would seem that qualitative differences would entail process repertoires or analytic modes that are dynamically independent. Selective activation of units, as envisioned by the present thesis, does not require this assumption. Whenever a nominal stimulus complex initiates an activated pattern of detectors comprising its corresponding mental representation, it occurs by means of the same physiological process. Processing can never be qualitatively different in this mechanistic sense. Besides, it is unlikely that qualitative and quantitative differences in processing can be distinguished, because processing is merely assumed to be a change of state in the activation of units. What, then, do the terms higher- and lower-order processes refer to if not to some qualitative dimension? One suggestion is that lower-order analysis involves the activation of units that require minimal "effort", "consciousness", or "attention", while higher-order processing places greater demands on capacity. But such a statement does not contribute much to our understanding of cognitive functioning. The critical distinction between processing modes is seen to depend upon the degree of previous experience in analysing a particular stimulus configuration. Low-order processes do not require much capacity because the activation of particular units in a familiar context occurs easily and as a function of practice. This assumption is necessitated by the observation that many complex behaviors (such as driving a car) can be accomplished with progressively less attention as the skill becomes better acquired. In other words, frequently activated constellations of units have permanently lowered thresholds. The intrusion of salient information (such as a subject's name) on unattended channels in dichotic listening experiments (Moray,

1959) supports this view. A person's name, being highly overlearned, is recognized with a minimum of effort due to altered stimulus thresholds. Similarly, preexposure to partial information (priming) influences the establishment of a subsequent representation because a subset of the defining features of the representation become activated by the prime. Depending on the task demands of a situation, this priming may facilitate or inhibit later responding.

The extent to which this type of automatic responding occurs during an organism's interaction with its environment can be scarcely underestimated. The detection of corners, colors, and other basic structural information occurs very frequently. Mental representations for these events are established so quickly as to appear preattentive and without awareness. Novel stimulus representations, in contrast, involve the activation of unique patterns of units. Because these pathways are infrequently, if ever activated together, a good deal of capacity is required to raise and keep these units above threshold. An implication of this view is that certain types of tasks can become automatic with practice. The work of Shiffrin and Schneider (1977) is impressive in this respect. They demonstrate that with extensive practice, certain search tasks can become so "automatic" that increasing stimulus load has no effect on search times. It is the present view that these differences in processing are quantitative, because the mechanism of unit activation is the same in all instances. There does not, in fact, appear to be any compelling reason to assume qualitatively different mechanisms of selection exist at all. This is not to say that all tasks, no matter how complex, become automatic with enough practice. Some kinds of processing never become automatic, and these will always make large demands on capacity.

An important reservation must be added to the suggestion that all processes are qualitatively similar. This qualification is that, although the means of activation must be the same for all representations, the type of information contained in the representation might be dissimilar. Thus the structural, phonemic, and semantic distinctions of information, central to the work of Craik and Lockhart (1972), are assumed to reflect variations in the type of information, but not necessarily distinct modes of processing. Each unit is different from all other units, but all units become activated in the same fashion. Hence, processing of information is not different; it is the codes established by processing that vary. Differential recall of information processed at different levels (i.e., Craik & Tulving, 1975) reflect the type of units activated rather than any qualitative differences in processing. Why some units are activated at some times and others at other times given "identical" stimuli is because the information available to the subject changes across tasks. When a phonemic match is required, for example, acoustic attributes are focused upon or activated to the exclusion of other features. Psychologically, this stimulus is functionally different from those established during structural and semantic matches. This suggests that intentions, plans, predispositions, emotions, or beliefs can be considered a type of information. Usually these have been treated as "context", but really they are nothing more than another source of information employed by the organism in performing a task. At a naive level these paradigms seem counterintuitive: Our behaviorist bias insists that identical stimuli map to consistently identical responses, assuming no intervening events. If it can be reasonably argued that these stimuli are not identical because of the organisms cognitive state at stimulus onset, the stimulus-response consistency assumption can be maintained.

Clearly, the term "process" is central to the present theoretical development. This focus is essential, in that it conveys the active, constructive way in which the human intellect operates on incoming stimulus information. Basically, processing refers to some manipulation or transformation of input information. Transformations include, but are not limited to, the change from the nominal (real world) stimulus to some functional representation. They are also assumed to include changes from one type of mental representation to another. Further, it is assumed that the maintenance of an established mental state is a form of stimulus manipulation, and thus, a process. Neurologically, processes include the excitation of nerve fibers, the transfer of nerve impulses, and the maintenance of an existing neurological state. The most important aspect of processing at the physiological level is the activation of gnostic units (Konorski, 1967). These units are assumed to correspond to mental relationships or nodes (Bindra, 1976; Blumenthal, 1977;

Morton, 1970), and will be discussed in more detail later.

All processes have certain features in common. They are assumed to have potentially observable physiological correlates. Also, every form of processing is assumed to require a finite amount of time to perform. "Automatic" process (Posner & Snyder, 1975) seem to demand no effort and very little time to complete, but this is because lower-order processes are well integrated by massive practice. Still, it is assumed that some time, effort, and capacity are demanded by these and all other process repertoires.

Another feature of stimulus processing is that once initiated, some memorial consequence of the processing remains. Further, the type of processing done on a stimulus is directly related to the type of memory that is established (cf. Craik & Lockhart, 1972; Lockhart, Craik & Jacoby, 1976). In the case of lower-order processes, such as feature analysis or movement detection, certain primary nodes are activated. Because these elementary processes are occurring nearly continually, the activated units are being changed rapidly as the flood of new information replaces the old. This rapid displacement of information leads to very short-lived memory phenomena as, for example, the "icon". Higher-order processing, on the other hand, results in durable representations because the pattern of activated units is more unique and involves novel integrated, cognitive units. The products of these processes are less likely to be displaced by subsequent information because similar patterns are less likely to be activated.

The implications of this view are twofold. First, this suggests that forgetting is due, in part, to the similarity of information abstracted from temporally approximate stimuli. Second, it should be the case that a lower-order analysis of stimuli may lead to a durable memory as long as no further analysis of the stimulus is carried out. Evidence for the first view has been amply demonstrated; stimulus similarity over a wide range of experimental paradigms has been found to lead to poorer performance (Shulman, 1971). Kroll (1975) has presented evidence supporting the latter interpretation. He has shown that visual codes which normally last for a second or less can be made available for 20 sec or more, as long as no further visual processing of the stimulus, or other stimuli, is required. Thus, "depth" effects appear to arise primarily because of the complexity of the cognitive structures activated and the similarity of contiguous information.

It is necessary to emphasize that the present conception of stimulus processing suggests that all stimulus transformations are selective in nature. Upon stimulus presentation, a series of successive analyses of the stimulus are carried out. Input into each analysis is the output of the preceding analysis. Structurally, each analysis corresponds to the activation of some subset of neural units. Which subset of units is activated at any one time is determined by the specific information available (i.e., units activated previously). The most basic, structural processes such as the activation of line detectors or color analysers, are followed by the more focused, deeper analysis like the interpretation or meaning of the stimulus. Selection occurs because any stimulus can activate a number of possible units. The printed word "BOX", for example, activates the same structural units in all contexts, but not the same semantic interpretations (a kind of sport vs. a type of container). Because words do not usually occur in isolation but in the context of other information as well, the particular meaning intended is clear. Units activated by associated context information are assumed to overlap with those of the word. Thus, one semantic interpretation is activated more easily than another because of the "priming" effect of context (Posner & Snyder, 1975). These deeper interpretations are selective in the sense that one set of units is activated at the expense of the other. Further, these interpretations do not have to be "consciously" or "actively" or "willfully" made by the organism; rather they represent the information available to the organism (i.e., units currently activated) at that instant in time.

Not all processes are necessarily observable, or distinguishable at the response level. Different processing of stimuli may result in the same behavioral output. For example, one might count the letters in a square array or multiply the number of rows of letters by the number of letters per row. In both cases the subject would arrive at the same result but by radically different means.

Furthermore, similar intervening mental states may also be the result of dissimilar processing. Because of this, serious methodological difficulties exist in trying to examine any one process by observing overt responses. Different processes may also be strung together, making any distinction between them arbitrary. Undoubtedly, a current difficulty in many areas of cognitive psychology is to define certain types of processing independent of other processes. Terms like selection, encoding, scanning, retrieving, and searching exemplify this problem. Each term certainly requires the assumption of processes in common with other terms, but which processes are implicated is problematical.

It is the present view that different processes vary with respect to the amount of time and effort necessary to run to completion, so that the appearance of parallel or serial processing may be misleading. This distinction is difficult to make because what is designed to be a multiple process task by the experimenter may be treated as a single or lower-order task by the subject. Also, preattentive or parallel processing may arise from several tasks being discretely handled, with rapid switching occurring among them. More complex; cognitive activities might appear serial in nature because the task demands of the situation require some intermediate mental product before further processing can occur. This would not necessarily mean that the system cannot function in parallel, but rather that the problem must be solved that way. Finally, a certain amount of minimal processing is involved in both complex and simple tasks, suggesting that the design of experiments intended to elucidate parallel-serial distinctions may be seriously confounded by the inclusion of some common processes. Other than to concede that certain mental activities can occur quickly, while others seem to take longer and demand more effort, no assumptions about parallel-serial processing appear necessary in the present account.

Structure

Assumptions about structure are necessary in the present approach, even though the emphasis is on process. Several levels of discourse regarding structure may be entertained. Discussion will first be confined to the neuroanatomical aspects of structural representation, and then extend consideration to a more abstract conceptualization of long-term storage.

It was noted earlier that at the sensory level a number of neurophysiological studies have suggested there is a converging and diverging hierarchical structuring of the central nervous system. The work of Hubel and Wiesel (1959, 1962, 1965, 1968) is salient in this respect. While the details of their work will not be reiterated here, it will be noted that their data indicate that visual receptive fields are structured such that there is convergence from lower- to higher-ordered neurons. These latter cells appear to be activated in response to specific features of a stimulus array, such as lines, pure tones, and corners. This is consistent with the present account of cognitive functioning and will serve as an acceptable neurophysiological model for the processing of primariy sensory information. It is also assumed that impinging stimuli initiate a transmission cascade such that the input to lower-ordered cells converges upon a higher-ordered cell sensitive to specific features. In contrast to the apparent convergence of the nervous system, there is appreciable divergence as well. Spinelli, Pribram and Bridgeman (1970) have demonstrated that there is often little or no deficit after substantial lesioning of the respective sensory system. This suggests that the higher-ordered cells are replicated and anatomically distributed rather than focally located.

There has been some attempt to employ this notion of hierarchical structuring as a model of cognitive functioning (Konorski, 1967; Walley & Weiden, 1973). If there are higher-ordered cells sensitive to particular features of a stimulus such as lines and corners, it has been reasoned that there may be even higher-ordered cells that are selectively activated in response to more molar stimulus attributes such as shape, or even meaning. The assumption of higher-order cell assemblies or "gnostic units" has been the basis for provocative accounts of a number of phenomena. From the viewpoint of the present theory, this approach is unacceptable. Conceptualization of a unified memory "trace", whether cloaked in the terminology of gnostic units, cell assemblies, or something else, as the basis for the ultimate form of mental representation, is not compatible with the current orientation. It may be that traces serve as elements of a pattern, but it is not assumed that these elements activate a higher-ordered unit. Patterns of activated units are assumed to be the basis of all simple and complex mental representations. Neurologically, this implies that the mental representation does not exist in and of itself in the nonactivated state. It is generated from specific input stimulus configurations and exists as an independent entity only when it is activated. Memories are merely patterns of units reliably activated upon stimulus onset.

This conception reinforces the process bias of cognition expressed earlier. Mental representations are generated patterns, rather than static structures which become activated by some transfer process. This allows for structural compatibility with such behavioral phenomena as the momentary and long-term distortions in the recall of experiences, priming phenomena, and the deleterious effect of similarity in recall. All these events are seen to occur because of the processing of subsets of stimulus features composing mental representations. For instance, distortion in recall is seen to arise from the deactivation of some of the units comprising a representation. Their subsequent replacement with units more frequently activated in the context of those remaining, accounts for why distortions occur in a culturally determined manner (Bruner & Postman, 1948). Similarly, preexposure to some stimulus attributes leads to enhanced recognition and recall because some of the features of the stimulus representation are activated by the priming procedure. Finally, confusion among nominally similar items is due to the overlap of identical features comprising the competing representations.

A more abstract account of the role of structure is possible as well. The organization of what has been called "long-term memory" (LTM) will be discussed along with some of the implications of the present conception. It is important to note that many writers have used the concepts outlined here in some form or another (see Bindra, 1976; Norman & Bobrow, 1975; Shiffrin & Schneider, 1977). Basically it is assumed that feature detectors can be organized into "nodes" or collections of features. These nodes are permanently in memory in the sense that particular input stimuli can activate the whole constellation of features making up the representation. (It is understood that activation is analogous to "processing", as used earlier.)

Nodes consist of features, but may also consist of other nodes as well. These features and nodes include structural elements in the case of concrete stimuli, or more highly organized features like the relationships with other nodes. Each feature may be represented in more than one node, as, for example, in the case of the orthographic characteristics of words. What makes one node distinct from another is the potential for all elements of the node to be activated at one time. Activation, however, can be restricted to only a small number of features of the node. The organization of features into nodes is a learning process that is influenced by variables such as the number of exposures (trials), previous integration (meaningfulness), and stimulus duration. Activation of a particular node or collection features requires a certain amount of mental effort or capacity. To activate an entire node involves more processing than to activate just a few of the elements. Further, it is assumed that there is a finite number of elements or nodes that can be activated at one time. While the system may have some flexibility in allocating capacity, depending on the task demands of a situation (Kahneman, 1973; Navon & Gopher, 1979; Norman & Bobrow, 1975), it is the limited number of features which can be activated that underlies the observed channel capacity of the organism (Broadbent, 1958). The automatic processing of information (Posner & Snyder, 1975; Shiffrin & Schneider, 1977) refers to the activation of the primary feature detectors of a node. Because of the massive practice acquired from constant structural analysis of stimuli, or perhaps because such detection is innate, the organism can process a large number of these features simultaneously, without overtaxing capacity.

Deeper, more cognitive processing involves activation of aggregates of units not usually associated together, or even the activation of previously unrelated nodes. This demands more capacity than lower-order analysis and thus leads to attentional focusing or the inability of subjects to process information outside an activated cognitive domain. More will be said about consciousness and attention later, but for the present it is important to note that structurally at least, there is no specific "filter" or mechanism where information flow is limited. In fact, the current approach suggests that one capacity limitation of information analysis is the extent to which the stimulus components are integrated preexperimentally. Extensive exposure to a stimulus configuration is assumed to result in more integration of the nodal components with an attendant decrease in the effort expended to activate the node. Hence, node activation, effort, capacity, processing, and focal attention are assumed to be determined by the extent to which stimulus features in a configuration make contact with their neurological representations.

Certain other aspects of nodes are worth noting. The activation of a node or feature detector takes place only when its threshold is exceeded. Whenever threshold is exceeded for a node and it is activated, related nodes have their thresholds reduced. This reduction of threshold is greatest for nodes that are closest to the activated node. This is assumed to occur because the activated node and its related counterpart would have a number of features in common. The more related two nodes are, the more features they will share, and the more likely activation of one node will lead to activation of the other. The lowering of the thresholds is usually temporary. Over time the threshold tends to return to its previous level if no other related information is input. With high degrees of learning, more permanent alteration of thresholds are possible. Thresholds of nodes are therefore critically dependent upon previous integration of the features comprising the representation. However, the terms "threshold" and "integration" are not interchangeable. Strictly speaking, the former refers the input energy needed to activate a feature or node, while the latter term relates to the tendency of all the features composing a node to be activated together. Treisman (1960) has argued that stimuli activate "dictionary units" (a concept similar to that of nodes) and that certain units, such as one's name, can have a permanently lowered threshold. Otherwise, she views the change in threshold as a rapid and shortlived change in the discriminability of the input signal. This conception is compatible with the current orientation.

Learning

The present approach can be extended to include learning phenomena as well. One critical assumption of the theory is that a constellation of activated primary features makes up the mental representation of an object or event. The way organisms acquire knowledge is by the repeated activation of the same feature detectors in response to a stimulus. This principle is central to the present account, and it surfaces in almost every aspect of learning. Here learning is regarded as a relatively permanent change in behavior in response to a stimulus configuration, due to experience. Every behavior made by an organism is assumed to occur in response to a specific stimulus event. These events can be external or internal. The task of the present thesis is to expand upon how the stimulus impinging upon an organism becomes psychologically transformed into response-producing event. Obviously, not all stimuli can control behavior at the same moment because of the response limitations of the system. Some acquire priority over others in certain contexts because of previous learning. Even in situations where so-called automatic responses occur, prior learning is implicated.

It has been argued earlier that patterns of activated detector units make up a mental representation. One can consider these units to come prewired and that they take on functional significance if stimulated during critical periods in an organism's development (Nash, 1971). That is, the normal organism is assumed to be equipped at birth with particular response potentialities. Learning certain responses at an optimal developmental moment seems to be required for some behaviors to be established (Lorenz, 1960). Activation of feature detectors at some time in an organism's early existence is probably necessary for the later functioning of these detectors. They are assumed to be part of the neural organization present at birth.

What is acquired by the repetitive occurrence of a stimulus is the tendency of particular feature detectors to be activated together. For example, the presentation of a square would lead to activation of four corner detectors, along with edge detectors. Eventually, with the repeated exposure to squares, the threshold for this constellation of detectors to be activated together would be lowered. What would have been an initially inadequate stimulus to establish a representation of "squareness" would later be sufficient. This example illustrates several important features of the model. Clearly, it is assumed that patterns of detectors are activated to comprise a representation. There are no specific units that become higher-order units corresponding to "squareness". Perception of form occurs when the established pattern representing that form is activated. It must be emphasized that learning merely lowers the activation threshold of objects; it does not transform them into something else. This assumption is critical because it reflects the belief that new learning occurs only in relation to the extant cognitive state of the organism. Furthermore, this approach is economical in that all unique constellations of activation are composed from a common pool of features. The almost limitless capacity of semantic memory is due to the overlap of features composing mental events. As learning progresses, these initially novel patterns become more and more easily activated as they become more familiar, but there is no qualitative change in the kind of mental representation of an event. This is not to say that elaboration cannot occur, but if it does, it merely adds to the critical features already in the representation. In fact, during learning it might be anticipated that an opposite effect would result: Some initially critical features of a representation may become less important and drop out with overlearning. Redundant information may diminish in importance as the organism acquires skill in encoding repetitive events. If this is the case, then capacity limitations evident early in learning may be minimized by alterations in feature thresholds or by changes in the defining characteristics of a representation.

The notion of thresholds is important in the present account as well. It is suggested that every feature detector has a threshold of activation. Apart from momentary variability indigenous to the system, there are always ways in which learning can alter these standard thresholds. A very salient stimulus can activate its mental representation easily because prior learning has lowered the activation threshold for that item. In fact, "salience" can be regarded as another term for a lowered threshold. A second and more important way in which learning influences thresholds is in the case where the establishment of one pattern alters the activation of another. This is the basis of the well-known priming effect (e.g., Posner & Snyder, 1975). Here the presentation of an initial stimulus facilitates or inhibits subsequent processing of a later stimulus, even after the first has been removed. This suggests that the activation of one set of detectors involves activation of detectors from other representations, proportional to the degree of overlap of common detectors. Hence, priming by presentation of a primary-associate leads to faster recognition of an item than priming with neutral words (Warren, 1972).

Other established effects can be interpreted from this perspective as well. The semantic set-size effect (Shaeffer & Wallace, 1974) is one such example. Subjects presented two words can decide more quickly if they are related the closer they are semantically. Thus, subjects can decide that a ROBIN is a type of BIRD faster than a ROBIN is a type of ANIMAL.

Once again, this effect is most likely due to some feature activation process, the basis of which is learning.

The foregoing discussion does not clarify the important issue of what leads particular information to be activated at one time. It has been argued that thresholds are lowered for related representations because many of the features activated in one representation overlap with those of other similar patterns. This does not explain just how some patterns become activated in the first place. To do this it is necessary to return to the assumption that all learning involves the establishment of stable patterns of activated features. What initially is activated are the very basic, structural aspects of an object. Later, as additional information becomes available to the organism (from previous learning, proprioceptive cues, moods, or personality characteristics), other features may become activated. The end product of all this input information is an assemblage of activated features that represents all the relevant aspects of the environment. The pattern established is in a sense a statement of the condition of the organism and an historical account as well. That is, not only does some verdical aspect of the stimulus become activated but also all other previously acquired information. In this way expectation is important in activation because previous learning is critically implicated in the nature of the pattern finally established. When the expectancy of an organism is violated in some fashion, a new pattern of activation arises and learning occurs in that context (c.f. Rescorla & Wagner, 1972). With repeated violations of expectancy the new pattern gradually becomes the most probable in the new context. It may also be surmized that the more expectancy is violated, the more learning occurs on a given trial, accounting for the typical finding of negatively accelerating learning.

It goes without saying that the role of learning is profoundly influential in selective behaviors as well. Recall that selection is assumed to be determined by the activation of certain configurations of patterns corresponding to stimulus processing at different levels. So called "preattentive" or "automatic" processes occur without intent, effort, or noticeable expenditure of capacity. Because of this, a considerable portion of the nominal stimulus field can be processed. Later, deeper analyses are presumably more costly with respect to the above, and a smaller, more focused analysis must be carried out so that capacity limitations are not exceeded. Learning is involved in that the degree of focus is primarily determined by the sophistication of the pattern established by prior learning. When a large amount of practice is expended in acquiring a representation, the activation of a complex pattern is much faster than it initially was, even to the point of it becoming automatic. In this regard Neisser (1976), Schneider and Shiffrin (1977), and Shiffrin and Schneider (1977) have all demonstrated that some complex behaviors can become reliably reproduced after massive practice with little effect on other ongoing behavior. The present thesis is concerned with just this effect: Selection that requires deeper processing of a stimulus is assumed to lead to a more focused analysis than selection repertoires that are based on lower-order processes. Elaboration of this assumption will be made later but for the moment it is important to emphasize the role learning plays in selection. Novel patterns cannot be selected from a stimulus complex as easily as familiar patterns because the threshold of activation for the former is higher than that of the latter. This difference is due to the relative practice subjects have had in establishing each representation. This last assumption implies that lower-order processes are mental transformations that have been conducted so frequently that, upon their initiation, completion follows with little demand upon capacity. Higher-order analysis and selection requires greater capacity because the activation of unique constellations of features does not occur with the benefit of previous learning.

Consciousness

Recently the concept of consciousness, long regarded by the behaviorist tradition as an untestable construct, has become a topic of theoretical interest (Bindra, 1976; Blumenthal, 1977; Mandler, 1974, 1975a,b; Neisser, 1967, 1976; Posner & Snyder, 1975; Posner & Warren, 1972; Shallice, 1972). While certain uses of the term must be avoided if theoretic clarity is to be attained (Miller, 1962), it remains, in Mandler's words "respectable, useful and probably necessary". Much of the difficulty associated with the term arises from the uniquely phenomenological character of the data envoked to support it. Appeals to introspection, however intuitively palatable, are an insufficient source of information regarding consciousness (Natsoulas, 1970). This poses a serious dilemma: How are we to examine phenomenon readily accessible to introspection, and indeed, an important aspect of introspection, without direct appeal to introspection? Compounding this difficulty is the definitional problem associated with constructs grounded upon private experience. As Mandler (1975a) cogently points out, there is no reason to assume conscious contents correspond to the language used to describe such contents. Even if there was an isomorphic relationship between conscious representation and language, it is not clear that the act of transmitting phenomenological data can occur without transformation of the data. Furthermore, as we question private experience, we unavoidably modify consciousness by the act of inquiry itself.

These difficulties still present formidable obstacles to a serious examination of consciousness now, as they did a century ago. However, there has been some recent theoretical reorientation that minimizes, although it does not eliminate, these classical problems. In this regard, the work of Neisser (1967) is seminal. He has suggested, by his use of the concepts of "preattentive" and "focal attention", that consciousness (although he called it attention) can be fruitfully studied from a process orientation. That is, certain cognitive behaviors occur automatically without apparent awareness, while other activities require the investment of voluntary attention with resultant awareness of completion. These processes often lead to an "internal verbalization"(Neisser, 1967). Hence, attention or consciousness was assumed to be related to a mode of stimulus processing. With the advent of human information processing theory, it became possible to discuss consciousness from this point of view, and several researchers have done so. The principle advantage gained is to avoid to a large degree the problems associated with a mentalistic definition of consciousness and to provide a means of acquiring data free from the methodological limitations imposed by an introspectionist approach.

Such a change in orientation can only be bought at the cost of several additional assumptions about human behavior, however. First, the process approach necessitates some explicit statement about the relationship between processes, states, and consciousness. Previously in this thesis the two former terms have been distinguished. However, relating the construct of consciousness to state and process is fraught with problems. Is consciousness a state, or is it a process? If it can be considered either or both, how can consciousness be conceptualized structurally? Given the recent advent of the process notion, it is not surprising that inconsistent use of the term has arisen in the literature. Thus, Mandler (1975b, p.53) states that "thinking is what takes place in consciousness", yet asserts that "consciousness is not a special place or space or area in the mind" (p.48). Furthermore, "consciousness is a mode of <u>processing</u> that effects the state of a structure" (p.50, italics mine) and at the same time it is a state: "cognitive structure...may...become conscious" (p.50). Similarly, Posner and Warren (1972) use the term in different contexts: "conscious processing" and "conscious attention" (p.36) are process conceptions, while the phrase "once an item is conscious..." (p.36) suggests a state definition. These are certainly not the only writers who have confused state and process notions of consciousness, but rather their work is indicative of the area as a whole.

Clarification of the term eluded scholars for years, and it is unlikely that a definitive definition of consciousness will be forthcoming in the near future. However, it is difficult to imagine cognitive theorizing progressing without some first approximation of what consciousness is. Several of the authors cited in this section have already provided some fruitful conceptual starting points. It is suggested that these notions, when applied to the present theoretical framework, can yield a satisfactory statement about consciousness.

Recall the assumptions made earlier regarding the structure of information in memory. It was argued that cognitive nodes were either activated quantitatively along a continuum or they were not. The state of a mental representation referred to degree of activation of a cognitive node at any instant in time. Conscious states are those combinations of activated features that comprise complex thoughts. Activation of a complex pattern of features can only occur by means of conscious processing. It is assumed that states that arise from low-level processing of information cannot be conscious. Automatic cognitive processing results in unconscious representations.

It is important to note that consciousness is not assumed to be a fixed capacity (Mandler, 1975a,b; Posner & Snyder, 1972). Absolute limits in attentional allocation, information processing or consciousness cannot be considered until some empirical measure of the psychological quantity of information can be made. Similar tasks may require very different cognitive capacities, but so long as our definition of capacity remains tied to overt response measures we may never satisfactorily examine process limitations. Further, recent demonstrations by Spelke, Hirst and Neisser (1976) and Schneider and Shiffrin (1977) have demonstrated that the capacities of human subjects can be dramatically modified by extended practice. The extent to which these findings can be extended to conscious processing is hypothetical, but nevertheless they suggest that strong limited capacity assumptions are unwarranted and possibly untenable.

A reasonable question at this point is why does complex processing lead to conscious representation? From the present theoretical perspective, it is because of inertia involved in establishing a higher-order activation. Since deeper processes are unpractised and more focused than lower-order automatic analysis, maintenance of these states requires considerable attentional investment by the subject. Additionally, higher-order representations are less likely to be displaced by similar information. Recall that lower-order information was assumed to be rapidly displaced by the continual flood of structural input. Unless this input is stopped, as in the Kroll, Parks, Parkinson, Beiber, and Johnson (1970) experiment, structural detail will be rapidly lost. This rapid loss will prevent conscious experience of these events. Complex mental activity is less likely to be displaced, because the component features that comprise the thought are relatively novel assemblies of units. This is to say that automatic processing of information leads to the establishment of a fleeting, unconscious representation. In contrast, the focused attention required to establish a semantic representation results in a conscious experience of the stimulus event. Not only does this mean that they are less practised and require more effort to establish and maintain, but they are also more resistant to removal by structural input. If, however, similar higher-order units are activated subsequent to the initial code, interference due to similarity will manifest its deleterious effect in this instance as well, and conscious experience of the initial representation will be minimized if not entirely eliminated.

Altered states of consciousness are also relevant to the present orientation. We have already discussed some of the implications of practice on the automaticity of encoding. It is quite likely that conscious experience diminishes in a lawful way with extended practice. Certainly some activities, like driving a car or typing, can be conducted without conscious awareness, but only after long periods of practice.

Learning these activities takes place with awareness, or conscious experience. It is important to note that the withdrawal of awareness occurs as the task becomes easier and less demanding. However, even the experiened driver will, on occasion, be confronted with a stimulus configuration that is unfamiliar (like a near collision). This usually results in an immediate conscious experience and focused attention to the task at hand. From the present perspective, this is because the task demands of the situation require activation of unique patterns of features (i.e., demand more attention), resulting in awareness.

Another example of altered states of consciousness has been discussed by Mandler (1975a,b). He has argued that stopping the "flow of ordinary consciousness" results in a meditative state that is held to be enriching and enlightening. Regardless of the purported benefits of such behaviors, it seems clear that reaching the desired state can occur only when higher-order relationships are excluded from thought. In fact, it is common practice to meditate on a specific object or perception. These behaviors seem to reverse to normal course of stimulus processing. Here structural analyses are concentrated upon, without displacement from incoming stimulation. Usually structural information never reaches consciousness because it is dealt with automatically and is rapidly displaced. If no other information is input, the initially activated features remain activated. When a single percept is so held in consciousness, unique features of it may be discerned. Because processing of other information is stopped and awareness results, it is correct to call this a conscious state. Typically, achieving this level of cognitive control is exceedingly difficult. Not surprisingly, devotees of these esoteric practices claim consciousness stopping can occur only with much practice.

Finally, it seems important to distinguish two aspects of consciousness that are accounted for by the current treatment of the topic. Hochberg (1970) has argued that consciousness is both selective and organized. This is consistent with the present approach because it is assumed that as processing goes more deeply, greater selection of meaning occurs along with conscious experience. This selection in consciousness occurs in exactly the same way it occurs in all higher-order processes. As attention becomes more and more focused, specific relationships between patterns are activated, while general relationships are inhibited. Selection results in conscious experience at the very highest levels of processing. Clearly, the assumption of qualitative and quantitative distinctions between processing modes must be reflected in consciousness. Indeed, it is quite possible that consciousness is not an all-or-none phenomenon; like processing it may vary along a continuum. Such an assumption follows from the theoretical position stated herein, and is also in agreement with the phenomenological experience of altered attentional states.

In addition, consciousness is organized. Thus, the activation of one pattern will make similar patterns more likely to be activated in the same context. This can only occur, according to Hochberg, if some "internal constraints" can be predicted on the basis of previous information. Because such organization is coincidental with higher-order processing, it is held to be conscious as well. As a corollary, it may be assumed that automatic processing is less well organized. That is, preexposure to a stimulus would be expected to prime lower-order detectors much less than higher-order representations, because elementary processes are assumed to be implemented without interruption of ongoing activity or awareness (Posner & Snyder, 1975). Although there is no extant data to support this notion, it may be predicted that these basic units are more prone to interruption from subsequent input, and are thus less well organized into higher units.

# COMPARISON WITH OTHER THEORIES OF ATTENTION

In what way does the present approach differ from the theoretical positions espoused recently by other researchers? How does the current undertaking account for the empirically established phenomena, and does it do it more successfully than other orientations? These questions must be answered if the present account is to be seriously considered. The strategy adopted in this section will be to review some of the crucial assumptions of different approaches and compare them with the corresponding assumptions of the present conception. While it is beyond the scope of this paper to exhaustively review the various theories of selection, certain important aspects will be examined in sufficient detail to make a meaningful comparison to the present view.

## Filter Theory

Perhaps the most influential attentional construct in recent years has been the assumption of a "filter" that selectively focuses attention to some input (Broadbent, 1958, 1970; Treisman, 1960, 1964a). Considering Broadbent's (1958) model for a moment, it is important to note that information is assumed to enter the system either through parallel sensory channels, such as the left or right ear, or on "functional" channels that include messages with a similar frequency, pitch, loudness, or location. Because there is a limited capacity processing channel later on in the system, a filter is postulated to account for the tendency of subjects to select one of the parallel input channels. Unselected channels are thought to be stored for a brief time in the short-term memory. Unless this information is rehearsed it will deteriorate in a matter of seconds and be lost altogether. Only attended messages are able to make contact with information in long-term memory, or to activate the motor output mechanism. Because of the limited capacity channel, attended messages must be serially processed to avoid overloading.

Certain objections can be made regarding Broadbent's conception of a filter. It is clear that the notion of solely a physical basis for the selection of channels is inadequate. Moray (1959) has shown that subjects will notice a semantically salient feature on the unattended channel such as the subject's own name, and Grey and Wedderburn (1960) have demonstrated that subjects will switch to the "unattended" channel while shadowing, if the information contained there is semantically predictable from the shadowed portion. Treisman (1964a) has modified the filter by postulating in more detail just how the mechanism works. Information enters into the organism through parallel sensory channels and is analyzed in a primary, physical manner. The filter works by attenuating the output from these analyzers, such that only messages with a particular physical characteristic are selected for further processing. The nonselected channels also pass deeper into the system, but in a weakened form. All messages processed at the physical level are potentially able to be consciously experienced by the subject. The attended and attenuated information is then processed by a recognition mechanism that consists of "dictionary units". These units fire when their threshold is exceeded by the corresponding input stimuli. There are two important features of the dictionary unit threholds: First, they could be different for each unit and second, they can vary depending on the context of a particular task. That is, thresholds can be permanently lowered from extended practice or temporarily altered by events that immediately precede the activating stimulus. Attenuated but "important" signals are perceived because the thresholds of the corresponding dictionary units are always low. In contrast, normally less salient stimuli may become activated easily in certain situations if they are previously primed by the occurrence of related stimuli. Unimportant, attenuated messages usually do not activate dictionary units because those units have higher thresholds. Thresholds can also be altered by instruction, or by the context of the input information. Hence, telling a subject to respond to a particular signal, or providing information that has been associated with the signal in the past, should make recognition of the signal more probable because the threshold of the corresponding dictionary unit has been lowered.

The present approach is compatible with a filter orientation, but entertains some important distinctions as well. For example, as in filter theory, it is assumed that selection of messages on the basis of some physical attribute is possible. Failure at that point may lead to selection at a semantic level. This is to say that the phenomena of selection is not in question but rather the mechanism by which it occurs. In this regard, it is presently convenient to adopt the assumptions of dictionary units and variable thresholds as stated by Treisman, albeit with some noteable caveats. First, dictionary units are assumed to consist of a converging hierarchy of elementary analyzers. While Treisman assumes activation and recognition of a whole unit occurs in an all-or-none fashion, it is presently suggested that a pattern of elementary analyzers are activated. Further, it is assumed that a continuum ranging from inactivity to full activation of elementary units exists. As stated earlier, the establishment of a representation does not mean all units composing that structure are active, but rather that at least a minimal subset of them have exceeded threshold.

The critical distinction between approaches lies in the conception of the filter. For Treisman the filter exists at a definite place in the information processing system, but it is never made clear just how selection is accomplished at this point. Selection higher up at the dictionary level depends upon the activation of recognition units. From the present point of view, the postulate of two selective mechanisms seems unnecessary, particularly since the means by which selection occurs in the first place remains unspecified. The present approach removes the need for a distinct low-level analyzer because it is assumed that all selection is due to activation of recognition units. In this way the restatement of the phenomena (i.e., that "filtering" occurs at the physical level) is not used as an explanation of the phenomena itself. It also seems most convenient to minimize the structural aspects of the information processing system. Filters, short-term memory, the icon, and control processes are unnecessary in the present account because the activation of recognition units procures these functions. Unlike the filter notion, the current orientation adopts a process account of the above phenomena. Filtering refers to the tendency of some units to be activated in a particular context while others are not. Short-term memory capacity is the number of such units activated. The icon is the most physicalistic representation of a stimulus in terms of unit activation, and control processes are the sequences of activation that occur after stimulus onset.

It should be pointed out that the notion of active attenuation of inputs does not appear in the present conception. Selection of a particular message occurs because the corresponding mental representations are deactivated, and not because competing messages are inhibited, deactivated or in some way restrained from reaching awareness. Nonselected inputs are simply not processed. Their presence in the stimulus field in no way interferes with the processing of more pertinent stimuli. However, it is critical to note that this does not deny that some functionally nonselected items can have a strong effect on the processing of other stimuli. Although an item does not appear to have been "attended" it may have been processed. Corteen and Wood (1972) have shown that the occurrence of a word previously associated with shock on a nonattended channel leads to an increase of the subject's GSR. Clearly, this suggests that some semantic analysis of the item occurred even though it was on a functionally nonattended channel. This merely underlines the necessity of considering attention as a process continuum. At the extreme end are those stimuli which are truly not processed and thus do not demand attention or capacity. Further along are those items that do not have any dramatic or apparent effect on attention, but which have used some processing capacity, if our methodology is sensitive to measure it (e.g., Corteen & Wood, 1972). At the other extreme are those tasks that very obviously demand a great deal of processing. The important point is that selection occurs by activation of inputs and not by any mechanism of inhibition.

Finally, two other constructs are used differently in the current theory. First, the "bottleneck" or capacity limitation typically observed in human behaviors is not necessarily to be found in any one place in the system. It is assumed that failure in unit activation can occur at any of several levels. Just as semantic information is lost because of input load, physical analysis may be terminated prematurely as well. Also, the concept of channels is de-emphasized in the present account. To Broadbent (1959) channels were distinguished by physical properties, or by semantic characteristics. Treisman (1964a) eroded the notion by assuming parallel processing of messages can occur as long as the messages do not overlap the same analyzers. The concept of channels thus becomes difficult to define within filter theory. Initially, it was assumed that channels were processed singly (indeed, this was the intended definition), but failures in shadowing tasks (e.g., Grey & Wedderburn, 1960) have changed this view. While it is often convenient to talk of channels, the construct appears to have no psychological validity. Hence, channels are assumed to be synonymous with the term information, and no strong assumptions of their structural nature will be entertained.

Analysis-by-Synthesis

A second major class of attentional formulations has been the encoding theories (Egeth, 1967; Haber, 1966; Hochberg, 1970; Neisser, 1967; Sperling, 1967). The basis of these theories, with several important variations, is that encoding of information is a necessary and sufficient condition for attention. Encoding is assumed to occur after some "preattentive", automatic analysis of the stimulus input has been made. Neisser (1967) has labeled the unencoded information iconic and echoic memory for vision and audition, respectively. Unless this information is processed or encoded, it is rapidly lost from a very large capacity, but short duration buffer. Subsequent encoding of preattentive information takes place in a limited capacity mechanism. Neisser (1967) has argued that encoding requires active reconstruction of the input stimulus; Hochberg (1970) has suggested that encoding involves the detailed testing of the expectancy of the input. Both views assume a constructive approach to perception.

This orientation appears to differ in fundamental ways from filter theory. It is clear that for filter theory the locus of selection is early in the system (although Treisman's dictionary units allow for later selection as well). In contrast, encoding theory suggests that selection occurs after automatic analysis of the input has been made. Also, selection in filter theory demands an analysis of the nonattended information to a level at which some choice of competing messages can be made. Encoding theory argues that attention is coincident with encoding, and that knowledge of the nonselected items fails simply because they are not processed. Deutsch and Deutsch (1963) have adopted a modified view of encoding theory based on the premise that all information is perceived and analyzed, but only the messages that are put in long-term memory are attended; the rest are rapidly lost from the short-term store.

Several writers have pointed out the underlying similarities of encoding and filter theory, despite their apparent differences (see Erdelyi, 1974; Kahneman, 1973; and Walley and Weiden, 1973 for a discussion). Thus, it may be argued Neisser's assumption that encoding proceeds serially as a means to avoid information overload is, in itself, a type of filter. Moreover, it is probably significant that both approaches employ the same data base as support for their respective positions. There does not seem to be much data that can be taken as a strong refutation of either position. This suggests that these approaches have a number of implicit assumptions in common, and encourages the possibility that both orientations can be incorporated into a single theory of selective attention having the salient characteristics of each approach.

From the present perspective, it is argued that the issue of pre- versus postperceptual selection is dependent on the definition of perception. Like Erdelyi (1974), we prefer to adopt an information processing bias for perception. That is, perception and selection of inputs can occur at several places in the process continuum of cognition. Erdelyi argues against an unimodal selector mechanism and suggests that selection can occur in a different fashion at any of several subsystems. The present approach, in contrast, assumes that selection is a result of process focusing that is in principle the same at all levels of cognition. It seems that a priori acceptance of the postulate that perception precedes the response system in a unidirectional information processor, seriously constrains the theoretic options available to explain selection effects (Erdelyi, 1974). Certainly, selection appears paradoxical if we adopt this assumption: How can we select and hence, perceive, a subset of information without first knowing (perceiving) that information in the first place? The question of whether selection is a perceptual or response effect is eliminated if we assume that perception and selection do not occur at any one place in the continuum but at many.

Other features of the encoding theories are represented in the present approach as well. Hochberg's (1970) finding of enhanced recognition for a stimulus in a congenial context is one example. He argues that confirmation of an expectation should lead to better recall of the stimulus. This follows from the present theory, because stimuli that are more likely to occur in a particular context have several features comprising their representation activated surreptitiously from the context itself. That is, related units have their common features activated concurrently when one of the units becomes activated. An empirical source of support can be found in Underwood's (1965) study of implicit associative responses (IARs). There it was demonstrated that the more closely a target and foil word were associated, the greater was the probability of a false recognition of the foil. This data has since been replicated by others (e.g., Kimbal, 1968), but its importance lies in the strong support these results lend to the present conception of attention. Organization also follows from the same assumption. Hochberg (1970) pointed out that attention implies organization of input into some meaningful form. In the present account this is accomplished by assuming the focused activation of particular units that are related to the presented stimulus. Selection of a specific interpretation is influenced by previous learning and the innate cognitive structure of the organism. Thus, attention to a particular detail of the stimulus input must occur as a result of previous neural organization. Or to put it differently, the only way attention can be limited to a single aspect of a representation is if there is some extensive preexperimental organization of that representation in memory.

Certain differences in the encoding theories and the present orientation are apparent also. Because encoding is assumed to occur at any level, perception and selection are not to be found at any one place in the process continuum. Preattentive mechanisms are not held to be substantively different from focal attention, except that they are more fundamentally organized and are activated with much less effort. Selection does not depend on "synthesis" of an input so much as the activation of the features constituting the mental representation of the nominal stimulus (if this is indeed different). This activation is not necessarily dependent on the input from some independent control process or homunculus; rather it is the result of learned responses to some stimulus configuration. Complex mental behavior is therefore limited in the same fashion as are elementary analyses. That is, the state of the organism (including previous association, motivation, and potential to respond) and the input stimulus configuration determine the nature of a response in a given context. There appears to be no necessity to assume that the echoic or iconic systems are sufficiently different from the central processor to justify their inclusion as separate entities within the cognitive domain.

## What is Attention?

Throughout the preceding pages there has been sketched in some detail the conceptual bases for a model of selective attention. Wherever applicable it has been related to structural constructs such as the icon, short-term memory, and the semantic store. Moreover, it also has been argued that a process conception of learning, selection and consciousness can be made as well. Discussing attention entirely from either of these perspectives has been deliberately avoided because it seems that attention includes characteristics of each approach. That is, attention seems to have both structural and process aspects.

Considering structure first, it is clear that attention must have some physiological locus. Less obvious is the appropriate behavioral structure implied by the attentional cognitive component. The extant data argues that attention cannot be regarded as a filter operative at any one place in a process continuum. Rather, it is best conceived as process limitation that can occur anywhere in cognition. Filter theory, as envisioned by Broadbent (1958) argues for a "perceptual" filter, but filters are certainly not restricted to early processing. Activation of different representations occurs and is correlated with the level of analysis carried out on that information. Limits exist in the capacity subjects have for activating representations at all levels. These limits are what researchers have generally regarded as attention. So long as the emphasis was on where activation of particular representations occurred it made sense to consider the structural aspects of attention. Nevertheless, attention can be thought of as a process as well. Psychological transformations of stimulus input are what defines attention, in that only a certain amount of new information can be activated in any one context. The variables affecting these transformations are process variables. Examination of attention from this perspective leads to a process interpretation of attentional phenomena.

Such a point of view has certain advantages. As Neisser (1976) eloquently argues, selection, and by implication attention, does not require an active process to filter out certain input. Organisms, for example, do not respond to cosmic rays and thus formally "filter" them out. This occurs without any particular system to reject these stimuli. They cannot be processed simply because they are inadequate to establish a representation. Even if they were potentially adequate, the organism may lack the skills, motivation, or capacity to do so. Selection can be made only by a direct and active processing of stimulus elements.

One may question just how this selection is accomplished: Does this mean that some homunculus is surreptitiously postulated to account for the fact that certain stimuli are processed at the expense of others? A long standing problem of attentional theories is the assumption of some internal, unexplained mechanism which determines what is attended. Whether this mechanism is called a homunculus, control process (Atkinson & Shiffrin, 1968), or even if it is not mentioned (e.g., Neisser, 1967), it appears necessary to most, if not all, extant theories of selection. In fact, the postulate of a homunculus appears as a logical device to avoid the seeming paradox of selective behaviors. We cannot "look" at all information, yet we must select the salient features in the environment. To do so requires us to "know" what the salient features are but this is precisely the problem in the first place. That is, selection can occur but only after some analysis on the entire field has been accomplished. How is the irrelevant or extraneous information eliminated before deeper processing without doing the processing itself? And if all information is processed at a relatively deep level, why is there a selection at all? The inclusion of a homunculus to control stimulus processing has an attraction for some theorists in that it separates peripheral from central attentional phenomena. It then becomes possible to describe where attention is limited, for example, rather than why this limitation occurs. The problem with this approach is that it appeals to infinite regress. That is, control of stimulus processing is not explained because the honumculus remains an enigmatic black box buried somewhere in the stimulus processing chain. It is the present view that the critical questions regarding attention cannot be broached, let alone answered, until theoretical formulations of the homunculus are attempted. While there are obvious difficulties in framing a cogent first approximation of what these central processes must be, the present theoretical orientation lends itself to such an enterprise. It was indicated earlier that selection is the processing, or activation of feature detectors comprising a mental representation. This is the same mechanism that determines what is attended to in the environment. Previously it was suggested that the activation of certain basic, elementary detectors may not have to be learned. Lines, colors, and frequency are examples of stimuli that activate these innate detectors. As an organism learns more about the environment, combinations of these detectors become activated in response to more complex stimuli. What is important, however, is that the process of activation is determined by the information available and the previous history of the organism. With respect to the first point, it is assumed that selection of one input over another is determined by external stimuli as well as those internal to the organism. Expectations, predispositions and emotional tone are as potentially important for determining which representation becomes activated as are objectively observable stimuli. It is also important to acknowledge the role of the organism's previous history in determining selection. Every mental response an organism makes is assumed to reflect this history. Determinants of selection include representations that were incidentally activated in the past due to their close temporal contiguity with another activated representation. Because previous learning influences which input stimuli activates its corresponding representation in memory, it procures all the functions of a homunculus. In this way the organism always has some algorithm for selection available. Processing of stimuli therefore does not depend on knowing beforehand what the stimuli are (as implied by other models) but rather by having some mode of selection available for handling the stimuli. The organism may acquire a repertoire of selective responses that become operative depending on the stimulus complex, and that is modifiable by experience. In this sense, what is perceived and attended is a historical statement of the organism. There need not be a homunculus, soul, or other construct assumed to account for selection behavior. In fact, it can be argued that the central selection mechanisms, like a homunculus, do not account for stimulus selection without appealing to infinite regress. Novel stimuli do not present any particular difficulty for this conception since there is substantial evidence to indicate that unique stimuli are viewed for a longer time than familiar stimuli (Berlyne, 1958). This may be one of many modes of responding, and it is probably based on the nature of the stimulus and the state of the organism. Hence, the presence of novelty initiates a particular selective response that is no different in principle from other selective repertoires.

Since the present theory assumes attention is a process, it follows that attention can occur at several levels. That is, if attention is isomorphic with stimulus analysis, then several degrees of attentional allocation can be made to the same nominal stimulus. To reiterate, these range from physical to semantic processes. Deeper analyses are assumed to involve greater effort, more capacity and are phenomenologically correlated with greater awareness and consciousness. In contrast, shallow analyses involve much less investment of effort and are often considered automatic. The important feature to be noted here is that attention is not assumed to be a specific behavior but rather a consequence of cognitive activity. Attention can be invested into some activity only by deeper processing of the stimulus complex. Elsewhere it was argued that attention is modifiable by practice. As learning occurs, activation of mental representations becomes easier, and more capacity is released for other modes of stimulus processing. It is not clear just how practice would change attention if it were only regulated by a filter.

The processing analogy to attention also has important implications for memory theory in other ways. In the present account, perception and memory become indistinct from attention. The separate study of each of these "classical" areas becomes impossible without examination of other areas as well. Erdelyi (1974) has cogently pointed out that the notion of perceptual defense is paradoxical if perception is considered to occur at one particular place in the train of stimulus processing. In order for perceptual defense to work the meaning of a stimulus would have to be processed before it could be censored, presumably defeating the purpose of such a censor. This, of course, is similar to the argument that can be advanced against a filter conception of attention, and the way out of both logical traps is similar. Perception, memory, and attention may be viewed as occurring anywhere in the processing continuum and need not be relegated to any one place. To assume perception (or memory, or attention) exists as an independent entity and is distinct from other cognitive phenomena, inevitably predisposes the kind of interpretation given to empirical data regarding these phenomena. In fact, there is no logical reason to suppose that these systems differ from each other. It is worthwhile to consider each of these as an aspect of the representational system. From this point of view selection is coincident with perception and can occur at several places and at different levels within the cognitive continuum. Memory has been extensively documented as being related to the level of analysis of the to-be-remembered material (e.g., Craik & Tulving, 1975), a finding which is consistent with the theoretical development stated herein.

Blumenthal (1977) presents another aspect of attention that is congenial with the present conception. He argues that a fundamental aspect of attentional phenomena are the time parameters involved in cognition. The most elementary of these temporal processes are termed "rapid attentional integration" (RAI) and these "...are brief pulses of integration that fuse a set of events or impressions into unitary experiences" (Blumenthal, 1977, p.30). For a number of phenomena, including central masking, apparent movement, time-intensity relations, memory scanning, perception of simultaneity, and stroboscopic fusion, a critical temporal interval of 50 to 200 msec seems to be involved. Several writers have commented on these data and have suggested that these can be considered minimal information processing intervals (Blumenthal, 1977; Harter, 1967; Stroud, 1955; White, 1963). It appears that in each of the above paradigms an attentional interval of about 100 msec exists which allows for the processing and integration of information. As an example, consider Turvey's (1973) work on masking. He was able to show that if the onset of two events is less than about 100 msec, the processing of the first event is disrupted paradigms from the point of view of stimulus processing.

Finally, it is important to acknowledge the role of attention in consciousness. Elsewhere we have discussed consciousness and related it as a subjective response to a deeper, capacity demanding process. It has been argued that shallow processes involve less effort, and never reach consciousness. The reason the former processes reach awareness while the latter do not is due to the degree of focus involved in each case. The term "focus" is intended to reflect the assumptions made earlier regarding the depth of analysis necessary to complete a task. Recall that preattentive processes were said to demand very little capacity, and could therefore be allocated over a broad range of stimuli. Deeper analysis of the stimulus field could also occur, but only by limiting attention to a subset of stimuli in the field. This trade-off between the number of representations activated in memory and the depth to which they are activated, is termed focus. With detailed semantic processing of stimulus information, focus becomes greater with increasing depth. This precludes processing of other information because of the capacity demanded by the task at hand. Shallow analyses do not require as much focusing and result in several types of information to be activated. The consequence of this is the reduced awareness to minimally attended stimuli. In other words, attention to several stimuli at a lower level is not conducive for establishing a state of awareness about any of those stimuli. Deeper processing and the concomitant focusing of attention upon by the onset of the second. Events that occur at an interval of longer than about 100 msec are perceived as being discrete. It is beyond the scope of this thesis to detail all the paradigms in which this effect occurs (the interested reader can refer to Blumenthal, 1977 for an elegant treatment of the topic), but it will be noted that it is pervasive throughout cognition. It is clear that the masking research indicates spatially overlapping and temporally contiguous information will not be perceived or attended under certain conditions. Typically, a certain amount of time must pass for a response to occur. Whenever these limits are exceeded, an apparent attentional allocation can be made. Since processing can be considered a change of state over time, and because time is fundamentally related to attention, there is obvious utility in considering attention as a process.

Equating attention to a change in the activation of mental representations over time leads to theoretical integration in other respects. To the extent that memory can be thought of as the activation of a representation, attention cannot be considered as a process different from memory. In fact, Mandler (1974) argues just this point: Attention can be conceptualized as a frame of processing. Whenever the frame includes mental representations activated by immediate experience the phenomena examined is termed perception. In contrast, processes that activate mental representations not having their corresponding real-world referents immediately present, are regarded as memory. The important point to note, however, is the implicit relatedness of the different other aspects of a stimulus leads to "conscious" perception and awareness of the features processed. This means that consciousness is implicated in attention, and is indistinguishable from it. Also, it is clear that consciousness, like attention, can be considered to have several different levels. In fact, Mandler (1974) suggests that consciousness can be regarded as a process, and like other processes, it can be manipulated. One example given by Mandler is the work on consciousness stopping. He has argued that certain higher states of consciousness are based upon the repetition of a single aspect of the stimuli. While it is agreed that different states are ordered in their potential to evoke a "conscious" representation, it seems unreasonable to suggest that these "higher" states are always associated with semantic information processing. Deep, capacity demanding behaviors can be observed with structural stimuli in cases where, in Mandler's terms, an "attentional frame" can be set upon the unique feature of the stimulus, and capacity to process this information is required.

To conclude, attention is not to be regarded as a structural component of cognition, but rather as a process of cognition. While others have discussed attention from the latter position (e.g., Mandler, 1974; Blumenthal, 1977) it bears repeating that this leads to a number of conceptual advantages not found in the former approach.

## INTRODUCTION TO EXPERIMENTS 1 AND 2

Several assumptions about the nature of human information processing have been made throughout the preceding discussion. It is important to establish the empirical validity of these statements for subsequent elaboration and refinement of the theory. Ideally, the whole range of assumptions should be subjected to critical empirical scrutiny. Rather than to undertake a task of this magnitude, however, the proposed research is directed toward an examination of only one aspect of the current orientation. Recall that earlier a process conception of cognition was put forth which was based upon the assertion that selection is an inevitable aspect of such processing. This necessitated the inclusion of a number of statements about the nature of the structures underlying cognition. Later, it was argued that certain aspects of the present approach allow for the incorporation of some diverse phenomena, such as the icon and consciousness, in an integrated fashion. Hence, the study of selection is necessary to establish the foundation upon which much of the theory rests.

It is clear that differential stimulus processing is necessary for attention to become focused in the present account. The intent of this section is to suggest a series of studies to empirically evaluate this assumption. If processing becomes deeper and more restricted, certain regularities in selective behaviors should become apparent.

Perhaps the most basic assumption made is that selection proceeds hierarchically to the depth necessary to establish an encoding of the nominal stimuli, as dictated by the task demands of the experimental context. In addition, the selective process is correlated with depth such that more intense analysis of a stimulus component can only occur with the loss of information about other components. This arises because activation of feature detectors becomes more focused as more specific information is abstracted from the stimulus. Evidence for such a position comes from several sources. Recall that Mackworth (1965) observed that the presence of noise letters sharply reduced the size of the visual field in a stimulus detection paradigm. Similarly, Keren (1976) reported that detection of target letters was poorer if they were semantically distinguishable from noise letters than if they differed physically. This suggests that attention and recall depend upon the degree to which information is processed. Other studies supporting this notion include the work of Craik and Tulving (1975) and Horton (1977). These experiments demonstrated that recall and reaction time measures depend upon the task demands of the situation, presumably because focusing of attention and depth of processing leads to "stronger" traces being formed.

These data, however, do not adequately address the issue of depth as focused attention. For example, the use of recall measures to infer depth is circular (e.g., Craik & Tulving, 1975). Better recall does not necessarily imply greater depth, nor does it have to be related to attentional allocation. The definition of depth also poses a problem, in that it should be defined independently of the dependent measure used to infer its existence. In Mackworth's experiment too much emphasis is placed on stimulus detection. Clearly, the acuity of the subject is modifid by noise but this does not mean that the depth of processing has been changed by the presence of distractors. In the Keren study the stimuli are different for each condition to insure differential processing. This may have occurred, but it is questionable as to whether or not the data were predisposed by this manipulation. That is, processing differences of dissimilar material may not be surprising, but it need not imply different depths are being employed. Taken together these experiments support the assumption of depth made in the present theory, but only indirectly. What is needed is some procedure that insures differential processing of identical stimuli and for which the verification of successful control does not rest on differential recall scores. One method that seems to meet this criterion has been modeled after that of Posner and his associates (see Posner, 1969, 1978).

In this procedure subjects are briefly presented a stimulus and then a probe or test stimulus. After presentation of the test stimulus, subjects are required to make a manual response if it matches the stimulus according to some preexperimentally known criterion, such as being physically identical or sharing the same name. This method has the advantage of allowing the experimenter to control for stimulus duration, probe duration and interstimulus interval. Moreover, the processing load imposed on the subject can be varied by either increasing the number of stimulus elements, or by increasing the difficulty of making a decision.

These advantages are not shared by other approaches such as that of Craik and Tulving (1975). With their method they control depth of processing by presenting an item and required subjects to make a structural, phonemic or semantic decision about the word. However, the difficulty of making a decision at any one level cannot be manipulated. That is, a semantic decision takes a certain amount of time to make and it is difficult, it not impossible, to vary the processing load for any one item. Moreover, it is not clear how the orienting task can be employed to investigate selective behaviors directly, because only a single item is presented for a decision. While this methodology is certainly relevant to the levels-of-analysis issue, it is not adequately suited for investigating the question of selection as a focused processing. This is to point out that, although the levels-of-analysis framework has been the conceptual starting point for much of the recent work in stimulus processing, the following experiments are based on a procedure that is more appropriate for the present theory.

# EXPERIMENT 1

An implication of the present theory is that whenever selection occurs, a certain degree of differential processing among the stimulus components takes place. The extent to which this happens, of course, depends on the context of the experimental situation. Thus, if a stimulus complex is presented briefly enough, only a subset of elements will be processed physically, and even fewer at deeper levels. In addition to the effect of presentation time, other variables should be important as well. When the stimulus is relatively simple and unintegrated, both physical and semantic analysis might be initiated and virtually completed if the subject is given enough time. However, when stimulus complexity is increased, physical analysis should be much less affected than semantic processing, particularly with heavier memory loads.

Before examining the results of the first experiment in detail, it is instructive to review some of the predictions that follow from the theoretical orientation put forth in the introduction. The most important outcomes concerned the manipulation of qualitative and quantitative processing demands. In the present experiment, stimulus processing was manipulated two ways. First, a distinction between processing at different levels was expected to be reflected in reaction times and error rates whenever subjects were analyzing stimuli by qualitatively different processes. This was manipulated by requiring physical versus name judgments with the expectation that name judgments would take longer because of the relatively greater depth involved in their processing. A second way stimulus processing can be manipulated is within a level. This was done by presenting 2, 4, or 6 items before the probe (test) stimulus was presented. Here quantitative differences in stimulus processing were expected to lead to changes in reaction times and error rates that are directly proportional to the number of items that are searched.

Focused processing should also be apparent in the present experiment as well. To reiterate the earlier discussion, "focusing" refers to the increasing limitation of stimulus processing that occurs with increasing depth. It was argued that as processing demands increase in a qualitative manner, quantitatively less information can be analyzed. This would result in a level of processing by number of items interaction for both the error and reaction time data. An outcome such as this is based on the assumption that the capacity for complex analysis may not differ substantially from shallower analysis when few stimuli are processed. In contrast, when many items are processed, deeper analysis would lead to poorer RT and error performance. If the stimulus materials are presented long enough for some processing to occur but not so long as to allow complete processing, then increasing the number of items should have greater deleterious effects for deeper analyses.

To test these predictions stimuli varying in complexity were presented, followed by a test stimulus. Complexity was varied within subjects by having the search set consist of 2, 4 or 6 consonants. Subjects had to press a button as quickly as they could to indicate if the test stimulus matched one of the letters of the search set. The matches were based on either physical identity or name identity. This latter manipulation presumably involved depth. More time is typically required for name matches to be made than for physical matches (e.g., Posner, 1969; 1978).

The present experiment differs from that of Posner and his associates in that several letters are presented simultaneously instead of a single letter. This complexity, or load, manipulation is predicted to have a greater effect on name than on physical processing. Theoretically, deeper analysis should occur at a slower pace and be more focused than superficial processing. As more elements are processed, differences between name and physical matches will become larger. Hence, a load by processing interaction is anticipated.

In this and the following experiment, two dependent measures will be employed to examine the hypothesis advanced herein. Most important of these is the reaction time (RT) measure. In recent years it has become increasingly acceptable to infer differential cognitive processes on the basis of RT data. While it is necessary to acknowledge the many conceptual issues raised by the use of such measures (see Pachella, 1974, for a good discussion), they will be employed because they have been found to be stable, reproduceable, and easy to obtain and use. Furthermore, the present research is such that comparisons with other data examining similar issues is most conveniently done when a common dependent measure is employed. In this respect, it is anticipated that differential RTs will be obtained in this study as in the Posner and Mitchell (1967) study for name and physical identity judgment.

The other dependent measure of interest is that of error rate. Since it is unlikely that subjects will complete the experiment without making an error, it is of considerable interest to know just where these errors will be made. It may be the case that errors are most frequent when decision load is greatest. This, of course, is consistent with the present theoretical development. In the next section the method to be employed will be outlined in more detail.

Method

Subjects. Twelve undergraduate students from an introductory psychology class served as subjects as an option for course credit. Half were male, all had normal or corrected-to-normal vision, and all were right-handed.

Apparatus and stimuli. A Hewlett-Packard 9825A computer and 1350A graphic translator were used to generate the stimuli, and they were presented on a Hewlett-Packard 1304A monitor with a P15 fast-fade phosphorous screen. A fixation cross appeared at all times on the screen except when subjects were undergoing a trial.

The stimuli were randomly generated and were drawn from a pool of all capital and small letters of the alphabet.

Strings of letters subtended horizontal visual angles of 1.72, 1.1, .54, and .19 degrees for stimuli of six, four, two and one letters, respectively. Vertically, the letters subtended an angle of .28 degrees. All stimuli appeared as a green fluorescent light on a black background. For each stimulus set half the letters were in upper case, half were lower case and they appeared in random serial order on each trial. Table 1 gives examples of the six classes of items employed for the four-letter search set, and the approximate percentage of the time each class of item occurred for each subject.

<u>Procedure.</u> There were a total of 36 within-subject conditions in the experiment formed from the type of instruction (name or physical), by the type of item (physical, name, or different), by case of target (capital or small), by the number of letters in the search set (2, 4 or 6) combinations. "Search set" refers to the group of 2, 4, or 6 letters that preceded the target letter. The term "item type" corresponds to the three possible search set-target relationships (physical, name, and different). For example, a physical item of search set size 2 would be Ab for target A, a name item would be Ab for target a, and a different item would be Ab for target D. Type of instruction designates the instructional set given within an experimental session. That is, on one session each subject was instructed to respond "yes" if the target letter matched one of the search set letters in name and case (i.e., for physical instruction: Ab/A), and on another session if the target letter matched a search set item in name only (name instruction: Ab/a).

Each subject was run for two 45 min sessions, one week apart. An entire session was devoted to either the name or physical match instruction condition. A session commenced with a block of 25 practice trials in which a search set of four letters was presented, and subjects were required to make a physical or name match, depending on the type of session that was to follow. Subsequent to this, two successive blocks of 50 trials were presented with each of the three sizes of search sets. Hence, a total of 25 practice and 300 experimental trials were presented in every session. The type of match required on each session and the order of presentation of search sets sizes was counterbalanced. The type of item and case of the target presented was randomly determined within each block.

Subjects were instructed to initiate each trial by pushing a button when they had the fixation cross in clear focus and when they were ready. Immediately upon pushing the button, the search set was presented for 100 msec. A 500 msec interstimulus interval (ISI) then appeared, and this was followed by a test stimulus which remained on the screen for 1 sec. After the subjects had responded with a button press indicating if the test letter was in the search set, the fixation cross reappeared and another test trial was initiated.

Results

In the present section emphasis will be on the reaction time data. Error data will be reported only where it clarifies or modifies the interpretations offered. Although there are good reasons for using error rates instead of reaction times, the use of RT data is employed because of the sensitivity of the measure. In this regard, nonsignificant error data will be ignored. Where significant differences in error data are in accord with the RT data, they will be noted. Although differences in the direction of RT and error data are rare, they will be presented as well.

In this experiment all reaction times of over three seconds were excluded from the analyses. This was done because they usually resulted from a failure to press the response button or to initiate a new trial correctly, and thus represent scores from a different response population. Whenever an RT was excluded from the data, the corresponding score was also excluded from the error data analyses. In practice, the exclusions had very little effect on the data, mostly because there were so few instances of unusually long reaction times (less than 1% of all responses). In addition, for the reaction time data only correct responses were reported. Finally, unless otherwise noted, the data reported are from a 3 (search set size) x 2 (type of instruction) x 3 (type of item) x 2 (case of target) ANOVA with reaction time and error rate as dependent measures.

Quantitative Effects. Table 2 shows the reaction times for each search set size, each item type, and each type of instruction. Figure 1 is a graphic presentation of the same data, where each of the three panels corresponds to an item type. It is apparent that the effect of quantitative load was strong, F (2,22) = 53.54, MSe = .044, $p < .01$. Error rates found on the last column of Table 2 also reflect this effect, F (2,22) = 208.11, MSe = .011, $p < .01$. The mean RTs for the physical, name, and different items analyzed separately all differ for each search set size, for both RT and error data, smallest F (2,22) = 31.30, $p < .01$. Hence, the main effect of load was as predicted: Decisions take longer to make as the search set size increases. While this outcome is not unusual and could certainly be predicted from other formulations (e.g., Sternberg, 1969), it does indicate that the present methodology is sensitive enough to detect these basic differences.

Qualitative Effects. On the basis of the present theoretical approach, differences were predicted between name and physical instructions. In this respect, physical matches were anticipated to occur faster than name matches because of the "deeper" processing required to make the latter decision. Similar findings have been frequently reported (e.g., Posner, 1969, 1978) and were expected to occur here, even though larger search set sizes were employed in the present context. However, an examination of the mean reaction times for physical and name instructions given on the last column of Table 3, indicates that the differences are in the opposite direction, F (1,11) = 4.85, MSe = .153, $p < .05$. This outcome is also reflected in separate comparisons between types of instructions for reaction times for both the physical items, F (1,11) = 6.25, MSe = .047, $p < .05$, and name items, F (1,11) =

9.69, MSe = .078, p < .01. There is no difference between physical and name instructions on the different items, F < 1.00. These data are respectively plotted in Figure 1. The error data (in brackets, Table 3) mirror these same effects. Physical and name items differ in proportion of errors, F (1,11) = 48.37, MSe = .006, p < .01, and F (1,11) = 6.05, MSe = .043, p < .05, respectively, but different items do not, F (1,11) = 3.18, MSe = .016. It should be noted that for physical items the most errors are made during physical instructions, while for name items more errors are made under name instructions.

Taken together, the theoretical orientation as earlier presented cannot account for all the qualitative processing effects, particularly with the type of instruction variable. Later in the thesis an accommodation of these data will be attempted.

It is instructive to note that the differences between types of items are highly reliable, F (2,22) = 14.35, MSe = .028, p < .01. The means for this comparison can be found in the last row of Table 3. These data seem to correspond closely with the orientation elaborated earlier. Correct matching decisions must occur more quickly when physical identity is apparent, since deeper analysis is not required for a correct match. For this reason, in separate analysis of each combination of item types, physical items are processed more quickly than either name or different items, F (1,11) = 43.08, MSe = .017, p < .01, and F (1,11) = 8.76, MSe = .048, p

$< .05$. In addition, a negligible difference between name and different items is expected since both items must have relatively deep processing to arrive at a correct decision for name instructions, and at a shallow level for physical instructions. This occurs, $F\ (1,11) = 2.44$, MSe = .019, but there is a trend for physical decisions to take longer to make (M = 976 msec) than name decisions (M = 897 msec) for name and different items combined, $F\ (1,11) = 3.98$, MSe = .113, $p < .10$.

Other reservations must be noted here, however, since the error data (in brackets on Table 3) differ substantially from the reaction time data. While there was an effect of item type (found in the last row of the error data), $F\ (2,22) = 3.99$, MSe = .049, $p < .05$, there was no reliable difference between physical and name, or physical and different items, $F < 1.00$, and $F\ (1,11) = 3.12$, MSe = .079, respectively. A difference between name and different items, $F\ (1,11) = 20.21$, MSe = .016, $p < .01$ was noted. There is no obvious interpretation of these data, except to suggest that different items are perceptually "easier" than either name or physical items, although they are processed at a different depth (as indicated by the reaction times). Contrary to the present orientation, it cannot be concluded that in all instances perceptual difficulty is isomorphic with depth of processing.

Yes-No Decisions. In the present experiment, subjects were required to respond either "yes" or "no" equally often to the presented targets. Manual reaction times have usually been found to be faster for positive than negative decisions (e.g., Craik & Tulving, 1975), and a strong effect was noted in the present study. Mean positive reaction time is 866 msec and the mean negative reaction time 946 msec, $F$ (1,11) = 12.96, MSe = .018, $p < .01$. Error rates differ significantly, $F$ (1,11) = 5.16, MSe = .036, $p < .05$, but they go in a different direction from the reaction time data (M = .203 for "yes" responses and M = .131 for "no" responses). It appears that "yes" responses are made faster but less accurately than "no" responses.

Effect of Case. There was a strong tendency for capital targets (M = 890 msec) to be matched faster than small targets (M = 923 msec), $F$ (1,11) = 23.44, MSe = .005, $p < .01$. In addition, there were fewer errors made matching capital targets (M = .149) than small targets (M = .176), $F$ (1,11) = 6.54, MSe = .012, $p < .05$. This is a theoretically uninteresting effect: Certainly some stimulus configurations will be more difficult to analyse than others.

Processing x Load Interactions. The principle evidence for focused processing was expected to be found in the instruction x load interactions. Lower-order processing is assumed to be much less affected by variations in load than more complex processes. Support for this proposition is lacking in the reaction time and error data in the present study, $F$ (2,22) = 1.45, MSe = .030, and $F$ (2,22) = 2.37, MSe = .006, respectively.

There was, however, a reliable instruction x item type interaction in both the reaction time and error data, $F(2,22) = 11.52$, $MSe = .014$, $p < .01$ and $F(2,22) = 12.34$, $MSe = .023$, $p < .01$, respectively. The means for these effects can be found in Table 3. A graphical presentation of the reaction time data is given in Figure 1. For both types of instructions, physical items are processed most quickly. Name items require the most time under physical instructions, although not under name instructions. This latter finding is important because it indicates that name identity on physically different items leads to the establishment of interfering codes. If so, name representations must be activated in this experimental context before physical codes are established.

Other interactions suggest that the item type may be an important variable in making identity judgments. A number of items x item type as well as a instruction x number of items x item type interaction materialize, $F(4,44) = 6.57$, $MSe = .008$, $p < .01$, and $F(4,44) = 5.52$, $MSe = .007$, $p < .01$, respectively. Only the latter interaction is reliable in the error data, $F < 1.00$, and $F(4,44) = 2.91$, $MSe = .010$, $p < .05$.

Interpretation of these interactions must be done with caution, however. The type of item variable in the present design is crossed with the type of decision variable for name items. That is, for physical instructions, name items are "no" responses, but for name instructions they are "yes" items. Hence, an interaction between item type and number of items may be misleading. For reaction times, separate analyses yield a significant item type x number interaction for physical, F (4,44) = 8.67, MSe = .009, p < .01, but not name, F (4,44) = 1.78, MSe = .006, instructions. This appears to be due to the effect of the name items in each instruction condition. With physical instructions the presence of an interfering name code results in item differences that cannot occur in the latter paradigm.

A more appropriate test of focusing may be to disregard name items entirely and look at the physical and different items only. In this way, the "yes/no" decision will be eliminated as a confound because physical items are always "yes" responses and different items are always "no" responses for both physical and name instructions. For reaction times the type of instruction x number of items interaction is not significant, F < 1.00, but the item type x number of items interaction is strongly so, F (2,22) = 9.43, MSe = .010, p < .01. From the reaction time means in Table 2, and the combined mean slopes of physical and name instruction of the physical (50 msec) and different (85 msec) panels of Figure 1, it appears that with increments in load, different items become increasingly more difficult to process relative to physical items. The error data is similar for the instruction x number interaction, F < 1.00, but the item type x number interaction does not occur, F (2,22) = 1.08, MSe = .024. For the combined physical and different items, the instruction type x item type x number of items interaction is present for reaction time, F (2,22) = 9.19, MSe = .007, p < .01, but exists only as a trend in the error data, F (2,22) = 3.40, MSe = .008, p < .10.

It is also instructive to examine the instruction x item type interaction for only the physical and different items. It was shown earlier that over all items the interaction was significant, but this could have been due to the effect of the name items alone. However, the effect is strong without the name items for both the reaction time, F (1,11) = 24.07, MSe = .004, p < .01, and error data, F (1,11) = 24.67, MSe = .011, p < .01. From the means given in Table 3, it appears that the relatively fast reaction times to name instruction, physical items accounts for this interaction. For the error data, the direction of change is different in that the name instruction error rates are stable over both types of items, but physical instruction error rates are much higher for physical instruction, physical items. Why this occurs is not clear.

Finally, it can be seen from the first panel of Figure 1 that an appearance of focusing occurs for physical items as load increases (but not reliably, F (2,22) = 2.12, MSe = .015). However, for different items the effect disappears altogether, F < 1.00.

Together, present results support the focusing hypothesis, but only for the differential effect of items, and not for type of instructions. As processing becomes more difficult (number of items increase), the reaction times increase more for physical than for different items. The error data admittedly do not mirror the same effects, but this may be due to the lack of sensitivity of that dependent measure.

Discussion

Experiment 1 was an attempt to monitor the course of stimulus processing that occurs when information must be abstracted from stimuli that are no longer available for direct processing. Earlier it was proposed that the rules governing this selection depend upon qualitative and quantitative stimulus processing, rather than a "filter" that eliminates or minimizes the processing of unnecessary information. Since the design of this experiment precluded the establishment of a filter (because subjects are given the target after a filter can be operative), it follows that filtering alone cannot account for the observed attentional phenomena.

How well, then, does a differential processing orientation account for the obtained data? Clearly, number and type of items have a strong effect on matching reaction times. As the number of items that must be processed increases, error rates and reaction times increase. As well, the type of items processed is important in RT measures. Items where the target was physically identical to one of the search set components are processed more quickly than those matching in name only, or those that do not match at all.

These results are generally consistent with a process notion of attention. Activation of units composing the mental representation of the nominal stimulus becomes more difficult as is evident from a slowing of reaction times and an increase in error rates as search set size increases. There is a substantial difficulty with two related aspects of the theory, however. The first is with the failure of physical matches to be made more quickly than name matches for the instruction variable. Possibly as a result of this, there was also a failure to note evidence of focused processing as the qualitative processing demands change, except possibly for the physical items.

In light of previous research, the apparent contradiction of physical instruction latencies exceeding those of name instruction is the more critical problem. It is important to note, however, substantial methodological differences in the present experiment may underlie this effect. Studies by Posner and his associates (Posner & Mitchell, 1967; Posner, 1969) typically present two letters side by side for name and physical matches. It is unclear why the present study obtained different data with a 2, 4, or 6 letter search set and a single target letter. One reason may be that the tasks entail radically different task demands. In the former, there is no memory search component; the matching process can begin immediately upon stimulus presentation. This cannot occur in the present study because processing of the search set must occur before it leaves the screen and the matching process begins.

The obtained data are understandable if it is assumed that processing first involves some elementary physical analysis, then the establishment of a deeper name code, and finally a very detailed analysis of the physical information. Because the item leaves the screen so quickly, some form of "tag" must be appended to the name representation of the item in order to make a later physical match. Implicit in this notion is the assumption that information about the physical aspects of the representation can exist after name codes are established. Such information could be either embodied in an actual physical encoding or in a higher-order "name" representation of the physical features (for example, "Capital" A). The name information by itself would allow the subject to generate or reconstruct a number of the physical features presented. Along with a tag of some type containing case information, this would permit an elaborated physical comparison to be made. This is supported by the present data. First, it is clear that name instructions lead to faster reaction times than physical instructions, indicating that name codes are abstracted first, and that the physical information is still available (or else the match could not be made). Secondly, physical instruction, name items take the longest time to match. This suggests interference from a positive matching decision based on a previously established name code that does not coincide with the negative decision made on the basis of later processing.

Other explanations of the data of the present experiment are also plausible. For instance, one could assume that physical instructions lead to longer reaction times because of the greater information load impressed upon the subject in the present experimental context. If more features must be stored in a "name" form to make a correct match for a physical instruction than a name instruction, it would be expected that the former instructions would act like a quantitative load variable, and thus lead to increased response latencies. This is possible because the present task always removes physical information. In Posner's successive match paradigm, only the name instruction requires the activation of information that is not present. Note that this interpretation can accommodate the interference effect for physical instructions, name items quite well. Because name information could be accessed relatively quickly compared to physical information, a previously established name code would interfere with later activated "physical" codes.

Whether these two interpretations can be distinguished is a debateable point. The present data do not allow an unequivocal choice between them. Clearly the argument that physical judgments are made on later-established and purely physical codes assumes qualitatively different processing under each instruction level. In contrast, it could also be argued that quantitative effects distinguish between instruction levels, so that physical matches involve a name code for the letter as well as a name label for the case of the letter. Thus, more, rather than different, processing would be invoked in this latter interpretation.

The assumption that detailed physical matches based on purely physical codes can occur after name processing runs counter to accounts of stimulus processing offered by Posner (1969). He argues that name coding is independent of, and initiated during, physical analysis, but completed sometime after the physical code is established. A study conducted by Posner and Mitchell (1967) supports this claim. In that experiment, physical identity judgments for name identical items (e.g., Aa and Bb) were made as quickly as for different items (e.g., Ad and Bc). Since there was no difference between these item classes, Posner and Mitchell suggested that there is no name code established to interfere with physical processing.

Another contradictory empirical result noted in the present experiment concerns the response times to different items under each level of instruction. Posner and Mitchell found physical instructions lead to faster decisions on these items than name instructions, while the differences in the present experiment were not reliable (see column 3 of Table 3 and panel 3 of Figure 1). This finding, along with the tendency of physical instruction reaction times to exceed those of name instructions and the presence of a strong interference effect on physical instruction name identical items, seems to be due to the relative size of the search set in each experiment. Support for the former effect can be found by comparing reaction times for the different items under each search set size. When only two items constitute the search set, physical matches are made, on the average, 43 msec faster than name matches. For four items the advantage of name matches is 2 msec, while for six items the name advantage increases to 86 msec. Clearly, the established effect is approached with small set sizes and disappears with larger set sizes.

One last issue remains to be addressed in this experiment. Focusing does not appear to be strongly supported on the basis of the data presented. From Figure 1 it is apparent that focusing seems to only have some validity for physical items, although the effect was not reliable. Perhaps the most important reason for this concerns the apparent lack of "automatic" processing anticipated to occur at the physical level. As noted in the introduction, several researchers have argued that preattentive processing involves minimal effort, occurs with no disruption of other ongoing mental activity, and takes place quickly. On the basis of reaction times, it is clear that the latter criterion has not materialized in the present experiment. Focusing, as envisioned in the theoretical section, cannot be adequately addressed since experimental control of the variables assumed to underlie the effect did not occur.

In considering the task demands of the experiment it may have been naive to expect subjects to attenuate processing after a cursory physical analysis of the stimulus. For one thing, they were specifically required to make correct decisions on a physical basis. This may have resulted in an "over-analysis" of the physical features of the stimulus, especially since they were instructed that they should adjust their reaction time so that maximum accuracy was achieved.

The work of Posner and his associates may not have shown this effect because of the relatively small size of their search sets (1 letter). If extensive elaborative physical processing can occur only after name codes are established, then longer physical instruction reaction times should be observed. This last suggestion is well supported by the reaction times to types of items. For physical instructions, name items take longest because the previously established decisions based on the interfering name codes must be ignored while elaborated physical codes are derived. Name instructed, name items can be analysed much faster because only the name codes need to be established for a decision to be reached. These items take longer to match than name instructed, physical items because the preliminary physical code established in these latter items is compatible with, and facilitates, the decision based on name codes.

A second problem that could have contributed to the failure to find a focusing effect (if it in fact exists) involves the order of stimulus presentation. Since the search set was presented for such a short period of time, and preceded the target, it may have been very difficult to maintain an unaltered physical code. Kroll (1975) has shown that physical information can exist for periods of time substantially longer than that used in the present experiment if no intervening information is processed. Since this was not the case (because the target occurs after the search set and may mask it), it may be that the actual paradigm used did not lend itself methodologically to resolving the issue.

Focusing may be more probable when a target precedes the search set. In that context, physical codes of the search set should not be replaced by any other information if the processing of the set is attenuated at that point.

# EXPERIMENT 2

Experiment 1 was concerned with selection that occurs without active search of the initial stimulus because the target is presented later. The brief presentation time was expected to lead to differential stimulus processing with a resulting decrease in the speed and accuracy of matching to a later probe stimulus, depending on the matching criterion required for the task. In a sense, this task was of spontaneous selection. While the obtained results are compatible with the present theory, they do not address the issue of selection of particular targets from a stimulus array while the array is physically present. To do this, selective attention paradigms must be employed. Although they have appeared in the literature in several forms (as noted in the earlier discussion), the collective data has been incorporated into several distinct theoretical formulations. However, it is not clear that these theories can satisfactorily account for both spontaneous selection and selective attention. For example, proponents of filter theory (Broadbent, 1958; Treisman, 1960) have argued that selection of relevant attributes occurs by blocking or attenuating processing of the irrelevant items. Although this work was addressed specifically to the dichotic listening paradigm, it does not seem inappropriate to apply it to selection paradigms in general. In filter theories the physical and semantic attributes of the selected channel are always being monitored against some criterion. Given the results of the first experiment, these theories are faced with the problem of explaining just how differential selection can occur when there is no initial target to establish the selection criterion. It appears that selection is not bound to one level, and proceeds throughout the cognitive domain.

From the present perspective, active search and spontaneous selection should be highly related. Selection is the activation of units comprising the stimulus representation. Whether or not this activation occurs surreptitiously or in response to search demands, the same mechanism is assumed to determine attentional focusing. As a consequence of this, it is predicted that the same variables that affect spontaneous selection will influence search tasks.

The design to be used to test this hypothesis closely resembles that of Experiment 1, except for one important difference. In this study the targets precede the presentation of the stimulus set, so that the search is of a physically present stimulus array. As in Experiment 1, it was possible to demand physical as well as name judgments, and to vary load by increasing the number of letters in the second stimulus. The probe stimulus in this experiment always appeared for 1000 msec, followed by 500 msec ISI, and then a 2, 4, or 6 lettered array which remained in view for 100 msec. Due to a programming error, the targets in this experiment were only one-half the size of those in the first study. It will be argued later that this difference is not critical, and does not limit the generalizability of any conclusions drawn from comparisons between the two experiments. In all other respects the second experiment was like the first.

Because the target precedes the search set in this experiment, subjects can terminate processing of the stimulus set before an exhaustive analysis is completed on some items. Hence, the paradigm employed is more of a "selection" methodology than that used in the first experiment. However, for the reasons discussed earlier, there should be no major difference in the pattern of results between the two experiments. Although subjects can "look for" some target and match it against a preestablished criterion, differential qualitative and quantitative processing effects were expected to be obtained.

There are expected to be some important differences between the experiments. For example, if physical matches are based on preattentive mechanisms in the present study, not only should physical instructions yield faster reaction times than name instructions, but focusing should occur as well. However, considering the data of the first experiment, it appears that physical instructions do not lead to faster reaction times than name instructions when the search set is removed from the screen. Because the search set in this study was on for only 100 msec, it did not appear for most of the subject's reaction time. This was expected to result in name instruction superiority in this experiment, as in the first. However, this effect should be reduced because the search set was temporally closer to the time of decision compared with the first experiment. Hence, the very rudimentary physical information is probably more intact in the present study. In addition, the target appeared after the search set in Experiment 1 and this may cause some masking of the physical information in that paradigm. It was also anticipated that overall reaction times in the present study would be faster than in Experiment 1 because a criterion is established (i.e., a target is presented) before the search set appears, rather than after it leaves.

<u>Results</u>

<u>Quantitative</u> <u>Effects.</u> Search set size had a strong effect on reaction times, $\underline{F}$ (2,22) = 12.48, $\underline{MSe}$ = .069, p < .01. The means for this comparison are found in the third column of Table 4. In addition, the error data of the sixth column reflect the same effect , $\underline{F}$ (2,22) = 10.28, $\underline{MSe}$ = .007, p < .01. For each individual item type, search set size had a strong effect as well, smallest $\underline{F}$ (2,22) = 7.85, p < .01. The only exception to this occurs in the error data for the name items, $\underline{F}$ (2,22) = 2.39, $\underline{MSe}$ = .013. Even here the mean proportion wrong for 2, 4 and 6 items was .088, .115, and .139, respectively, which is clearly in the predicted direction. Together, these data support the arguments made earlier: Stimulus processing is strongly effected by the number of items analyzed, as determined by reaction time and error rates.

<u>Qualitative</u> <u>Effects.</u> It was anticipated that both instructions and item types would have a pronounced effect in reaction times and error rates for the theoretical reasons

discussed earlier. With regard to the type of instruction variable, the previous experiment found that physical processing took longer to accomplish than name processing. As is apparent from the means in the last column of Table 5, the same trend was found in Experiment 2, $F$ (1,11) = 4.66, $MSe$ = .196, $p < .10$. Analysis of type of instruction within each individual item type reveals the source of this difference is between the name items in each level of instruction, $F$ (1,11) = 12.06, $MSe$ = .102, $p < .01$, and not with the physical, $F$ (1,11) = 2.65, $MSe$ = .077, or different, $F < 1.00$ items. None of the above analyses are significant in the error data, largest $F$ (1,11) = 2.28.

It should be noted that in determining the relative effects of physical and name instructions, only comparable decisions should be contrasted. That is, the only relevant comparisons that should be made are between physical and different items which are "yes" and "no" items, respectively, for both name and physical instructions. The strong effect noted between types of instructions on the name items may be due to either type of instruction (physical or name) or the type of decision required ("no" for physical and "yes" for name instructions). Analyses of within subject means for "yes" or "no" decision reaction times for physical (yes) and different (no) items yields no significant effect of instruction for the reaction time, $F$ (1,11) = 2.49, $MSe$ = .069, or error data, $F < 1.00$. Thus, there is no strong support for the conjecture that differential processing of physical and name items can be manipulated by the type of instruction required by subjects. Indeed, whatever support there is seems to be consistent with the data of the first experiment and contrary to the findings of other researchers, most noteably Posner (1969).

Another means of manipulating qualitative processing in the present study was by presenting different item types, where evidence of differential processing may be inferred by comparing reaction times and error rates collapsed across type of instruction. There was a large difference between item types for the RT and error data, $F$ (2,22) = 18.06, MSe = .021, and $F$ (2,22) = 18.24, MSe = .016, respectively. In terms of individual comparisons, each item type reliably differed from the others, smallest $F$ (1,11) = 8.69, $p < .05$, for both the error and reaction time data. These data can be found in Table 5. Summed across instruction type, name items take longest to process and this occurs with the most errors. Physical items can be processed more quickly than different items, although with more errors. Hence, across instruction type, decisions about physically identical items are arrived at more quickly than those of either name identical or different items. Again, it must be remembered that the type of decision (yes/no) may underlie the physical item superiority, although it cannot account for the fact that name items take longer to process than different items. In addition, it is clear that support for the assumption that physical instructions lead to faster reaction times than name instructions finds little support in these data.

Type of Decision. Consistent with the data found by other researchers, there is a strong tendency for "yes" responses ($M = 805$ msec) to occur faster than "no" responses ($M = 874$ msec), $F$ (1,11) = 15.79, $MSe$ = .011, $p < .01$. However, there was a trend for "no" responses to be made more accurately ($M = .049$) than "yes" responses ($M = .071$), $F$ (1,11) = 3.49, $MSe$ = .005, $p < .10$.

Effect of Case. A trend for capital letters ($M = 831$ msec) to be responded to more quickly than small letters ($M = 853$ msec) was observed, $F$ (1,11) = 4.64, $MSe$ = .011, $p < .10$. There was no difference between error rates, (M capital = .063, M small = .067), $F < 1.00$. Together these data are consistent with the interpretation that different stimulus classes are not equally well discriminated and are thus responded to differentially.

Processing x Load Interaction. Focusing was defined as the tendency for complex processing to diminish in speed and/or accuracy relative to simpler analyses, as the size of the search set increases. Because of this, it was expected that physical instructions would be much less affected by search set size than name instructions. Physical and name item types would also be expected to show the same effects. Statistically, these predictions would be confirmed by instruction x number and item type x number interactions. However, in the present experiment neither interaction was reliable for the reaction time data, although there was a trend for the instruction x number interaction, $F$ (2,22) =

2.68, MSe = .011, p < .10. The F for the item type x number interaction was less than 1.00. Error data analyses indicated a strong effect for the instruction x number of items interaction, F (2,22) = 13.70, MSe = .005, p < .01, but not for the items x number interaction, F (2,22) = 1.62, MSe = .006. As can be seen from the error data from the fifth column of Table 4, the significant interaction seems to be due to increasing errors with load in the name instruction condition. It is also apparent that reaction times increase more rapidly for name instructions than physical instructions, although this was not a reliable effect. In addition, there was a strong instruction x item type x number of items interaction in the error data, F (4,44) = 3.85, MSe = .006, p < .01, but not in the reaction time data, F (4,44) = 1.43, MSe = .008.

All these interactions must be interpreted with caution because of different yes/no responses to name items under each instruction condition. Examination of the instruction x number of items interaction for the physical and different items only, reveals a trend for focused processing in the reaction time data (see Figure 2), F (2,22) = 2.74, MSe = .008, p < .10, and a reliable effect in the error data, F (2,22) = 3.87, MSe = .002, p < .05. The means of the first interaction for search set sizes of 2, 4 and 6 letters (779, 834, 902 msec for physical instructions; 702, 792, 884 msec for name instructions) suggests a rapidly diminishing advantage of name processing as the size of the search set increases. Error means indicate a similar effect (.039, .025,

.057 for physical instructions; .022, .026, .075 for name instructions).

The item type x number of items interaction was not reliable in an analysis of the reaction time data, $\underline{F}$ (2,22) = 1.42, $\underline{MS}$e = .005, but was reliable in the error analysis, $\underline{F}$ (2,22) = 4.88, $\underline{MS}$e = .002, $p < .05$. However, this latter interaction is due to a large error rate in the analysis of physical items for a set size of six (physical items .039, .038, .094; different items .022, .013, .038), and cannot be taken to support the focusing hypothesis because it is the simpler physical analysis that deteriorates most as load increases. From Figure 2, there is evidence of focusing for physical items alone, $\underline{F}$ (2,22) = 3.57, $\underline{MS}$e = .003, $p < .05$, indicating that the physical instruction is associated with more complex processing than name instructions, but the effect diminishes with increasing load.

A strong instruction x item type interaction was present for reaction times, $\underline{F}$ (2,22) = 10.58, $\underline{MS}$e = .025, $p < .01$, but not for the error data, $\underline{F} < 1.00$, when all three item types were examined together. Excluding the name items eliminates the effect for reaction time, $\underline{F}$ (1,11) = 3.08, $\underline{MS}$e = .021, while the error interaction remains nonsignificant, $\underline{F}$ (1,11) = 1.12, $\underline{MS}$e = .005. From the means in the second column of Table 5, it appears that the significant interaction is due to the wide difference in name item reaction times over each type of instruction. Because type of decision is perfectly correlated with instruction type for name items, it may account for the significant instruction x item type interaction when all items are included. For this reason, the effect is of little theoretical interest.

Discussion

Experiment 2 was concerned with how subjects come to abstract a predetermined stimulus from a search set that was presented later. It has been shown that certain qualitative and quantitative effects occur in a manner that follows directly from the theoretical development advanced earlier. Increases in quantitative demands of processing have been shown to greatly effect error rate and reaction time. In addition, there was evidence to suggest that different types of items are processed differently. As might be expected, physically identical items are processed most quickly, while name identical items take longest to analyze. This finding suggests that, to a degree, process repertoires are stimulus determined.

To argue that stimulus type determines the kind of processing that occurs may seem logically impoverished in that it would require the identification of a stimulus before it became analyzed. If, however, it is assumed that the initial pattern of activated units determines what patterns become activated later, the assumption appears more plausible. In the present experiment, it is clear that the type and number of items has a strong effect on stimulus processing, while the type of instruction has a marginal effect and goes in a direction opposite to what other researchers have found. Even though the subject has no prior knowledge about what item type is to be presented before it appears, stimulus structure seems to be a more critical variable than subjects' intentions in this experimental context.

Reasons for the failure to replicate the Posner (1969) findings were discussed in Experiment 1 and they are applicable to the present experiment as well. Either the variable search set sizes, or their temporal relationship to the target are possible methodological changes that underlie the observed differences. Since many items must be matched, it is possible that automatic processes cannot be engaged readily. In fact, the present experiment resembles the work of Shiffrin and Schneider (1977) and Schneider and Shiffrin (1977) in that their evidence for automatic analysis came from overlearned constant memory sets. The physical match condition employed randomly generated search sets that are similar to their varied match condition where no automatic processing was found. In addition, the two theoretical mechanisms suggested in the first study are plausible in this experiment also. To reiterate, one interpretation is that detailed physical analysis comes after name processing has established an activated name code. This, along with sensory information about the physical features of the letter, forms the basis of a later elaborated physical match. Alternately, it could also be argued that the physical information imposes a greater load upon memory than name information because physical judgments require a case label as well as a letter name label. This leads to slower reaction times in the physical instruction condition.

Failure to obtain control of automatic processing strongly limits examination of the focusing hypothesis advanced earlier. Despite this, there is some suggestion that with increasing load, name matches become more difficult than physical matches. What limits this interpretation is the lack of strong evidence of differential processing across levels of instruction. Moreover, it is the initially "slower" physical matches that remain stable across the levels of load, while the initially "fast" name matches deteriorate markedly. Given the empirically established differences in instructions, it should be the former matches that show the greatest decrement with increasing load, because those items are the most difficult to process.

A second major reservation that must be acknowledged about the focusing hypothesis concerns the lack of focusing when item types are considered. Although it was previously argued that different item types initiate different process repertoires, focusing with increasing load does not occur, except for the physical items. Moreover, elimination of the name items does not change the effect.

The data, however inadequate to evaluate focusing, have certain features that fit with the general theoretical orientation advanced earlier. In this regard, it is instructive to note that item effects summed across instruction type strongly support the notion that stimuli are processed to the depth necessary to execute the demands of the task. Hence, physical items are matched much faster than either name or different items. In both the physical and name instruction conditions processing can stop once the subject determines that the target and one letter in the search set match physically. However, name items must be analyzed more deeply for a correct match to be made. It is interesting to note that across instruction type different items are in between these two extremes, even though under each instruction condition different comparisons must be made. It seems to take as long to match the different items against a physical as against a name criterion. For the physical and name items, this effect reverses so that name instructions take much less time to complete than physical instructions. This suggests that name processing occurs before detailed physical analysis takes place. However, some very early physical processing must also occur before this in order for the name code to become activated. If the time limitations of the experiment are considered, it is plausible that the presentation of the search set for so short a time initiates a very quick analysis to maintain as much physical information as possible. One interpretation of the reaction time data is that name processing occurs next, and it is followed by a detailed physical analysis. Exceptions to this are apparent from Table 5, but can be qualified with few assumptions. Considering name instructions, it is clear that physically identical items are matched faster than name identical items, even though the same decision must be reached in each case. This could be due to physical priming by the target of the physically identical letter in the search set. Physical priming cannot occur with name items in this condition because of the structural differences between the targets and the search set. For physical instructions, the longer reaction time for name compared to physical items would be related to this effect. But for the latter items, a conflicting positive name decision would also have to be inhibited before the final detailed negative physical analysis is communicated. Near identity of reaction times between the different items in each instruction condition suggests that these items are processed to the same level. That is, the initial physical analysis does not lead to faster processing by priming (since there is no structural similarity) and later name processing indicates there is no name similarity either. Hence, for both types of instructions, further processing can be attenuated.

Finally, it is important to consider the effect of probe letter size on the outcome of the present experiment. There is ample reason to believe that there would be little change in the data if the search set and probes were identical in size. First, the error rate in this study is substantially lower than that of Experiment 1. Methodologically, there are only two plausible reasons for this. One is related to the ordering of the probes and search sets in the studies, and the other to the respective size of the probe letters. Since fewer errors were made in Experiment 2, where probe letter size was smallest, it seems that probe-search set ordering accounts for most of the differences between the studies. Unless this assumption is made, it would have to be argued that perceptual difficulty is negatively correlated with performance in the present paradigms. In addition, it is clear that in the present study probe processing is not a limiting factor. With two letters in the search set, responding was quite accurate (five percent error). This percentage represents the most error that can be attributed to failures in probe letter processing, and it is undoubtedly an overestimate (since other sources of error, including search set processing and decision error, are present as well). Hence, it is clear that subjects were encountering very little difficulty associated with the smaller probe letters. A second reason to discount the argument that probe letter size predisposes the present data is that other researchers have not found physical information to be lost in a variety of procedures that are even more deleterious for the maintenance of a physical code. For example, Posner (1969) has shown that with successive matches and a 500 msec ISI, physical matches are made faster than name matches, even if subjects are presented aural letters and instructed to consider them as capitals. Clearly, subjects do not need a verdical physical representation to make a physical match faster than a name match. Although letter size has been found to be more critical for physical than name instructions (Bundensen & Larson, 1975), the effect for letter sizes of a 2:1 ratio is not large (about 15 msec). Even though this effect is small, the question remains as to whether this could contribute to the tendency for physical instructions to take more time to execute than name instructions. Fortunately, there is some empirical evidence that this is not the case. In the pilot data of the present thesis, 18 subjects were presented 2, 4, or 6 letter search set sizes and given physical and name instructions in a between groups design. The critical aspect of this design was that search set and target letters were always the same size, while the temporal parameters were identical with those of Experiment 2. Comparisons between physical and name instruction groups for the physically identical and different items revealed that name instructions led to faster reaction times relative to physical instructions (767 msec and 859 msec, respectively). Logical and empirical considerations thus seem to rule out any suggestion that probe letter size had a substantial effect in the present experiment.

# GENERAL DISCUSSION

The two experiments reported here have strong implications for the theoretical orientation presented earlier. Each by itself contributes something to the overall understanding of attention, and together they support even more strongly the views discussed in the introduction.

Perhaps the most important aspect of the data concerns the relationship between presenting the target before and after the search set in each design. It was argued earlier that directed and spontaneous attention are closely related phenomena. The notion of changes in the activation of neural units was assumed to underlie what were termed process and state definitions of attention. From this perspective it was argued that whenever activation of the neural units occurs, attentional phenomena are manifested. For this reason, there was no necessity to postulate the existence of "filters", nor to distinguish between attention to stimuli that are physically present and those that are merely a memory set. The same processing is assumed to apply in each context.

Recall that in the first study, presentation of the target followed the occurrence of the search set, while in the second experiment the reverse was true. This temporal ordering is critical for filter theories because filters cannot be established until some criterion is established. When a target follows a search set, filter theories cannot, in principal, account for selection.

But, how alike is selection between the experiments? Although the answer to this question cannot be quantified, there are so many similarities between them that to postulate radically different processing seems unnecessary. For example, reaction times and error rates increase with search set size in both paradigms, in a way consistent with the research of Sternberg (1969). He noted that reaction times increased linearly (at about 40 msec/item) for increasing string lengths when subjects have memorized the search set beforehand. In the first experiment, the effect occurs but the slope is greater than what Sternberg observed (about 64 msec/item). The data from the second experiment matches the Sternberg's slope more closely (about 39 msec/item). Unlike Sternberg's paradigm and the first experiment, the probe preceded the search set in Experiment 2. What is clear, however, is that there is a linearly increasing reaction time in both studies. Whether or not this is due to serial exhaustive search (as claimed by Sternberg) or some other mechanism, the similarities between experiments are strong. Moreover, the differences that exist between the slopes of the present experiments are explainable from a common activation perspective. The search set in Experiment 2 is temporally closer to the time of processing than in Experiment 1. This results in less degradation of the search set in the former paradigm, leading to relatively faster access and comparison times. Alternately, it could be argued that the first experiment requires a greater memory load than the second. This would occur if it is assumed that the name codes of the former paradigm also include a case tag to allow matches to occur after the search set disappears. The second experiment does not require this tag because it is less dependent on memory. Consequently, search times are faster in the second experiment because the memory load is less than in the first study. It is important to note that the same assumptions can account for the differences as well as the similarities between experiments.

Another major way in which the paradigms are related is in their qualitative processing effects. In both experiments there was near perfect correspondence between the ranking of reaction times for item types under each instruction condition. Summed across instruction type, name identical items take the most, and physically identical items take the least time to process. In each case, different items are intermediate. There was also a marked tendency in both experiments for name instructions to lead to faster reaction times than physical instructions. In the first study, this effect was statistically reliable for reaction times, although only a trend for the effect was observed with the second design. Earlier it was argued that this is consistent with the assumption that a detailed physical comparison can occur only after name codes have been established. If this is true, then from the theoretical orientation established previously the change over studies is as expected. That is, presenting the target after the search set does not allow the search set to be analyzed physically for any predetermined features, while presenting the target before the search set does.

Hence, the relative differences between physical and name instructions would be greatest in the first experiment where the initial physical search set is further removed in time from the matching decision.

A comparison between the load x level interactions also reveals a basic similarity between experiments. Recall that for other than the error data of Experiment 2, there was no instruction x number of items interaction. Despite the radical change of probe letter placement, the effect of the search set size for physical and name instructions is not differential in either study. This suggests a basic similarity in processing. Considering the type of item x number of items interaction, focused processing occurs only in the reaction time data in the first study when all items are considered. While this would seem to run counter to the suggestion that the experiments are similar, closer examination of the mean reaction times in each study indicates a tendency for the different types of items to become more difficult to process as search set size increases. Although one effect attains significance while the latter does not, there is a resemblance between the two studies.

Finally, there is a strong similarity in the instruction x item type and instruction x item type x number of items interactions. While the former interaction fails to reach reliable levels in the error analysis of Experiment 2, and the latter in the reaction time data of the same study, there is little major difference between the patterns of data. This is particularly striking in comparing Figures 1 and 2. Focused processing seems most evident with physical items and clearly absent with different items.

The similarity between the experiments does not confirm the present notions about attention put forth earlier, any more than differences between the paradigms would argue definitively against the theoretical framework established earlier. There is probably no design that could unequivocally determine the usefulness of such an attentional orientation. It could be the case that similar effects between studies arise because of different processing mechanisims in each context. The more important feature of the present data is that both experiments coincide in their important effects, and that each is interpretable by a selective activation orientation of attention.

Assumptions of automatic processing have played a major part in the theoretical development of the present thesis, although there is no strong evidence that it occurred in either study. Automaticity has usually been defined as involving no intention, occurring without awareness, and involving little disruption of ongoing activity (Posner & Snyder, 1975). It was anticipated that physical instructions should approximate this condition. Given that automatic processing can occur in some contexts, while more detailed processing must occur in others, it was anticipated that load (quantitative) variables would interact with process (qualitative) variables to give evidence of what is here termed "focused processing". Some recent work by Logan (1976, 1978, 1979) uses this rationale to examine automaticity. In one study (Logan, 1978), a concurrent memory load paradigm was used to vary attentional demand in performing a memory search task. Evidence for automaticity was found in a search set size x memory load interaction. On the basis of this research, it was concluded that practice and consistent mapping may be necessary and sufficient conditions for automaticity to develop. The failure of the present experiments to demonstrate automatic processing may be related to the procedure employed. Subjects did not receive massive practice in the present study nor did the search set remain constant from trial to trial. It can only be suggested that with these modifications, automaticity would develop. It should be noted, however, that work by Briggs, Peters and Fisher (1972) and Griffith and Johnston (1977) did not obtain this crucial interaction, even though these considerations were taken into account. In addition, there was some evidence, albeit slight, that focusing did occur to some extent. This was found in the item type x load and instruction x load interactions in Experiment 2 (error data for physical and different items combined and with physical items separately).

One of the reasons for the failure to obtain automatic processing might be found in the choice of independent variables used to control qualitative processing in the present experiments. The instruction variable can be thought of as a criterion manipulation: Subjects were required to voluntarily process items differentially to make the required match. Item variables, on the other hand, were stimulus defined such that differential processing was ensured by the nature of the item itself. The robust Posner effect (name instructions taking longer than physical instructions) has usually been reported with the item type variable (Posner & Keele, 1967; Posner, Boies, Eichelman & Taylor, 1969). What has been demonstrated in the present experiments is that processing differences occur within both variable classes. Comparisons between item type and instructional manipulations are somewhat inappropriate because they undoubtedly involve different mechanisms. However, it is clear that physical instructions and name items are the slowest processed in the instruction and item variable classes, respectively. Why this is so is not obvious, but it might be speculated that a conscious decision about physical information that is no longer present results in this effect. Hence, in this experimental context, it is understandable that physical decisions took longer than name judgments. With the type of item variable, the commonly observed effects were replicated strongly: Making name matches between physically identical and name identical stimuli has been found to differ by about 80 msec (Posner, 1969). This effect was observed in Experiments 1 and 2 (75 and 47 msec, respectively).

Together, both studies indicate that a distinction must be made between processing that is explicit (subject determined) and implicit (stimulus determined). The former processes are related to the instruction variable while the latter correspond to the type of item variable in the present experiment. Although it is true that processing cannot arise without some subject cooperation (such as accommodating head and eye orientation), it is also true that, to a degree, the process repertoire is stimulus limited. This is simply to say that the nature of the stimulus predisposes the type and degree of processing that can occur with that item. The product of the initial analysis of a stimulus is assumed to serve as input to later analysis. In this way, the type of stimulus item has a direct influence on how it is processed. Masking, for example, can terminate or eliminate stimulus processing in certain situations, irrespective of the subject's intention.

Implicit and explicit processes should not be confused with the distinction between preattentive and focal attention discussed earlier in that the former can be either automatic or controlled. It is also of some interest to note that some variables behave similarly under each processing classification. The number of items (load) has a similar effect in both studies for each type of process, as does the effect of case. Specifically, the more items there are, the longer processing takes for both instructions and item types. In addition, capital targets were more quickly processed than small targets for each process variable class. Case also interacted with each qualitative process type for the reaction time data in both experiments.

The relationship between reaction times and error rates requires examination as well. Error data were used in a secondary role throughout this thesis because they appear to be a less sensitive measure of processing. In most instances, these data either go the same direction as the reaction time data or they do not differ. Rarely do they go in an opposite direction. It is clear, however, that certain conditions lead to more errors than in others. Average percent error in Experiments 1 and 2 were 16.3 and 6.5, respectively. These relatively high error rates invite scrutiny, especially to determine if a speed-accuracy tradeoff can account for the present results. Generally speaking, this does not seem to be the case because reaction times increase with error rates, such that decisions that require the most time to make occur with the most error. This effect is particularly strong in the first experiment where error rates become very large for the greatest search set size. Thus, the difficulty of making a decision is closely related to the time taken to make the decision. An apparent exception to this occurs in physical matches for Experiment 2, where the rates are relatively low and uniform throughout.

A related consideration concerns the relative proportion of errors in the different instruction and item conditions. Since explicit processing involves subject control, it is expected that speed-accuracy tradeoffs would occur in types of instructions (an explicit process) rather than item types (an implicit process), if it were to appear at all. It is apparent that in both experiments this is not the case. Error rates for instruction types are virtually identical within each experiment, while item types tend to differ in error rates. The item differences cannot be attributed to strategies because the type of item to be presented to subjects was randomly determined, and thus unknown before it was presented. Item types must be processed and identified for a speed-accuracy manipulation to occur. The differences between "yes" and "no" error rates in both experiments (more in the former response class) also cannot be attributed to subjective criterion changes, for the same reason they cannot occur across item types.

A more serious problem exists in interpreting data from the cells where large error rates exist. Since errors would occur approximately half the time if responding is random, it is clear that a cautious approach must be adopted where up to 38.5% of the responses are incorrect. Moreover, the remaining responses can be correct for the wrong reasons: Improper analysis of a stimulus could lead to a "correct" response in some instances. In effect, this means that the proportion of errors is a conservative measure of how often processing breaks down. Nevertheless, the existence of large error rates does not diminish the central importance of the argument presented within this thesis, namely that changes in selective processing are a function of the amount and type of information analyzed. Given large error rates, one can argue that an item selection bias may be present, so that "easy" items are decoded correctly while "hard" items are not. This would result in the inclusion of proportionally more reaction times to easy items in conditions where error rates are comparatively large. This occurrence, however, would tend to obscure real differences between cells where such differences exist, and thus present a conservative estimate of differential processing.

It has been repeatedly argued that one of the consequences of the attentional framework proposed earlier is a basic similarity between the two experiments. Do differences in the magnitude of error rates between the studies represent an apparent contradiction to this hypothesis? It does not seem so. The different error rates are predictable on the basis of the activation hypothesis discussed previously. Because the search set in the first experiment is removed before the probe appears, it is temporally further from the time of decision than the search set in the second experiment, which follows the probe. Therefore, there is more degradation of the search set in the first study, and an ensuing greater probability of error. It might be argued that this is counterintuitive, because if activation differences underlie the different error rates, then the opposite effect would be anticipated for probes, since probes in the first experiment are closer to decision than in the second. While there could be some form of a tradeoff, search set decoding is clearly the limiting factor in each paradigm. This is because error rates for small sets are minimal but increase for larger set sizes. The increases in error occur much more rapidly with set size in the first experiment, suggesting that differences in the availability of the search sets between experiments underlie the effect.

Finally, it seems appropriate to comment upon the implications of the present work for extant conceptions of attention. Initially, certain assumptions were made about the nature of selective attention mechanisms, and these assumptions were the foundation of the later empirical work. To what extent do the present findings relate to aspects of the orientation presented earlier? Much of the work has already addressed these issues, but not in the broader context of attentional theory.

It has been suggested that a unit activation of selection fits well with the present data. What has not been emphasized, however, is the extent to which this is a radical departure from other attentional formations. While it has become increasingly popular to use the term "processing" in the context of attention paradigms, there has often been confusion about the relationship of processing and the phenomena of attention itself. In discussing the nature of automatic processes Shiffrin and Schneider (1977) suggest that unit activation may be very fleeting "...unless attention is directed to the process when it occurs..." (p.156). This argument clearly necessitates the assumption that attention exists independently of automatic neural processing. However, they also state that "These attention responses then direct attention (i.e., will direct controlled processing) automatically to a target..." (Schneider & Shiffrin, 1977, p.2), and then go on to argue that "A controlled process is a temporary sequence of nodes activated under control of, and through attention by, the subject" (p.2). Hence, the distinction between automatic processes, controlled processes, and attention are never made clear, despite their elegant attempt to operationalize these concepts.

Another recent paper also encounters difficulty with the concept of attention. To Logan (1979) attentional capacity is limited, and this is what partially underlies most short-term memory limitations: "...it follows that loading memory will reduce the capacity available to a task and interfere with performance to the extent that the task requires attentional capacity" (p.190). Statements such as this imply that something more than attention absorbs capacity to do a task. Nevertheless, from Logan's point of view, attention can certainly be considered as requiring a capacity. Yet in an earlier paper (Logan, 1978) he considers "...attention is best construed as selective allocation of central processing capacity..." (p.60). Hence, the distinction between processing and capacity aspects of attention is suggested (as in the theoretical section of the present thesis), but confusion exists as to whether it is capacity, or allocation of capacity, that constitutes attention. Other researchers have also attempted to discuss attention from processing and capacity orientations. Invariably, they appeal to a conception of attention that has either state or process characteristics, but always as an entity uniquely distinct from the process they are attempting to explain. The present account holds that attention is isomorphic with all ongoing cognitive activity. The extent to which an organism is engaged in a task is the degree to which attention is involved. This is not to suggest that practice will not reduce attentional demands, but rather to state that a construct of attention beyond process demands is excess to what is logically necessary to explain attentional phenomena. If attention is seen to be some "executive" that directs different processing modes under different stimulus conditions, the whole question of what constitutes attention is avoided or appeals to infinite regress. Empirically, the present results are accommodated rather well into this view. More difficult tasks involve more processing and, hence, more attention. It may be that the conceptual simplicity of this orientation will provide a useful framework to investigate attentional phenomena.

Table 1

Examples of Items, Approximate Percent of Occurrence,

and Correct Responses for Experiments 1 and 2

| Type of Item | Example | | Physical Instruction | | Name Instruction | |
|---|---|---|---|---|---|---|
| | Search Set | Test Item | Correct Response | % Occurrence | Correct Response | % Occurrence |
| Physical Capital | BVan | V | Yes | 25 | Yes | 12.5 |
| Physical Small | BVan | a | Yes | 25 | Yes | 12.5 |
| Name Capital | BVan | N | No | 12.5 | Yes | 12.5 |
| Name Small | BVan | b | No | 12.5 | Yes | 12.5 |
| Different Capital | BVan | T | No | 12.5 | No | 25 |
| Different Small | BVan | r | No | 12.5 | No | 25 |

Table 2

Reaction Time and Error Rate for Type of Instruction and

Type of Item Under Each Search Set Size in Experiment 1

| | | Reaction Time (in msec) | | | Proportion Error | | |
|---|---|---|---|---|---|---|---|
| Search Set Size | Type of Item | Physical Instruction | Name Instruction | M | Physical Instruction | Name Instruction | M |
| 2 | P[a] | 816 | 666 | 741 | .062 | .024 | .043 |
| | N[b] | 918 | 728 | 823 | .051 | .086 | .068 |
| | D[c] | 749 | 792 | 771 | .018 | .028 | .023 |
| | M | 827 | 729 | 778 | .043 | .046 | .045 |
| 4 | P | 889 | 836 | 862 | .224 | .111 | .167 |
| | N | 993 | 915 | 854 | .152 | .223 | .187 |
| | D | 911 | 913 | 912 | .071 | .108 | .090 |
| | M | 931 | 888 | 909 | .149 | .147 | .148 |
| 6 | P | 973 | 904 | 938 | .381 | .270 | .326 |
| | N | 1154 | 988 | 1070 | .234 | .385 | .309 |
| | D | 1131 | 1045 | 1088 | .215 | .281 | .248 |
| | M | 1086 | 979 | 1032 | .277 | .312 | .294 |

[a] Physical Items [b] Name Items [c] Different Items

Table 3

Reaction Time in msec and Proportion Error[a] for Type of Instruction and Type of Item for Experiment 1

| Type of Instruction | Type of Item: Physical | Name | Different | M |
|---|---|---|---|---|
| Physical | 893 (.222) | 1022 (.146) | 930 (.102) | 948 (.157) |
| Name | 802 (.135) | 877 (.231) | 917 (.139) | 865 (.168) |
| M | 847 (.179) | 949 (.189) | 923 (.120) | |

[a]Error data is in brackets.

Table 4

Reaction Time and Error Rate for Type of Instruction and

Type of Item Under Each Search Set Size in Experiment 2

| Search Set Size | Type of Item | Reaction Time (in msec) | | | Proportion Error | | |
|---|---|---|---|---|---|---|---|
| | | Physical Instruction | Name Instruction | *M* | Physical Instruction | Name Instruction | *M* |
| 2 | P[a] | 778 | 666 | 727 | .055 | .023 | .039 |
| | N[b] | 921 | 702 | 812 | .132 | .043 | .088 |
| | D[c] | 771 | 738 | 754 | .023 | .022 | .022 |
| | *M* | 826 | 702 | 762 | .070 | .029 | .050 |
| 4 | P | 836 | 744 | 790 | .046 | .030 | .038 |
| | N | 987 | 818 | 902 | .125 | .105 | .115 |
| | D | 832 | 841 | 836 | .003 | .022 | .013 |
| | *M* | 885 | 801 | 843 | .058 | .052 | .055 |
| 6 | P | 868 | 856 | 862 | .081 | .106 | .094 |
| | N | 1054 | 887 | 970 | .093 | .183 | .139 |
| | D | 936 | 913 | 925 | .033 | .043 | .038 |
| | *M* | 953 | 885 | 919 | .069 | .111 | .090 |

[a]Physical Items [b]Name Items [c]Different Items

Table 5

Reaction Time in msec and Proportion Error[a] for Type of Instruction and Type of Item for Experiment 2

| Type of Instruction | Type of Item: Physical | Name | Different | M |
|---|---|---|---|---|
| Physical | 830 (.061) | 987 (.117) | 846 (.020) | 888 (.066) |
| Name | 755 (.053) | 802 (.111) | 830 (.029) | 796 (.064) |
| M | 793 (.057) | 895 (.114) | 838 (.024) | |

[a]Error data is in brackets.

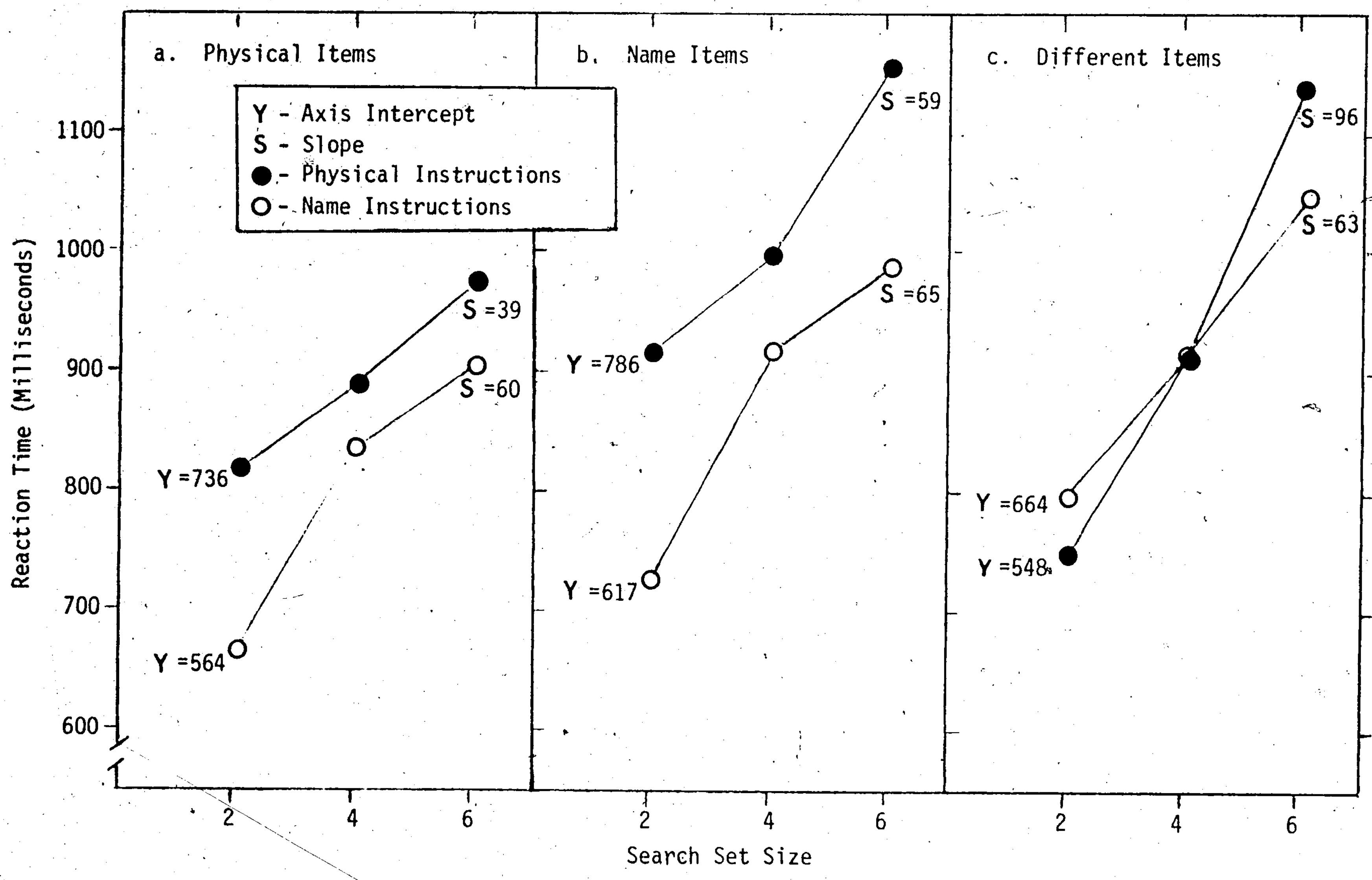


Figure 1. Reaction time for physical, name, and different items for each search set size under name and physical instructions in Experiment 1.

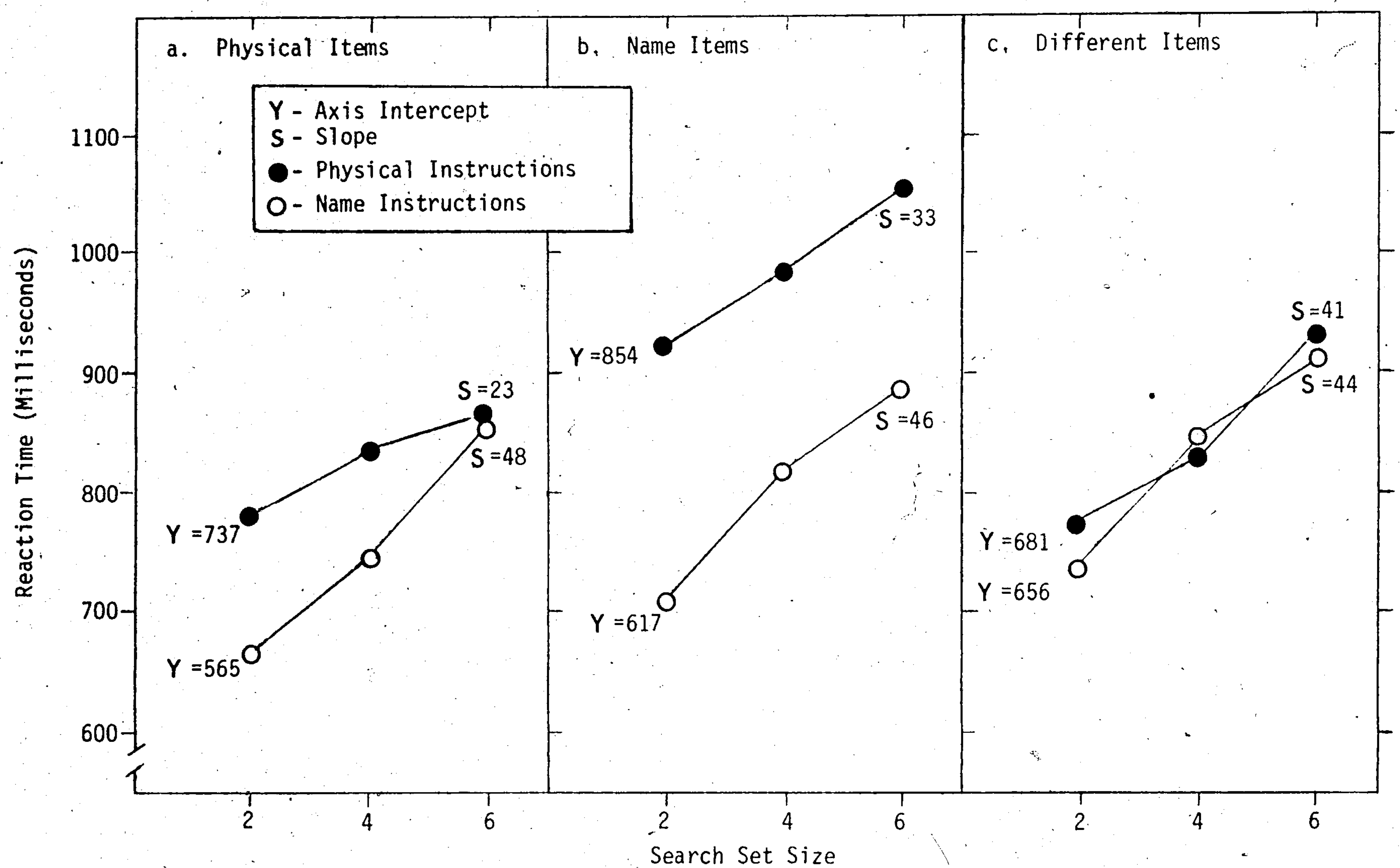


Figure 2. Reaction time for physical, name, and different items for each search set size under name and physical instructions in Experiment 2.

References

Atkinson, R. C., Holmgren, J. E., & Juola, J. F. Processing time as influenced by the number of elements in a visual display. Perception & Psychophysics, 1969, 6, 321-326.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory (Vol.2). New York: Academic Press, 1968.

Berlyne, D. E. Conflict, arousal and curiosity. New York: McGraw Hill, 1960.

Berlyne, D. E. Structure and direction in thinking. New York: John Wiley, 1965.

Berlyne, D. E. Arousal and reinforcement. In D. Levine (Ed.), Nebraska Symposium on Motivation. Lincoln: University of Nebraska Press, 1967.

Bindra, D. A theory of intelligent behavior. New York: John Wiley, 1976.

Blumenthal, A. L. The process of cognition. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Briggs, G. E., Peters, G. L., & Fisher, R. P. On the locus of divided attention effects. Perception and Psychophysics, 1972, 11, 315-320.

Broadbent, D. E. The role of auditory localization in attention and memory span. Journal of Experimental Psychology, 1954, 47, 191-196.

Broadbent, D. E. Perception and communication. London: Pergamon Press, 1958.

Broadbent, D. E. Stimulus set and response set: Two kinds of selective attention. In D. I. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appleton-Century-Crofts, 1970.

Bruner, J. S., & Postman, L. On the perception of incongruity: A paradigm. Journal of Personality, 1949, 18, 206-223.

Bundensen, C., & Larsen, A. Visual transformation of size. Journal of Experimental Psychology: Human Perception and Performance, 1975, 1, 214-220.

Chapman, D. W. Relative effects of determinate and indeterminate Aufgaben. American Journal of Psychology, 1932, 44, 163-174.

Cherry, E. C. Some experiments on the recognition of speech, with one and two ears. Journal of the Acoustical Society of America, 1953, 25, 975-979.

Cohen, J. C., & Musgrave, B. S. Effect of meaningfulness on cue selection in verbal paired-associate learning. Journal of Experimental Psychology, 1964, 68, 284-287.

Corballis, M. C. Access to memory: An analysis of recognition times. In P. M. A. Rabbitt and S. Dornic (Eds.), Attention and performance V. New York: Academic Press, 1975.

Corteen, R. S., & Wood, B. Autonomic responses to shock-associated words in an unattended channel. Journal of Experimental Psychology, 1972, 94, 308-313.

Craik, F. I. M., & Jacoby, L. L. A process view of short-term retention. In F. Restle, R. M. Shiffrin, N. J. Castellan, M. R. Lindman, and D. B. Pisoni (Eds.), Cognitive theory. Volume 1. Hillsdale, N.J.: Lawrence Erlbaum, 1975.

Craik, F. I. M., & Lockhart, R. S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.

Craik, F. I. M., & Tulving, E. Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 1975, 104, 268-294.

Dallett, K. M. Effects of a supplementary prefix on recall. Journal of Experimental Psychology, 1964, 67, 296-298.

Deutsch, J. A., & Deutsch, D. Attention: Some theoretical considerations. Psychological Review, 1963, 70, 80-90.

Di Lollo, V. Temporal integration of visual memory. Journal of Experimental Psychology: General, 1979, in press.

Dixon, N. F. Subliminal perception: The nature of a controversy. Maidenhead, England: McGraw-Hill, 1971.

Dobbs, A. R., & Carlson, D. Transfer of selection rules in stimulus coding. American Journal of Psychology, 1975, 88, 253-261.

Donders, F. C. On the speed of mental processes. Acta Psychologica, 1969, 30, 412-431.

Dyer, F. H. The Stroop phenomenon and its use in the study of perceptual, cognitive and response processes. Memory and Cognition, 1973, 1, 106-120.

Egeth, H. E. Selective attention. Psychological Bulletin, 1967, 67, 41-57.

Egeth, H. E. Attention and preattention. In G. H. Bower (Ed.), The psychology of learning and motivation (Vol. II). New York: Academic Press, 1977.

Egeth, H. E., Jonides, J., & Wall, S. Parallel processing of multi-element displays. Cognitive Psychology, 1972, 3, 674-698.

Erdelyi, M. A new look at the new look: Perceptual defense and vigilance. Psychological Review, 1974, 81, 1-25.

Fantz, R. L. Pattern vision in young infants. Psychological Record, 1958, 8, 43-47.

Fantz, R. L. Visual perception from birth as shown by pattern selectivity. Annals of the New York Academy of Sciences, 1965, 118, 793-814.

Garner, W. R. The stimulus in information processing. American Psychologist, 1970, 25, 350-358.

Garner, W. R., & Felfoldy, G. L. Integrality of stimulus dimensions in various types of information processing. Cognitive Psychology, 1970, 1, 225-241.

Gray, J. A., & Wedderburn, A. A. I. Grouping strategies with simultaneous stimuli. Quarterly Journal of Experimental Psychology, 1960, 12, 180-184.

Griffith, D., & Johnston, W. A. Stage 2 processing and the divided-attention effect. Memory and Cognition, 1977, 5, 597-601.

Haber, R. N. Effects of coding strategy on perceptual memory. Journal of Experimental Psychology, 1964, 68, 357-362. (a)

Haber, R. N. A replication of selective attention and coding in visual perception. Journal of Experimental Psychology, 1964, 67, 402-404. (b)

Haber, R. N. Nature of the effect of set on perception. Psychological Review, 1966, 73, 335-351.

Harris, C. S., & Haber, R. N. Selective attention and coding in visual-perception. Journal of Experimental Psychology, 1963, 65, 328-333.

Harter, M. R. Excitability cycles and cortical scanning: A review of two hypotheses of central intermittency in perception. Psychological Bulletin, 1967, 68, 47-58.

Hintzman, D. L., Carre, F. A., Eskridge, V. L., Owens, A. M., Shaff, S. S., & Sparks, E. M. "Stroop" effect: Input or output phenomenon? Journal of Experimental Psychology, 1972, 95, 458-459.

Hochberg, J. E. Attention, organization, and consciousness. In D. J. Mostofsky (Ed.), Attention: Contemporary theory and analysis. New York: Appelton-Century-Crofts, 1970.

Horton, K. D. Depth of processing: Theory and research. Unpublished doctoral dissertation, University of Alberta, 1977.

Hubel, D. H., & Wiesel, T. N. Receptive fields of single neurones in the cat's striate cortex. Journal of Physiology, 1959, 148, 574-591.

Hubel, D. H., & Wiesel, T. N. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. Journal of Physiology, 1962, 160, 106-154.

Hubel, D. H., & Wiesel, T. N. Receptive fields of cells in striate cortex of very young, visually unexperienced kittens. Journal of Neurophysiology, 1963, 26, 994-1002.

Hubel, D. H., & Wiesel, T. N. Receptive fields and functional architecture in two non-striate visual areas (18 and 19) of the cat. Journal of Neurophysiology, 1965, 28, 229-289.

Hubel, D. H., & Wiesel, T. N. Receptive fields and functional architecture of monkey striate cortex. Journal of Physiology, 1968, 195, 215-243.

Hyde, T. S., & Jenkins, J. J. Differential effects of incidental tasks on the organization of recall of a list of highly associated words. Journal of Experimental Psychology, 1969, 82, 472-481.

James, W. The principals of psychology. New York: Holt, 1890.

Jenkins, J. J. Stimulus "fractionation" in paired-associate learning. Psychological Reports, 1963, 13, 409-410.

Jonides, J., & Gleitman, H. A conceptual category effect in visual search: 0 as letter or as digit. Perception and Psychophysics, 1972, 12, 457-460.

Kahneman, D. Attention and effort. Englewood Cliffs, N.J.: Prentice-Hall, 1973.

Keren, G. Some considerations of two alleged kinds of selective attention. Journal of Experimental Psychology: General, 1976, 105, 349-374.

Kimble, G. A. Mediating associations. Journal of Experimental Psychology, 1968, 76, 263-266.

Konorski, J. Integrative activity of the brain. Chicago: University of Chicago Press, 1967.

Kroll, N. E. visual short-term memory. In D. Deutsch and J. A. Deutsch (Eds.), Short-term memory. New York: Academic Press, 1975.

Kroll, N. E., Parks, T., Parkinson, S. Z., Bieber, S. L., & Johnson, A. L. Short-term memory while shadowing: Recall of visually and of aurally presented letters. Journal of Experimental Psychology, 1970, 85, 220-227.

Kulpe, O. Versuche uber abstraktion. Berlin International Congress of Experimental Psychology, 1904, 56-68.

Lawrence, D. H., & LaBerge, D. L. Relationship between recognition accuracy and order of reporting stimulus dimensions. Journal of Experimental Psychology, 1956, 51, 12-18.

Lockhart, R. S., Craik, F. I. M., & Jacoby, L. L. Depth of processing in recognition and recall: Some aspects of a general memory system. In J. Brown (Ed.), Recall and recognition. London: John Wiley, 1976.

Logan, G. D. Converging evidence for automatic perceptual processing in visual search. Canadian Journal of Psychology, 1976, 30, 192-200.

Logan, G. D. Attention in character-classification tasks: Evidence for the automaticity of component stages. Journal of Experimental Psychology: General, 1978, 107, 32-63.

Logan, G. D. On the use of a concurrent memory load to measure attention and automaticity. Journal of Experimental Psychology: Human Learning and Memory, 1979, 5, 189-207.

Lorenz, K. Z. Imprinting. In R. C. Birney and R. C. Teevan (Eds.), Instinct: An enduring problem in psychology: Selected readings. Princeton, N.J.: Van Nostrand, 1960.

Mackworth, N. H. Visual noise causes tunnel vision. Psychonomic Science, 1965, 3, 67-68.

Mandler, G. Memory storage and retrieval: Some limits on the reach of attention and consciousness. In P.M.A. Rabbitt and S. Dornic (Eds.), Attention and performance V. London: Macmillan, 1974.

Mandler, G. Consciousness: Respectable, useful, and necessary. In R.L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Hillsdale, N.J.: Lawrence Erlbaum, 1975. (a)

Mandler, G. Mind and emotion. New York: John Wiley, 1975. (b)

Martin, E. Stimulus component independence. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 715-721.

Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Miller, G. A. Psychology: The science of mental life. New York: Harper and Row, 1962.

Moray, N. The perception of short phrases presented simultaneously for visual and auditory reception. Quarterly Journal of Experimental Psychology, 1954, 6, 86-92.

Moray, N. Attention in dichotic listening: Affective cues and the influence of instructions. Quarterly Journal of Experimental Psychology, 1959, 11, 56-60.

Moray, N. A functional model for memory. In D.A. Norman (Ed.), Models of memory. New York: Academic Press, 1970. (a)

Moray, N. Introductory experiments in auditory time sharing: Detection of intensity and frequency increments. Journal of the Acoustical Society of America, 1970, 47, 1071-1073. (b)

Moray, N., Crowder, R. G., & Prussin, H. A. Experiments with the stimulus suffix effect. Journal of Experimental Psychology Monograph, 1971, 91, 169-190.

Moray, N., & Jordan, A. Practice and compatibility in two-channel short-term memory. Psychonomic Science, 1966, 4, 427-428.

Nash, John. Developmental psychology: A psychobiological approach. Englewood Cliffs, N.J.: Prentice-Hall, 1970.

Natsoulas, T. Concerning introspective "knowledge". Psychological Bulletin, 1970, 73, 89-111.

Navon, D., & Gopher, D. On the economy of the human-processing system. Psychological Review, 1979, 86, 214-255.

Neisser, U. Cognitive psychology. Englewood Cliffs, N.J.: Prentice-Hall, 1967.

Neisser, U. Cognition and reality. San Francisco: Freeman, 1976.

Ninio, A., & Kahneman, D. Reaction time in focused and divided attention. Journal of Experimental Psychology, 1974, 103, 394-399.

Norman, D. A., & Bobrow, D. G. On data-limited and resource-limited processes. Cognitive Psychology, 1975, 7, 44-64.

Pachella, R. G. The interpretation of reaction time in information-processing research. In B. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. Hillsdale, N.J.: Lawrence Erlbaum , 1974.

Posner, M. I. Abstraction and the process of recognition. In G. Bower & J. T. Spence (Eds.), Psychology of learning and motivation. New York: Academic Press, 1969.

Posner, M. I. Chronometric explorations of the mind. Hillsdale, N.J.: Lawrence Erlbaum , 1978.

Posner, M. I., & Boies, S. J. Components of attention. Psychological Review, 1971, 78, 391-408.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor, R. L. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, 1-16.

Posner, M. I., & Keele, S. W. Decay of visual informaion from a single letter. Science, 1967, 158, 137-139.

Posner, M. I., & Mitchell, R. F. Chronometric analysis of classification. Psychological Review, 1967, 74, 392-409.

Posner, M. I., & Snyder, C. R. R. Attention and cognitive control. In R. L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Hillsdale, N.J.: Lawrence Erlbaum , 1975. (a)

Posner, M. I., & Warren, R. Traces, concepts and conscious constructions. In A. W. Melton and E. Martin (Eds.), Coding theory in learning and memory. New York: Winston, 1972.

Postman, L., & Greenbloom, R. Conditions of cue selection in the acquisition of paired associate lists. Journal of Experimental Psychology, 1967, 73, 91-100.

Poulton, E. C. The basis of perceptual anticipation in tracking. British Journal of Psychology, 1952, 43, 295-302.

Rabinowitz, F. M., & Witte, K. L. Stimulus selection as a function of letter color. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 167-168.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 1969, 81, 275-280.

Rescorla, R. A., & Wagner, A. R. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black and W. F. Prokasy (Eds.), Classical conditioning II: Current theory and research. New York: Meredith, 1972.

Richardson, J. Cue effectiveness and abstraction in paired-associate learning. Psychological Bulletin, 1972, 75, 73-91.

Richardson, J. Component selection in paired associate learning: Research and theory. American Journal of Psychology, 1976, 89, 3-49.

Sanders, A. F. The selective process in the functional visual field. Monograph from Institute for Perception, National Defense Research Organization. Saesterberg, The Netherlands, 1963.

Schaeffer, B., & Wallace, R. Semantic similarity and the comparison of word meanings. Journal of Experimental Psychology, 1969, 82, 343-346.

Schneider, W., & Shiffrin, R. M. Controlled and automatic human information processing: I. Detection, search and attention. Psychological Review, 1977, 84, 1-66.

Shallice, T. Dual functions of consciousness. Psychological

Review, 1972, 79, 383-393.

Shiffrin, R. M., & Schneider, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 1977, 84, 127-190.

Shulman, H. G. Similarity effects in short-term memory. Psychological Bulletin, 1971, 75, 399-415.

Spelke, E., Hirst, W., & Neisser, U. Skills of divided attention. Cognition, 1976, 4, 215-230.

Sperling, G. Successive approximations to a model for short-term memory. Acta Psychologica, 1967, 27, 285-292.

Spinelli, D. N., Pribram, K. H., & Bridgeman, B. Visual receptive field organization of single units in the visual cortex of monkey. International Journal of Neuroscience, 1970, 67-74.

Sternberg, S. High speed scanning in human memory. Science, 1966, 153, 652-654.

Sternberg, S. The discovery of processing stages: Extensions of Donders' method. In W. G. Koster (Ed.), Attention and performance II. Amsterdam: North-Holland, 1969.

Stroop, J. R. Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643-661.

Stroud, J. M. The fine structure of psychological time. In J. Quastler (Ed.), Information theory in psychology. Glencoe, Ill.: Free Press, 1955.

Treisman, A. M. Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.

Treisman, A. M. Monitoring and storage of irrelevant messages in selective attention. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 449-459. (a)

Treisman, A. M. Verbal cues, language and meaning in selective attention. American Journal of Psychology, 1964, 77, 206-219. (b)

Treisman, A. M. Strategies and models of selective attention. Psychological Review, 1969, 76, 282-299.

Treisman, A. M., & Fearnley, J. S. Can simultaneous speech stimuli be classified in parallel? Perception and Psychophysics, 1971, 10, 1-7.

Tulving, E., & Lindsay, P. H. Identification of simultaneously presented simple visual and auditory stimuli. Acta Psychologica, 1967, 27, 101-109.

Turvey, M. T. On peripheral and central processes in vision: Inferences fron an information processing analysis of masking with patterned stimuli. Psychological Review, 1973, 80, 1-52.

Underwood, B. J. Stimulus selection in verbal learning. In C. W. Cofer and B. S. Musgrave (Eds.), Verbal behavior and learning. New York: McGraw-Hill, 1963.

Underwood, B. J. False recognition produced by implicit verbal responses. Journal of Experimental Psychology, 1965, 70, 122-129.

Underwood, B. J., Ham, M., & Ekstrand, B. Cue selection in paired-associate learning. Journal of Experimental Psychology, 1962, 64, 405-409.

Walley, R. E., & Weiden, T. D. Lateral inhibition and cognitive masking: A neuropsychological theory of attention. Psychological Review, 1973, 80, 284-302.

Warren, R. E. Stimulus encoding and memory. Journal of Experimental Psychology, 1972, 94, 90-100.

Waugh, N. C., & Norman, D. A. Primary memory.

Psychological Review, 1965, 72, 89-104.

Wheeler, D. D. Processes in word recognition. Cognitive Psychology, 1970, 1, 59-85.

White, C. T. Temporal numerosity and the psychological unit of duration. Psychological Monographs, 1963, 77, 1-37 (Whole No. 575).

Wundt, W. Grundzuge der physiologischen psychologie (2nd Ed., Vol. 2). Leipzig: Engelmann, 1880.

# Appendix 1

## Instructions to Subjects

Experiment 1: Physical Match

This is an experiment about how people come to attend to certain events in their environment. The knowledge gained from these and other studies is expected to contribute significantly to our understanding of the human attentional mechanism. This experiment is part of Dr. Dobb's research program and is supported by a grant from the National Research Council of Canada. The experiment will take about 40 minutes of your time, and it requires that you be attentive and work hard.

The procedure is quite simple. On the screen in front of you will appear a group of letters for a very short period of time (.1 sec). After they are turned off a single letter will be shown for 1 sec. If this letter matches exactly any of the group of letters first shown, I want you to push the button on the left labeled "same". If it is different, I want you to push the button on the right labeled "different". In order for a match to be correct the letters must be exactly identical. That is, the group of letters will always be printed in capital letters or small letters while the single letters shown later will also be either in small or capital letters. You are to press the "same" button on the left if this letter is capital and was in the first group. If it is only the same name but in small letters, or if it is not in the first group, you are to press the "different" button on the right. In this experiment it is very important that you respond as fast as you possibly can without sacrificing accuracy. In addition, always make a response, even if it is a guess. Errors will not count against you.

The actual arrangement of the groups of letters will vary in this experiment. For practice you will see groups of 4 letters. Before each group you will see a cross. I want you to focus your eyes on the cross as each group comes up. It is very important that you do this, as it will give all letters a fair chance at being seen. After the practice items, test items will appear also with 2, 4, or 6 letters with a cross in the center. You are to respond in the same way to these items as you did on the practice items.

Finally, it is important to reemphasize that the slide containing the group of letters will be on for so short a period of time that with even a small moment of inattention you may miss it. Concentrate very hard on the screen when each item comes up.

Are there any questions?

Experiment 1: Name Match

This is an experiment about how people come to attend to certain events in their environment. The knowledge gained from these and other studies is expected to contribute significantly to our understanding of the human attentional mechanism. This experiment is part of Dr. Dobb's research program and is supported by a grant from the National Research Council of Canada. The experiment will take about 40 minutes of your time, and it requires that you be attentive and work hard.

The procedure is quite simple. On the screen in front of you will appear a group of letters for a very short period of time (.1 sec). After they are turned off a single letter will be shown for 1 sec. If this letter is the same name as any of the group of letters first shown, I want you to push the button on the left labeled "same". If it is different, I want you to push the button on the right labeled "different". In order for a match to be correct the letters must be the same name. That is, the group of letters will always be printed in capital or small letters, while the single letters shown later will be either in small or capital letters. You are to press the "same" button on the left if this letter is capital and was in the first group. If it is the same name but in small letters, also press the "same" button on the right. In this experiment it is very important that you respond as fast as you po-sibly can without sacrificing accuracy. In addition, always make a response, even if it is a guess. Errors will not count against you.

The actual arrangement of the groups of letters will vary in this experiment. For practice you will see groups of 4 letters. Before each group you will see a cross. I want you to focus your eyes on the cross as each group comes up. It is very important that you do this, as it will give all letters a fair chance at being seen. After the practice items, test items will appear also with 2, 4 or 6 letters with a cross in the center. You are to respond in the same way to these items as you did on the practice items.

Finally, it is important to reemphasize that the slide containing the group of letters will be on for so short a period of time that with even a small moment of inattention you may miss it. Concentrate very hard on the screen when each item comes up.

Are there any questions?

Experiment 2: Physical Match

This is an experiment about how people come to attend to certain events in their environment. The knowledge gained from these and other studies is expected to contribute significantly to our understanding of the human attentional mechanism. This experiment is part of Dr. Dobb's research program and is supported by a grant from the National Research Council of Canada. The experiment will take about 40 minutes of your time, and it requires that you be attentive and work hard.

The procedure is quite simple. On the screen in front of you will appear a letter for a short period of time (1 sec). After it is turned off a group of letters will be shown very quickly (.1 sec). If the first letter you saw exactly matches any of those in the group of letters, I want you to push the button on the left labeled "same". If it is different, I want you to push the button on the right labeled "different". In order for a match to be correct the letters must be exactly identical. That is, the first letter will be printed in either capital or small letters, and the group of letters will be printed in capitals or small letters. You are to press the "same " button on the left if the first letter is capital, and if it is in the second group. If it is the same name but in lower case, or if it is not in the second group, you are to press the "different" button on the right. In this experiment it is very important that you respond as fast as you possibly can without sacrificing accuracy. In addition, always make a response, even if it is a guess. Errors will not count against you.

The actual arrangement of the groups of letters will vary in this experiment. For practice you will see groups of 4 letters. Before each group you will see a cross. I want you to focus your eyes on the cross before each group comes up. It is very important that you do this, as it will give all letters a fair chance at being seen. After the practice items, test items will appear also with 2, 4 or 6 letters with a cross in the center. You are to respond in the same way to these items as you did on the practice items.

Finally, it is important to reemphasize that the slide containing the group of letters will be on for so short a period of time that with even a small moment of inattention you may miss it. Concentrate very hard on the screen when each item comes up.

Are there any questions?

Experiment 2: Name Match

This is an experiment about how people come to attend to certain events in their environment. The knowledge gained from these and other studies is expected to contribute significantly to our understanding of the human attentional mechanism. This experiment is part of Dr. Dobb's research program and is supported by a grant from the National Research Council of Canada. The experiment will take about 40 minutes of your time, and it requires that you be attentive and work hard.

The procedure is quite simple. On the screen in front of you will appear a letter for a short period of time (1 sec). After it is turned off a group of letters will be shown very quickly (.1 sec). If the first letter you saw matches in name any of those in the group of letters, I want you to push the button on the left labeled "same". If it is different, I want you to push the button on the right labeled "different". In order for a match to be correct the letters must be the same name. That is, the first letter will be printed in either capital or small letters, and the group of letters will always be printed in capitals or small letters. You are to press the "same" button to the left if the first letter is capital, and if it is in the second group. If it is the same name but in lower case, also press the button. In this experiment, it is very important that you respond as fast as you possibly can without sacrificing accuracy. In addition, always make a response, even if it is a guess. Errors will not count against you.

The actual arrangement of the groups of letters will vary in this experiment. For practice you will see groups of 4 letters. Before each group you will see a cross. I want you to focus your eyes on the cross as each group comes up. It is very important that you do this, as it will give all letters a fair chance at being seen. After the practice items, test items will appear also with 2, 4 or 6 letters with a cross in the center. You are to respond in the same way to these items as you did on the practice items.

Finally, it is important to reemphasize that the slide containing the group of letters will be on for so short a period of time that with even a small moment of inattention you may miss it. Concentrate very hard on the screen when each item comes up.

Are there any questions?

# Appendix 2

## Stimulus Generation Program

```
0: dim D[6],A$[1]
1: cli 7;wrt 718,"em::en::ex::um"
2: ent "Seed",S;1/S→S;rnd(S)→S
3: ent " # Stimuli",N
4: ent "Duration Stim. 1",D[1]
5: ent "Duration Stim. 2",D[2]
6: ent "Duration Mask",D[3]
7: ent "ISI 1",D[4]
8: ent "ISI 2",D[5]
9: ent "set(+1) or target(-1) first?",r2
10: if abs(r2)#1;gto -1
11: ent "Physical(<0) or Name(>0) Match?",r0
12: ent "# Trials",T
13: fmt 1,f4.0,",",f4.0,";"
14: fmt 2,f6.0,"/"
15: fmt 3,f2.0,1x,f2.0,2x,f8.2
16: wrt 9,"A U2=02 U4=I4"
17: oni 9,"int"
18: wrt 9.2,"U2D150/U2C U2G"
19: dim X$[N],M$[N],V[3,T],G[N]
20: for I=1 to N;"#"→M$[I];next I
21: for X=1 to T
22: eir 9,0;cfg ;wrt 718,"em::um";3→B
23: for I=1 to N
24: int(rnd(S)*26)+65→P
25: if I=1;gto +4
26: for J=1 to I
27: if X$[J,J]=char(P);gto -3
28: next J
29: char(P)→X$[I,I];next I
30: if N/2=int(N/2);gto +3
31: if rnd(S)>=1/3;1+int(N/2)→O;gto +4
32: if rnd(S)>=.5;int(N/2)-1→O;gto +2
33: int(N/2)→O
34: if O<=0;gto +8
35: for I=1 to O
36: int(rnd(S)*N)+1→G[I]
37: if I=1;gto +4
38: for J=1 to I-1
39: if G[I]=G[J];gto -3
40: next J
41: char(num(X$[G[I],G[I]])+32)→X$[G[I],G[I]];next I
42: "Pos or Neg":int(rnd(S)*N)+1→R
43: "+=same;-=diff":if rnd(S)>=.5;1→r1;gto +2
44: -1→r1
45: if r0>0;gto "Name"
46: if r1<0;gto +2
47: "P-Match":X$[R,R]→A$;1→r4;gto "show"
48: "N-Match":if rnd(S)>=.5;gto +3
49: if X$[R,R]=cap(X$[R,R]);char(num(X$[R,R])+32)→A$;3→r4;gto "show"
50: char(num(X$[R,R])-32)→A$;3→r4;gto "show"
51: gto +4
52: "Name":if r1<0;gto +3
53: if rnd(S)>=.5;gto "P-Match"
```

```
54: "N-Match":gto -5
55: "N-dif":int(rnd(S)*26)}P
56: for I=1 to N
57: if X$[I,I]=char(P+65);gto -2
58: if X$[I,I]=char(P+97);gto -3
59: next I
60: 5}r4;if rnd(S)<=.5;char(P+65)}A$;gto +2
61: char(P+97)}A$
62: "show":wrt 718,"cs1,::pe0,::pa480,500;"
63: wrt 718,"pe1,::tx+";cli 7
64: cfg 8,10,11;dsp X
65: gto +0;if flg8;gto +1
66: cfg ;wait 500;wrt 718,"em";gto "time"
67: "X":wrt 718.1,"cs2,::pe0,::pa",500-40*int(N/2),500
68: wrt 718,"pe1,::tx",X$;cli 7
69: wrt 9.2,"U2D",C,"U2C U2G";sfg 1;gto "time"
70: "A":wrt 718,"pe0,::pa 500,500;"
71: wrt 718,"pe1,::tx",A$;cli 7
72: wrt 9.2,"U2D",C,"U2C U2G";sfg 2;gto "time"
73: "M":wrt 718.1,"pe0,::pa",500-40*int(N/2),500
74: wrt 718,"pe1,::tx",M$;cli 7
75: wrt 9.2,"U2D",D[3],"U2C U2G";sfg 3
76: "time":eir 9
77: if flg1 and flg2;gto +21
78: if flg3;gto +12
79: if flg1 xor flg2;gto +3
80: D[1]}C;if r2>0;gto "X"
81: gto "A"
82: gto +0;if flg4;gto +2
83: gto -1
84: if D[4]<5;B+1}B;gto +4
85: wrt 9.2,"U2D",D[4],"U2C U2G"
86: gto +0;if flg5;gto +2
87: gto -1
88: if D[3]<5;B+1}B;gto +4
89: gto "M"
90: gto +0;if flg6;gto +2
91: gto -1
92: if D[5]<5;B+1}B;gto +4
93: wrt 9.2,"U2D",D[5],"U2C U2G"
94: gto +0;if flg7;gto +2
95: gto -1
96: D[2]}C;if r2>0;gto "A"
97: gto "X"
98: wrt 9,"U4G U4C"
99: cfg 10,11
100: gto +0;if flg10 or flg11;gto +2
101: gto -1
102: wrt 9,"U4V";red 9,Q
103: if flg11;gto +3
104: if r1>0;gto +4
105: -Q}Q;gto +3
```

```
106: if r1<0;gto +2
107: -Q}Q
108: if r4>4;0}r5;gto +5
109: 1}I
110: if cap(X$[I,I])=cap(A$);I}r5;gto +3
111: 1+I}I;if I>N;0}r5;gto +2
112: gto -2
113: "score":if A$=cap(A$);gto +2
114: r4+1}r4
115: if r0>0;r4+6}r4
116: r5}V[2,X];r4}V[1,X];Q}V[3,X]
117: prt X$,A$,Q
118: next X
119: gto "Data"
120: "int":wrt 718,"em";eir 9;1+B}B;sfg B
121: wrt 9,"W";rdb(9)}W;if not W;iret
122: gto -2
123: "Data":dim Z[7,4];spc 3
124: for I=1 to T
125: wrt 16.3,V[1,I],V[2,I],V[3,I]
126: if r0>0;V[1,I]-6}r4;gto +2
127: V[1,I]}r4
128: Z[r4,1]+1}Z[r4,1]
129: if V[3,I]<0;Z[r4,2]+1}Z[r4,2];gto +3
130: V[3,I]+Z[r4,3]}Z[r4,3]
131: V[3,I]^2+Z[r4,4]}Z[r4,4]
132: next I
133: spc 3;if r0<0;prt "P-Match Block";gto +2
134: prt "N-Match Block"
135: if r2>0;prt "  Set First";gto +2
136: prt "  Target First"
137: prt "  size of set=",N
138: prt "  Timing was:"
139: prt "  Stim.1=",D[1]
140: prt "  Stim. 2=",D[2]
141: prt "  Mask=",D[3]
142: prt "  ISI(1)=",D[4]
143: prt "  ISI(2)=",D[5]
144: spc 2;prt "P-match trials";1}r4;gsb "mean"
145: spc ;prt "N-match trials";3}r4;gsb "mean"
146: spc ;prt "Diff. trials";5}r4;gsb "mean"
147: spc 3;prt "Cumulative Data";gsb "Tot"
148: spc 3
149: ent "Same block again?(1=yes)",Y
150: if Y=1;gto 21
151: end
152: "mean":if r4<7;prt " Capitol Target"
153: fxd 0;prt "# trials=",Z[r4,1]
154: prt "# Errors=",Z[r4,2]
155: prt "sum X=",Z[r4,3]
156: prt "sum X2=",Z[r4,4]
157: if Z[r4,1]-Z[r4,2]=0;prt "no correct";gto +5
```

```
158: fxd 2;prt "mean RT=",Z[r4,3]/(Z[r4,1]-Z[r4,2])
159: if Z[r4,1]-Z[r4,2]<2;prt "S.D.=0";gto +3
160: Z[r4,4]-(Z[r4,1]-Z[r4,2])*(Z[r4,3]/(Z[r4,1]-Z[r4,2]))^2}r12
161: prt "S.D.=",\(r12/(Z[r4,1]-Z[r4,2]-1))
162: if flg0;cfg 0;ret
163: r4+1}r4;if r4<7;sfg 0;prt " Small Targets";gto -10
164: ret
165: "Tot":7}r4
166: for I=1 to 6
167: for J=1 to 4
168: Z[7,J]+Z[I,J]}Z[7,J];next J
169: next I
170: gsb "mean"
171: ret
*7145
```

## Appendix 3

## Distribution Characteristics for Item Types

## Distribution Characteristics for Item Types

### Experiment 1: Reaction Time (msec)

| VAR NO | MEAN | S.D. | S.E. OF MEAN | SAMPLE | MAXIMUM | MINIMUM | RANGE |
|---|---|---|---|---|---|---|---|
| 1 | 0.7897 | 0.1878 | 0.0542 | 12 | 1.1240 | 0.4740 | 0.6500 |
| 2 | 0.8413 | 0.1631 | 0.0471 | 12 | 1.1590 | 0.6260 | 0.5330 |
| 3 | 0.9455 | 0.2000 | 0.0577 | 12 | 1.2430 | 0.6910 | 0.5520 |
| 4 | 0.8901 | 0.1880 | 0.0543 | 12 | 1.2300 | 0.5910 | 0.6390 |
| 5 | 0.7378 | 0.1316 | 0.0380 | 12 | 1.0600 | 0.5720 | 0.4880 |
| 6 | 0.7602 | 0.1203 | 0.0347 | 12 | 1.0000 | 0.6110 | 0.3890 |
| 7 | 0.8264 | 0.2540 | 0.0733 | 12 | 1.4800 | 0.5490 | 0.9310 |
| 8 | 0.9521 | 0.2034 | 0.0587 | 12 | 1.2990 | 0.6720 | 0.6270 |
| 9 | 0.9732 | 0.2465 | 0.0712 | 12 | 1.4810 | 0.7150 | 0.7660 |
| 10 | 1.0119 | 0.2543 | 0.0734 | 12 | 1.5620 | 0.7040 | 0.8580 |
| 11 | 0.8638 | 0.1585 | 0.0458 | 12 | 1.1090 | 0.6850 | 0.4240 |
| 12 | 0.9578 | 0.1997 | 0.0577 | 12 | 1.1790 | 0.6880 | 0.4910 |
| 13 | 0.9317 | 0.2160 | 0.0623 | 12 | 1.4150 | 0.5990 | 0.8160 |
| 14 | 1.0139 | 0.1983 | 0.0572 | 12 | 1.3980 | 0.6660 | 0.7320 |
| 15 | 1.1441 | 0.3049 | 0.0880 | 12 | 1.6270 | 0.7870 | 0.8400 |
| 16 | 1.1634 | 0.3166 | 0.0914 | 12 | 1.7690 | 0.8120 | 0.9570 |
| 17 | 1.0437 | 0.2995 | 0.0865 | 12 | 1.5540 | 0.6530 | 0.9010 |
| 18 | 1.2181 | 0.2860 | 0.0826 | 12 | 1.6500 | 0.8460 | 0.8040 |
| 19 | 0.6577 | 0.1751 | 0.0505 | 12 | 1.0750 | 0.4750 | 0.6000 |
| 20 | 0.6737 | 0.1756 | 0.0507 | 12 | 1.0710 | 0.5310 | 0.5400 |
| 21 | 0.7249 | 0.1380 | 0.0398 | 12 | 1.0080 | 0.5740 | 0.4340 |
| 22 | 0.7312 | 0.1823 | 0.0526 | 12 | 1.1060 | 0.5630 | 0.5430 |
| 23 | 0.7757 | 0.1967 | 0.0568 | 12 | 1.1680 | 0.5980 | 0.5700 |
| 24 | 0.8085 | 0.2573 | 0.0743 | 12 | 1.2810 | 0.5930 | 0.6880 |
| 25 | 0.8212 | 0.3047 | 0.0880 | 12 | 1.6140 | 0.5300 | 1.0840 |
| 26 | 0.8500 | 0.2500 | 0.0722 | 12 | 1.3430 | 0.5800 | 0.7630 |
| 27 | 0.9667 | 0.2993 | 0.0864 | 12 | 1.4540 | 0.6220 | 0.8320 |
| 28 | 0.8625 | 0.2185 | 0.0631 | 12 | 1.2620 | 0.5670 | 0.6950 |
| 29 | 0.9136 | 0.2799 | 0.0808 | 12 | 1.5080 | 0.6340 | 0.8740 |
| 30 | 0.9119 | 0.2696 | 0.0778 | 12 | 1.4860 | 0.6920 | 0.7940 |
| 31 | 0.8736 | 0.2309 | 0.0667 | 12 | 1.4340 | 0.6010 | 0.8330 |
| 32 | 0.9347 | 0.2720 | 0.0785 | 12 | 1.5620 | 0.6220 | 0.9400 |
| 33 | 1.0322 | 0.2744 | 0.0792 | 12 | 1.4920 | 0.7290 | 0.7630 |
| 34 | 0.9437 | 0.2751 | 0.0794 | 12 | 1.6900 | 0.6040 | 1.0860 |
| 35 | 1.0068 | 0.2715 | 0.0784 | 12 | 1.5630 | 0.6770 | 0.8860 |
| 36 | 1.0838 | 0.3515 | 0.1015 | 12 | 1.8570 | 0.7040 | 1.1530 |

## Distribution Characteristics for Item Types

### Experiment 1: Proportion Error

| VAR NO | MEAN | S.D. | S.E. OF MEAN | SAMPLE | MAXIMUM | MINIMUM | RANGE |
|---|---|---|---|---|---|---|---|
| 1 | 0.0451 | 0.0485 | 0.0140 | 12 | 0.1350 | 0.0 | 0.1350 |
| 2 | 0.0798 | 0.0599 | 0.0173 | 12 | 0.1900 | 0.0 | 0.1900 |
| 3 | 0.0572 | 0.0815 | 0.0235 | 12 | 0.2730 | 0.0 | 0.2730 |
| 4 | 0.0442 | 0.0717 | 0.0207 | 12 | 0.2000 | 0.0 | 0.2000 |
| 5 | 0.0151 | 0.0382 | 0.0110 | 12 | 0.1250 | 0.0 | 0.1250 |
| 6 | 0.0211 | 0.0394 | 0.0114 | 12 | 0.1110 | 0.0 | 0.1110 |
| 7 | 0.1250 | 0.0559 | 0.0161 | 12 | 0.2220 | 0.0450 | 0.1770 |
| 8 | 0.3221 | 0.2053 | 0.0593 | 12 | 0.8440 | 0.0430 | 0.8010 |
| 9 | 0.1279 | 0.1379 | 0.0398 | 12 | 0.4290 | 0.0 | 0.4290 |
| 10 | 0.1762 | 0.1554 | 0.0449 | 12 | 0.4670 | 0.0 | 0.4670 |
| 11 | 0.0733 | 0.0829 | 0.0239 | 12 | 0.2730 | 0.0 | 0.2730 |
| 12 | 0.0694 | 0.1089 | 0.0314 | 12 | 0.3330 | 0.0 | 0.3330 |
| 13 | 0.3163 | 0.1299 | 0.0375 | 12 | 0.5000 | 0.0770 | 0.4230 |
| 14 | 0.4459 | 0.1902 | 0.0549 | 12 | 0.8000 | 0.2000 | 0.6000 |
| 15 | 0.1691 | 0.1385 | 0.0400 | 12 | 0.4440 | 0.0 | 0.4440 |
| 16 | 0.2984 | 0.1518 | 0.0438 | 12 | 0.5000 | 0.0 | 0.5000 |
| 17 | 0.1680 | 0.1826 | 0.0527 | 12 | 0.6360 | 0.0 | 0.6360 |
| 18 | 0.2624 | 0.1718 | 0.0496 | 12 | 0.5240 | 0.0 | 0.5240 |
| 19 | 0.0387 | 0.0511 | 0.0147 | 12 | 0.1250 | 0.0 | 0.1250 |
| 20 | 0.0092 | 0.0320 | 0.0092 | 12 | 0.1110 | 0.0 | 0.1110 |
| 21 | 0.0938 | 0.1161 | 0.0335 | 12 | 0.3330 | 0.0 | 0.3330 |
| 22 | 0.0774 | 0.0936 | 0.0270 | 12 | 0.3080 | 0.0 | 0.3080 |
| 23 | 0.0246 | 0.0396 | 0.0114 | 12 | 0.1300 | 0.0 | 0.1300 |
| 24 | 0.0313 | 0.0430 | 0.0124 | 12 | 0.1110 | 0.0 | 0.1110 |
| 25 | 0.0996 | 0.1049 | 0.0303 | 12 | 0.3080 | 0.0 | 0.3080 |
| 26 | 0.1216 | 0.1417 | 0.0409 | 12 | 0.3850 | 0.0 | 0.3850 |
| 27 | 0.2507 | 0.1932 | 0.0558 | 12 | 0.6000 | 0.0 | 0.6000 |
| 28 | 0.1944 | 0.1178 | 0.0340 | 12 | 0.4380 | 0.0630 | 0.3750 |
| 29 | 0.0922 | 0.0857 | 0.0248 | 12 | 0.2690 | 0.0 | 0.2690 |
| 30 | 0.1232 | 0.0912 | 0.0263 | 12 | 0.2900 | 0.0 | 0.2900 |
| 31 | 0.2035 | 0.1206 | 0.0348 | 12 | 0.5000 | 0.0 | 0.5000 |
| 32 | 0.3873 | 0.1468 | 0.0424 | 12 | 0.5380 | 0.1110 | 0.4270 |
| 33 | 0.4951 | 0.1616 | 0.0466 | 12 | 0.7270 | 0.1820 | 0.5450 |
| -34 | 0.2752 | 0.1284 | 0.0371 | 12 | 0.5000 | 0.0910 | 0.4090 |
| 35 | 0.2888 | 0.1325 | 0.0383 | 12 | 0.4780 | 0.0480 | 0.4300 |
| 36 | 0.2737 | 0.1503 | 0.0434 | 12 | 0.5220 | 0.0770 | 0.4450 |

In the following Tables the variable numbers corresponding to specific Item Types are as follows:[a]

| VARIABLE NUMBER | ITEM TYPE | CASE | INSTRUCTION | SEARCH SET SIZE |
|---|---|---|---|---|
| 1 | P | C | P | 2 |
| 2 | P | S | P | 2 |
| 3 | N | C | P | 2 |
| 4 | N | S | P | 2 |
| 5 | D | C | P | 2 |
| 6 | D | S | P | 2 |
| 7 | P | C | P | 4 |
| 8 | P | S | P | 4 |
| 9 | N | C | P | 4 |
| 10 | N | S | P | 4 |
| 11 | D | C | P | 4 |
| 12 | D | S | P | 4 |
| 13 | P | C | P | 6 |
| 14 | P | S | P | 6 |
| 15 | N | C | P | 6 |
| 16 | N | S | P | 6 |
| 17 | D | C | P | 6 |
| 18 | D | S | P | 6 |
| 19 | P | C | N | 2 |
| 20 | P | S | N | 2 |
| 21 | N | C | N | 2 |
| 22 | N | S | N | 2 |
| 23 | D | C | N | 2 |
| 24 | D | S | N | 2 |
| 25 | P | C | N | 4 |
| 26 | P | S | N | 4 |
| 27 | N | C | N | 4 |
| 28 | N | S | N | 4 |
| 29 | D | C | N | 4 |
| 30 | D | S | N | 4 |
| 31 | P | C | N | 6 |
| 32 | P | S | N | 6 |
| 33 | N | C | N | 6 |
| 34 | N | S | N | 6 |
| 35 | D | C | N | 6 |
| 36 | D | S | N | 6 |

[a]P = Physical
N = Name
D = Different
C = Capital
S = Small

Distribution Characteristics for Item Types

Experiment 2: Reaction Time (msec)

| VAR NO | MEAN | S.D. | S.E. OF MEAN | SAMPLE | MAXIMUM | MINIMUM | RANGE |
|---|---|---|---|---|---|---|---|
| 1 | 0.7675 | 0.1897 | 0.0547 | 12 | 1.0610 | 0.4940 | 0.5670 |
| 2 | 0.8077 | 0.1992 | 0.0575 | 12 | 1.2250 | 0.5820 | 0.6430 |
| 3 | 0.8853 | 0.2099 | 0.0606 | 12 | 1.1980 | 0.5330 | 0.6650 |
| 4 | 0.9564 | 0.2597 | 0.0750 | 12 | 1.4070 | 0.5950 | 0.8120 |
| 5 | 0.7763 | 0.1851 | 0.0534 | 12 | 1.0800 | 0.5170 | 0.5630 |
| 6 | 0.7651 | 0.1580 | 0.0456 | 12 | 0.9960 | 0.5030 | 0.4930 |
| 7 | 0.8226 | 0.2354 | 0.0680 | 12 | 1.2200 | 0.5270 | 0.6930 |
| 8 | 0.8487 | 0.1955 | 0.0564 | 12 | 1.1660 | 0.6000 | 0.5660 |
| 9 | 0.9571 | 0.2049 | 0.0591 | 12 | 1.3500 | 0.6400 | 0.7100 |
| 10 | 1.0167 | 0.2517 | 0.0727 | 12 | 1.4750 | 0.6000 | 0.8750 |
| 11 | 0.8278 | 0.1891 | 0.0546 | 12 | 1.2600 | 0.5840 | 0.6760 |
| 12 | 0.8363 | 0.1782 | 0.0514 | 12 | 1.2010 | 0.5810 | 0.6200 |
| 13 | 0.8257 | 0.1863 | 0.0538 | 12 | 1.2000 | 0.5850 | 0.6150 |
| 14 | 0.9105 | 0.1605 | 0.0463 | 12 | 1.1510 | 0.6880 | 0.4630 |
| 15 | 1.0382 | 0.2689 | 0.0776 | 12 | 1.5830 | 0.6190 | 0.9640 |
| 16 | 1.0693 | 0.1953 | 0.0564 | 12 | 1.3470 | 0.7310 | 0.6160 |
| 17 | 0.9090 | 0.2001 | 0.0578 | 12 | 1.2060 | 0.6330 | 0.5730 |
| 18 | 0.9633 | 0.2068 | 0.0597 | 12 | 1.4450 | 0.6850 | 0.7600 |
| 19 | 0.6532 | 0.1550 | 0.0447 | 12 | 0.9500 | 0.5010 | 0.4490 |
| 20 | 0.6787 | 0.1868 | 0.0539 | 12 | 1.0290 | 0.3220 | 0.7070 |
| 21 | 0.7322 | 0.2075 | 0.0599 | 12 | 1.2700 | 0.4940 | 0.7760 |
| 22 | 0.6727 | 0.1767 | 0.0510 | 12 | 1.0360 | 0.4280 | 0.6080 |
| 23 | 0.7371 | 0.1649 | 0.0476 | 12 | 1.0190 | 0.5220 | 0.4970 |
| 24 | 0.7382 | 0.1782 | 0.0515 | 12 | 1.0710 | 0.5320 | 0.5390 |
| 25 | 0.6838 | 0.1064 | 0.0307 | 12 | 0.8410 | 0.5250 | 0.3160 |
| 26 | 0.8035 | 0.1942 | 0.0561 | 12 | 1.1520 | 0.5260 | 0.6260 |
| 27 | 0.8665 | 0.1751 | 0.0505 | 12 | 1.1180 | 0.5770 | 0.5410 |
| 28 | 0.7692 | 0.1919 | 0.0554 | 12 | 1.1490 | 0.5390 | 0.6100 |
| 29 | 0.8193 | 0.1743 | 0.0503 | 12 | 1.1550 | 0.5440 | 0.6110 |
| 30 | 0.8618 | 0.2020 | 0.0583 | 12 | 1.3030 | 0.5760 | 0.7270 |
| 31 | 0.8007 | 0.1847 | 0.0533 | 12 | 1.2160 | 0.5670 | 0.6490 |
| 32 | 0.9107 | 0.1987 | 0.0574 | 12 | 1.2210 | 0.5780 | 0.6430 |
| 33 | 0.9471 | 0.1950 | 0.0563 | 12 | 1.3030 | 0.6270 | 0.6760 |
| 34 | 0.8259 | 0.1690 | 0.0488 | 12 | 1.1980 | 0.5340 | 0.6640 |
| 35 | 0.9103 | 0.2261 | 0.0653 | 12 | 1.5560 | 0.6410 | 0.9150 |
| 36 | 0.9160 | 0.2275 | 0.0657 | 12 | 1.4580 | 0.6130 | 0.8450 |

## Distribution Characteristics for Item Types

### Experiment 2: Proportion Error

| VAR NO | MEAN | S.D. | S.E. OF MEAN | SAMPLE | MAXIMUM | MINIMUM | RANGE |
|---|---|---|---|---|---|---|---|
| 1 | 0.0628 | 0.0964 | 0.0278 | 12 | 0.3500 | 0.0 | 0.3500 |
| 2 | 0.0464 | 0.0737 | 0.0213 | 12 | 0.2350 | 0.0 | 0.2350 |
| 3 | 0.1338 | 0.1442 | 0.0416 | 12 | 0.4290 | 0.0 | 0.4290 |
| 4 | 0.1305 | 0.1431 | 0.0413 | 12 | 0.4120 | 0.0 | 0.4120 |
| 5 | 0.0234 | 0.0350 | 0.0101 | 12 | 0.0830 | 0.0 | 0.0830 |
| 6 | 0.0220 | 0.0326 | 0.0094 | 12 | 0.0710 | 0.0 | 0.0710 |
| 7 | 0.0291 | 0.0446 | 0.0129 | 12 | 0.1430 | 0.0 | 0.1430 |
| 8 | 0.0634 | 0.0898 | 0.0259 | 12 | 0.2380 | 0.0 | 0.2380 |
| 9 | 0.1489 | 0.1542 | 0.0445 | 12 | 0.4170 | 0.0 | 0.4170 |
| 10 | 0.1015 | 0.1174 | 0.0339 | 12 | 0.3640 | 0.0 | 0.3640 |
| 11 | 0.0069 | 0.0240 | 0.0069 | 12 | 0.0830 | 0.0 | 0.0830 |
| 12 | 0.0 | 0.0 | 0.0 | 12 | 0.0 | 0.0 | 0.0 |
| 13 | 0.0695 | 0.1018 | 0.0294 | 12 | 0.3600 | 0.0 | 0.3600 |
| 14 | 0.0932 | 0.0868 | 0.0250 | 12 | 0.2630 | 0.0 | 0.2630 |
| 15 | 0.1088 | 0.1176 | 0.0339 | 12 | 0.3890 | 0.0 | 0.3890 |
| 16 | 0.0773 | 0.0976 | 0.0282 | 12 | 0.2730 | 0.0 | 0.2730 |
| 17 | 0.0316 | 0.0607 | 0.0175 | 12 | 0.1540 | 0.0 | 0.1540 |
| 18 | 0.0347 | 0.0374 | 0.0108 | 12 | 0.0830 | 0.0 | 0.0830 |
| 19 | 0.0221 | 0.0557 | 0.0161 | 12 | 0.1820 | 0.0 | 0.1820 |
| 20 | 0.0232 | 0.0440 | 0.0127 | 12 | 0.1110 | 0.0 | 0.1110 |
| 21 | 0.0353 | 0.0490 | 0.0142 | 12 | 0.1430 | 0.0 | 0.1430 |
| 22 | 0.0510 | 0.0549 | 0.0158 | 12 | 0.1820 | 0.0 | 0.1820 |
| 23 | 0.0189 | 0.0244 | 0.0070 | 12 | 0.0590 | 0.0 | 0.0590 |
| 24 | 0.0248 | 0.0267 | 0.0077 | 12 | 0.0650 | 0.0 | 0.0650 |
| 25 | 0.0044 | 0.0153 | 0.0044 | 12 | 0.0530 | 0.0 | 0.0530 |
| 26 | 0.0562 | 0.0830 | 0.0239 | 12 | 0.2500 | 0.0 | 0.2500 |
| 27 | 0.1048 | 0.1091 | 0.0315 | 12 | 0.3000 | 0.0 | 0.3000 |
| 28 | 0.1046 | 0.1415 | 0.0408 | 12 | 0.4440 | 0.0 | 0.4440 |
| 29 | 0.0262 | 0.0483 | 0.0139 | 12 | 0.1580 | 0.0 | 0.1580 |
| 30 | 0.0175 | 0.0262 | 0.0076 | 12 | 0.0590 | 0.0 | 0.0590 |
| 31 | 0.0839 | 0.1117 | 0.0322 | 12 | 0.3000 | 0.0 | 0.3000 |
| 32 | 0.1287 | 0.1175 | 0.0339 | 12 | 0.3000 | 0.0 | 0.3000 |
| 33 | 0.1839 | 0.1533 | 0.0442 | 12 | 0.4550 | 0.0 | 0.4550 |
| 34 | 0.1839 | 0.1596 | 0.0461 | 12 | 0.5000 | 0.0 | 0.5000 |
| 35 | 0.0334 | 0.0497 | 0.0144 | 12 | 0.1600 | 0.0 | 0.1600 |
| 36 | 0.0532 | 0.0641 | 0.0185 | 12 | 0.1670 | 0.0 | 0.1670 |

# Appendix 4

## Analysis of Variance Summary Tables

Analysis of Variance Summary Table

Experiment 1: Reaction Time

| Source | SS | df | MSe | F |
|---|---|---|---|---|
| Mean | 355.038 | 1 | 355.038 | 246.36 |
| Subjects (S) | 15.852 | 11 | 1.441 | |
| Type of Instruction (I) | .742 | 1 | .742 | 4.85* |
| Search Set Size (N) | 4.663 | 2 | 2.331 | 53.54** |
| Type of Item (T) | .810 | 2 | .405 | 14.35** |
| Case of Target (C) | .112 | 1 | .112 | 23.44** |
| S x I | 1.682 | 11 | .153 | |
| S x N | .958 | 22 | .044 | |
| I x N | .086 | 2 | .043 | 1.45 |
| S x T | .621 | 22 | .028 | |
| I x T | .312 | 2 | .156 | 11.52** |
| N x T | .200 | 4 | .050 | 6.57** |
| S x C | .053 | 11 | .005 | |
| I x C | .092 | 1 | .092 | 5.72* |
| N x C | .032 | 2 | .016 | 3.07 |
| T x C | .214 | 2 | .107 | 6.01** |
| S x I x N | .651 | 22 | .030 | |
| S x I x T | .298 | 22 | .014 | |
| S x N x T | .335 | 44 | .008 | |
| I x N x T | .165 | 4 | .041 | 5.52** |
| S x I x C | .177 | 11 | .016 | |
| S x N x C | .114 | 22 | .005 | |
| I x N x C | .073 | 2 | .037 | 2.63 |
| S x T x C | .391 | 22 | .018 | |
| I x T x C | .001 | 2 | .000 | 0.02 |
| N x T x C | .047 | 4 | .012 | 2.46 |
| S x I x N x T | .328 | 44 | .007 | |
| S x I x N x C | .305 | 22 | .014 | |
| S x I x T x C | .330 | 22 | .015 | |
| S x N x T x C | .212 | 44 | .005 | |
| I x N x T x C | .031 | 4 | .008 | 1.20 |
| S x I x N x T x C | .288 | 44 | .007 | |

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

Analysis of Variance Summary Table

Experiment 1: Proportion Error

| Source | SS | df | MSe | F |
|---|---|---|---|---|
| Mean | 11.396 | 1 | 11.396 | 207.56 |
| Subjects (S) | .604 | 11 | .055 | |
| Type of Instruction (I) | .015 | 1 | .015 | .82 |
| Search Set Size (N) | 4.534 | 2 | 2.267 | 208.19** |
| Type of Item (T) | .390 | 2 | .195 | 3.99* |
| Case of Target (C) | .077 | 1 | .077 | 6.54* |
| S x I | .205 | 11 | .019 | |
| S x N | .240 | 22 | .011 | |
| I x N | .031 | 2 | .015 | 2.38 |
| S x T | 1.077 | 22 | .049 | |
| I x T | .574 | 2 | .287 | 12.34** |
| N x T | .075 | 4 | .019 | .93 |
| S x C | .129 | 11 | .012 | |
| I x C | .196 | 1 | .196 | 20.45** |
| N x C | .044 | 2 | .022 | 3.54* |
| T x C | .192 | 2 | .096 | 10.06** |
| S x I x N | .142 | 22 | .006 | |
| S x I x T | .511 | 22 | .023 | |
| S x N x T | .882 | 44 | .020 | |
| I x N x T | .117 | 4 | .029 | 2.91* |
| S x I x C | .105 | 11 | .010 | |
| S x N x C | .137 | 22 | .006 | |
| I x N x C | .075 | 2 | .038 | 5.13* |
| S x T x C | .210 | 22 | .010 | |
| I x T x C | .074 | 2 | .037 | 3.21 |
| N x T x C | .089 | 4 | .022 | 2.59* |
| S x I x N x T | .442 | 44 | .010 | |
| S x I x N x C | .161 | 22 | .007 | |
| S x I x T x C | .254 | 22 | .012 | |
| S x N x T x C | .376 | 44 | .009 | |
| I x N x T x C | .198 | 4 | .049 | 5.74** |
| S x I x N x T x C | .379 | 44 | .009 | |

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

Analysis of Variance Summary Table

Experiment 2: Reaction Time

| Source | SS | df | MSe | F |
|---|---|---|---|---|
| Mean | 306.215 | 1 | 306.215 | 418.38 |
| Subjects (S) | 8.051 | 11 | .732 | |
| Type of Instruction (I) | .915 | 1 | .915 | 4.66 |
| Search Set Size (N) | 1.724 | 2 | .862 | 12.48** |
| Type of Item (T) | .751 | 2 | .376 | 18.06** |
| Case of Target (C) | .051 | 1 | .051 | 4.64 |
| S x I | 2.159 | 11 | .196 | |
| S x N | 1.519 | 22 | .069 | |
| I x N | .061 | 2 | .031 | 2.68 |
| S x T | .458 | 22 | .021 | |
| I x T | .530 | 2 | .265 | 10.58** |
| N x T | .021 | 4 | .005 | .60 |
| S x C | .121 | 11 | .011 | |
| I x C | .038 | 1 | .038 | 3.07 |
| N x C | .006 | 2 | .003 | .34 |
| T x C | .138 | 2 | .069 | 5.20* |
| S x I x N | .252 | 22 | .011 | |
| S x I x T | .550 | 22 | .025 | |
| S x N x T | .380 | 44 | .009 | |
| I x N x T | .047 | 4 | .012 | 1.44 |
| S x I x C | .136 | 11 | .012 | |
| S x N x C | .192 | 22 | .009 | |
| I x N x C | .011 | 2 | .006 | 0.62 |
| S x T x C | .291 | 22 | .013 | |
| I x T x C | .166 | 2 | .083 | 18.80** |
| N x T x C | .044 | 4 | .011 | 1.64 |
| S x I x N x T | .357 | 44 | .008 | |
| S x I x N x C | .200 | 22 | .009 | |
| S x I x T x C | .097 | 22 | .004 | |
| S x N x T x C | .292 | 44 | .007 | |
| I x N x T x C | .019 | 4 | .005 | .91 |
| S x I x N x T x C | .229 | 44 | .005 | |

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

Analysis of Variance Summary Table

Experiment 2: Proportion Error

| Source | SS | df | MSe | F |
|---|---|---|---|---|
| Mean | 1.825 | 1 | 1.825 | 109.01 |
| Subjects (S) | .184 | 11 | .017 | |
| Type of Instruction (I) | .000 | 1 | .000 | .01 |
| Search Set Size (N) | .139 | 2 | .070 | 10.28** |
| Type of Item (T) | .588 | 2 | .294 | 18.24** |
| Case of Target (C) | .002 | 1 | .002 | .33 |
| S x I | .303 | 11 | .028 | |
| S x N | .149 | 22 | .007 | |
| I x N | .124 | 2 | .062 | 13.70** |
| S x T | .355 | 22 | .016 | |
| I x T | .006 | 2 | .003 | .19 |
| N x T | .037 | 4 | .009 | 1.62 |
| S x C | .078 | 11 | .007 | |
| I x C | .010 | 1 | .010 | .93 |
| N x C | .002 | 2 | .001 | .21 |
| T x C | .022 | 2 | .011 | 1.60 |
| S x I x N | .099 | 22 | .005 | |
| S x I x T | .368 | 22 | .017 | |
| S x N x T | .250 | 44 | .006 | |
| I x N x T | .097 | 4 | .024 | 3.85** |
| S x I x C | .122 | 11 | .011 | |
| S x N x C | .091 | 22 | .004 | |
| I x N x C | .000 | 2 | .000 | .06 |
| S x T x C | .149 | 22 | .007 | |
| I x T x C | .003 | 2 | .001 | .18 |
| N x T x C | .024 | 4 | .006 | .95 |
| S x I x N x T | .276 | 44 | .006 | |
| S x I x N x C | .068 | 22 | .003 | |
| S x I x T x C | .175 | 22 | .008 | |
| S x N x T x C | .276 | 44 | .006 | |
| I x N x T x C | .001 | 4 | .000 | .07 |
| S x I x N x T x C | .229 | 44 | .005 | |

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