1981

Processing of Unattended Information: An Evaluation of Current Explanations

Susan Gelmini Tammaro
Loyola University Chicago

PROCESSING OF UNATTENDED INFORMATION: AN EVALUATION OF CURRENT EXPLANATIONS

by

Susan Gelmini Tammaro

A Dissertation Submitted to the Faculty of the Graduate School of Loyola University of Chicago in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

July

1981

ACKNOWLEDGEMENTS

The author would like to thank Dr. Mark S. Mayzner, the director of her dissertation committee, for his helpful suggestions and advice throughout the development of her dissertation. She would also like to thank committee members Dr. D. L. Holmes and Rev. D. O'Connell.

VITA

The author, Susan Gelmini Tammaro is the daughter of Charles and Helen (Lafferty) Gelmini. She was born on June 28, 1956 in Connecticut.

Her elementary eductation was obtained in the public school of Beacon Falls, Connecticut. She graduated from John Hersey High School in Arlington Heights, Illinois in June of 1973.

In September, 1973, she entered Regis College in Weston, Massachusetts, and in May of 1977 received the degree of Bachelor of Arts with a major in psychology. She was elected a member of Psi Chi in 1976. During that same year she was named an Undergraduate Fellow and Honorary Student Member of the New England Psychological Association.

In September, 1978, she entered graduate school at Loyola University of Chicago, where she was granted a research assistantship.

In 1979 she published a paper in the Bulletin of the Psychonomic Society entitled, "Angular estimation: An exploratory study." She was second author of an abstract entitled, "The effects of interletter confusability on word and non-word recognition processes." This abstract appeared in that same bulletin the same year.

In January, 1981 she was awarded the Master of Arts in Psychology. She was elected an associate member of Sigma Xi in April of 1981.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure | Page

CONTENTS OF APPENDICES

INTRODUCTION

In any given situation there is a large amount of information available to an observer, not all of which is attended to. Selective attention refers to the ability to selectively attend to some information and to "filter out" or not attend to other information. That information which is filtered out, or not attended to, is usually considered irrelevant by an observer, and consequently, is not processed. This paper will discus that information which is not consciously attended to. Of major import will be the small portion of unattended information which <u>is</u> processed by an observer without effort or intent.

The phenomenon of selective focusing on incoming information with attention allotted only to information deemed relevant (and occasional processing of the unattended information) is particularly evident in the case of auditory events. Consider the amount of incoming information one guest receives at a cocktail party, where many simultaneous conversations are occurring. Although that guest can hear quite a few different conversations, as they are all taking place in the same room, he is probably attending to only one - the conversation he is engaged in. Our guest is probably comprehending his conversation alone and is unaware of the content or messages that any of the surrounding conversations contain. Let his name be mentioned in one of the surrounding conversations however, and he will suddenly become very aware of that seemingly unprocessed message!

Selective focusing also occurs in the case of visual events. When driving along a well traveled path one seems to do so almost automatically, and is virtually unaware of the pedestrians on the sidewalks or the cars driving in the opposite direction. If one of those pedestrians or drivers in the passing cars is someone close to the first driver, however, he will almost certainly notice that person - picking him out from an almost indistinguishable mass of seemingly unprocessed information.

The processing of information from an unattended source (e.g. background conversations or passing cars) is a relatively infrequent event. The bulk of unattended information is not processed by an observer, who is completely unaware of its content. Only occasionally does some unattended information become meaningful to an observer. Two explanations are usually offered to account for this phenomenon.

Units of information with low recognition thresholds (such as one's own name) are recognized very easily, even without conscious effort or intent. These units can thus be recognized even when present at an unattended source.

Another current explanation of processing of unattended information is seen in the idea of automaticity of processing, which suggests that some information is recognized "automatically". According to this view, when an observer has enough practice with a stimulus word (enough practice recognizing something), he is able to recognize it without attention (i.e. conscious effort or intent), even when it is present at an unattended source. It should be noted that while these two explanations account for the same phenomena - the processing of unattended information, and that they overlap in that often low recognition threshold information is the same information that is said to be processed automatically, they are quite different as they postulate very different mental processes.

While both low recognition threshold theory and automatic processing theory are adequate explanations of the recognition of very familiar or very meaningful stimuli, it is felt that if information is processed that is neither highly practiced nor highly meaningful, these theories might be deemed inadequate explanations. A series of studies will be conducted that will investigate the processing of unattended visual information and the adequacy of current explanations of such processing. A brief summary of the studies to be conducted and the logic behind them is presented below.

It has been established that although subjects are generally unaware of unattended visual information, they will notice their own name if it is printed in the area of the unattended information. This series of studies will attempt to determine if any other information is processed when presented at an unattended source. At the level of attended information it has been found that subjects are able to remember information much more successfully if it can be clustered into one semantic category than if it is a bulk of seemingly unrelated information. This study will investigate that same effect at the level of unattended information (the amount of unattended information identified on a subsequent recognition test when all of the unattended information can be grouped into one semantic category will be compared to the subsequent recognition of unattended information when the information cannot be semantically grouped). It has also been found that, at the level of attended information, concrete stimuli are remembered much more succesfully than abstract stimuli. This effect will be investigated at the level of unattended information (subsequent recognition of concrete stimuli will be compared to the subsequent recognition of abstract stimuli). Previous research has shown that when subjects are asked to respond to one of two conflicting dimensions of a stimulus the response to the first dimension will interfere with the response to the second dimension (this is called a Stroop type interference effect). This interference effect will be tested using unattended information - one dimension will be at the level of attended information and one at an unattended level.

It is felt that the results of these studies will directly relate to the current explanations of processing of unattended information. If, when stimulus words are neither highly practiced nor highly meaningful (to the subjects), no interference of the types described above occurs, it would suggest that unattended information is processed only when it is highly practiced or highly meaningful (such as one's own name) and would thus support current explanations. If however, information is processed when it is neither highly practiced nor highly meaningful (as would be evidenced by the semantic processing of category information, a superiority effect for concrete over abstract stimuli or a Stroop type interference effect), it would clearly suggest a need to revise current explanations.

REVIEW OF THE RELEVANT LITERATURE

This literature review will cover three major topics relevant to the evaluation of the current explanations of processing of unattended information. The first topic to be covered will be attention, specifically selective attention. Auditory information processing studies, Stroop effects, evidence for "automatic processing", and explanations of processing of unattended information will all be discussed.

Following the discussion of attention will be presentations of research related to clustering effects as seen in recall tests and the recall of concrete versus abstract stimuli. This literature is important as the recall of clustered (categorized) items and the recall of concrete versus abstract stimuli will later be tested at the level of unattended information and compared to the recall patterns at the level of attended information.

Attention

Introduction. In 1890 William James wrote, "Everybody knows what attention is," and that without selective focusing, "experience is utter chaos." Unfortunately however, the matter is not quite that simple. In 1890 everybody did not know what attention was, and almost 100 years later, we still don't! The subject of attention is a very broad one.

The are many different definitions of it, models describing it, and subcategories within it. Posner and Boies (1971) suggested that there are three major topics or categories under which studies of attention might be grouped. The first was the notion of alertness. Maintaining attention in the sense of alertness refers to the ability to perform long, boring tasks without letting attention drift. A second category of attention was defined as selectivity, the ability to select information from one source or kind over other possible sources or kinds. The third topic of attention was defined as processing capacity, the limit on man's ability to perform simultaneous mental operations.

These three topics of attention encompass a great deal of research, but demonstrate one very general principle which is the foundation of most major theories of attention (Kahneman, 1973; Norman & Bobrow, 1975; Posner & Snyder 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider 1977): The conceptualization that attention is a very limited natural resource. We are unable to attend to something for an unlimited amount of time, or to attend to an unlimited amount of things. The more complex (difficult) a task, the more attention it requires. While we are able to walk and talk at the same time, it is very difficult to perform two less practiced tasks simultaneously, such as reading a difficult book and delivering a lecture. If the difficulty of a task varies, the attentional allotment will also vary. Learning to drive is a very difficult task and takes the full concentration of a new driver - he or she probably has trouble talking while driving. After becoming practiced however, many people are able to carry on a lively conversation while driving a car, although if a difficult turn must be negotiated, conversation may temporarily stop while the driver concentrates on that turn (Kahneman, 1973).

This paper will investigate aspects of Posner and Boies' second category, selective attention. Everyday experience tells us that we attend to some environmental stimuli more than others and that the unattended stimuli often pass unnoticed. While we are normally aware of all attended information, the bulk of the unattended information is usually never processed, we are neither able to recognize unattended information, nor recall it. When reading an interesting book or engrossed in a conversation, we are often unaware of a radio playing in the background, unable to identify the last few songs played. Only occasionally do we become aware of the content of unattended information.

Auditory information processing studies have provided evidence for selective attention and the occasional processing of unattended information. These studies will be discussed in the next section of this paper. Following that will be a discussion of the Stroop effect, which provides evidence for the processing of unattended visual information. This chapter on attention will then be directed to the presentation of some very recent selective attention research and a discussion of the concept of automatic processing, and finally, conclude with a discussion of current explanations of processing of unattended information.

Auditory information processing research: Evidence for selective attention. Much work on selective attention has used the auditory modality. The advantages of this modality are clear: Auditory attention can be studied without the encumbrance of orientation movements which dominate visual attention (Broadbent, 1958), audition can be characterized by two distinct and obvious channels (Kahneman, 1973), and there is no physical mechanism for selective attention in audition while there is an excellent one in vision, namely, looking away (Wolford & Morrison, 1980).

Research by Cherry (1953) led to the development of an experimental procedure called shadowing which is instrumental in studying unattended information. In that technique a subject is asked to follow a spoken message, repeating every word, and ignore other messages to which he is simultaneously exposed. It was found that the presence of a distracting message barely impaired shadowing performance when the rejected and attended messages were seperated by an obvious physical characteristic, such as spatial origin (i.e. a different message presented to each ear). It was also found that subjects were always aware of the presence of the rejected message at the unattended ear, but could recall virtually none of its content or even the language in which it was spoken. Subjects were only aware of gross units of information in the unattended channel, such as the sex of the voice delivering the message, and could only detect major physical changes, such as a change of voice or a switch from a voice to a tone.

An early theory of attention was developed by Broadbent (1958). This theory can be classified as a filter theory and was based on the idea that information processing is restricted by channel capacity. Briefly, Broadbent postulated a sequence of three processes: A short term store (S-system), a selective filter, and a limited capacity channel (P-system). Concurrent stimuli enter into the S-system in parallel and are analyzed there for physical features such as location or tone. There is no definite limit on the capacity of the S-system. The selective filter allows relevant stimuli to enter the P-system for further processing. Filter theory interprets selective attention as setting the filter to select a certain class of stimuli and to reject all others. Irrelevant messages are simply allowed to decay in the S-system without undergoing more advanced processing in the P-system. Filter theory implies that attention cannot be divided, as the P-system performs no parallel processing of discrete stimuli. According to this theory, the apparent division of attention in the performance of simultaneous activities can be explained by alternation between channels or between acts.

Intuitively, the filter theory seems correct. It is obvious that we have a limited processing capacity and we do sometimes "switch" attention (e.g. stopping a conversation in order to negotiate a difficult turn while driving). An early experiment using the dichotic listening technique supported this theory (Broadbent, 1954). Broadbent presented three digits to one ear of his subjects, and simultaneously, presented three different digits to the other ear. He found that the subjects could report the digits as they were presented to each ear much more successfully than they could report the digits as they were presented temporally (if the digits 6, 3, 9 were presented to the left ear and the digits 5, 8, 7 were presented to the right ear, subjects were able to report them in that order much more successfully than in correct temporal order which would have 6,5 3,8 9,7). Broadbent interpreted this difference to be the result of having to switch attention between sources (channels) more often in the case of temporal report.

These results, along with Cherry's earlier results support the view that only one signal (message) can be processed at one time, and provided the foundation for Broadbent's theory. Later studies have shown that Broadbent's filter theory was incorrect, however.

Although Cherry (1953) showed that, as a rule, subjects were unaware of the content of the unattended message when performing a shadowing task, Moray (1959) was able to show that there are exceptions to that rule. Using a paradigm similar to Cherry's, it was shown that although subjects were generally unaware of the unattended message (the message they did not shadow), they did notice the presence of their own name within that message. Broadbent's filter theory does not account for this phenomena.

Two experiments conducted by Gray and Wedderburn (1960) further challenged Broadbent's theory. Using a paradigm similar to Broadbent's (1954) they presented to alternate ears the syllables composing a word (in sequence) and random digits; when a syllable was presented to one ear, a digit was presented to the other simultaneously. For example, they presented OB, 2, TIVE to the left ear of a subject and 8, JEC, 3 to the right ear, with OB 8, JEC 2, and TIVE 3 occuring simultaneously. If Broadbent's theory were correct, subjects would have found it easier to report the stimuli ear by ear, such as OB-2-TIVE or 8-JEC-3. This was not the case: Subjects would report OBJECTIVE, 8,2,3. In a second experiment Gray and Wedderburn used the same procedure but presented phrases and digits simultaneously, such as MICE-2-CHEESE to one ear, and 8-EAT-9 to the other (with the pairs MICE-8, 2-EAT, and CHEESE-9 each occurring simultaneously). As in the fractured word experiment, subjects grouped the message segments by meaning rather than by channel.

Treisman (1960) looked at another situation in which subjects were instructed to shadow a particular ear. The message in the to-be-shadowed ear was meaningful until a certain point, at which time it turned into a random sequence of words (such as, I SAW THE GIRL song was wishing). Simultaneously, the meaningful message switched to the other ear, which had previously been a random sequence of words (such as, me that bird JUMPING IN THE STREET). Many subjects switched ears, against instructions, and continued to follow the meaningful message (that is, the shadowed message they would report would be, "I SAW THE GIRL JUMPING IN THE STREET").

Although Broadbent's filter theory and early research showed that very little was known about the unattended message and suggested that subjects simply "turned one ear off" the above studies showed that this was not the case and that there are times when the unattended message is processed and becomes meaningful. In an attempt to accomodate the evidence against filter theory, Treisman (1960, 1964) proposed a modification of that theory that described filtering as a relative process: The rejected message was attenuated, not eradicated.

According to Treisman, a sensory message activates hypothetical "dictionary units" in memory. Each unit has a threshold which must be exceeded for perception to occur. The threshold for highly significant stimuli, such as one's name, is very low. Because of the variation of thresholds, a word presented in an irrelevant channel may be perceived in spite of attenuation, which would explain Moray's (1959) name effect. Thresholds can be temporarilly lowered, according to Treisman, when an external context makes the occurance of a given word highly probable, which would explain Gray and Wedderburn's (1960) and Treisman's (1960) results.

In a major departure from filter theory, Treisman concluded that divided attention and parallel processing are possible for two simultaneous inputs, but only if they do not reach the same analyzers; serial processing must occur when the same analyzer is used. Treisman's model suggests that: a) perception is contingent upon recognition thresholds, which are variable, b) parallel processing can occur, but only when different analyzers are used, and c) "irrelevant messages" fall on a dull not a deaf ear. This model will be discussed in greater detail in a later section of this chapter.

Stroop effects. A Stroop type interference occurs when a subject is asked to respond to one of two dimensions of a given stimulus and the second dimension delays or interferes with that response. Traditional Stroop stimuli are color words printed in an ink color that is inconsistent with the meaning of the word. Interference occurs when a subject is asked to respond to the color of the ink. The printed word interferes with his response and he will characteristically respond faster to patches of color than he will if it is in the form of a printed color word that signifies a color other than that of the ink.

The origins of the Stroop test go back almost to the beginning of experimental psychology. In 1883, Wilhelm Wundt is said to have suggested to one of his students, James Cattell, that he do his doctoral research on the time it takes to name colors and objects and to read the corresponding words (Jensen & Rohwer, 1966). The conflict or interference situation, which is the main feature of the Stroop effect was first discussed by Jaensch (1929, cited by Jensen & Rohwer, 1966) in connection with his research on perceptual types. The color-word interference test was first introduced by John Ridley Stroop. Stroop's doctoral thesis was concerned with serial verbal reactions and used the color-word interference test now associated with his name (Stroop, 1935).

The original Stroop test consisted of three cards: A word card with the names of colors printed in black ink (W), a color card with rows of patches of colors (C), and a color word card with rows of color names printed in ink of a conflicting color (CW). Red, green, blue, brown, and purple were used. The words and colors were arranged in a 10 x 10 matrix of evenly spaced rows and columns. Any regularity of sequence (horizontally or vertically) was avoided. Each of the five colors or words occurred twice in each column and each row, and no attribute was immediately adjacent to itself in either column or row. Subjects were instructed to verbally report either the colors or the words reading from left to right, starting with the top row, and to respond as rapidly as possible while trying to be as accurate as possible.

Within the format of reporting a series of words or colors the basic data are the total time needed to name the stimuli (colors or words) for each card. This format has been very successful in the production of interference. There is a color-word interference, or conflict, experienced when the subject is asked to name the color of the lettering of the incongruous CW card. This effect is quite robust and is exhibited over a wide range of phenomena. For example, Stroop like interference has been found not only for naming colors in the presence of color words, but in the presence of other words (Klein, 1964; Warren, 1972), in the naming of achromatic shades (Dyer, 1971a), in naming four positions of a compass when the positions are labeled with incongruent direction names (White, 1969), in naming directions specified by arrows when the arrows are labeled with conflicting direction names (Shor, 1970), in naming words above or below a fixation point when the positions are labeled with conflicting position names (Logan & Zbrodoff, 1979; Seymour, 1973), and with different preexposure times to a color word (Dyer, 1971b).

Studies alluded to above have used stimuli such as arrows, compass points, and "above" or "below" position judgements. It appears that in order to be correctly called a Stroop task the stimuli used must meet two criteria: Stimuli must be constructed in such a way that subjects can be asked to respond to one dimension of a two dimensional stimulus, and within those two dimensions one must represent an attribute or concept and one must represent an attribute name.

Varied explanations of the Stroop effect have been offered, many of which hinge on the finding by Fraisse (1969) that reading is faster than naming. From that finding it is assumed that verbal information is processed faster than non-verbal information (the attribute name is processed faster than the attribute itself) and thus, the verbal information interferes with the non-verbal information. This position was refined by Palef and Olson (1975). They contend that the verbal versus non-verbal information is not important per se, but rather the relative speeds at which the two forms of information (dimensions) are processed. They postulated that interference results when the response is required to the slower of the two processing modes (the non-verbal dimension in the color-word stimuli).

Hintzman, Carre, Eskridge, Owens, Shaff and Sparks (1972) felt that the effect is not caused by interference but by response competition. They argued that if the effect were due to interference at the time of encoding, any printed word (attribute name) would interfere with the encoding of the color (attribute). This is simply not so. Klein (1964) has shown that although all words will affect the processing of a color stimulus, different attributes of words will differentially affect the color naming responses. A standard Stroop type experiment was conducted which investigated the interference effects of verbal stimuli varying in their relationship to the ink colors. Six conditions were used. In each condition the verbal stimuli consisted of items typed in the colors red, green, yellow, and blue. In Condition A all verbal items were nonsense syllables (hjh, eugic, bdhr); in Condition B they were rare English words (sol, helot, eft, abjure); in Condition C they were common English words not closely associated with colors (put, take, friend); in Condition D they were words which were not color names but which implicated colors in their meaning (lemon, grass, sky) and were presented in incongruent combinations with the ink colors; in Condition E they were different words of the same response class as the ink colors (tan, purple, black). Condition F was the standard Stroop Condition, the words represented the color names but were presented in incongruent combinations of color and word. Results showed that in all conditions responses were significantly slower for the conflict-stimuli than for the colors-alone stimuli. As the words became more meaningful and more closely related to colors the interference increments became increasingly larger. It was concluded that the impeding effect of the verbal stimuli upon the relevant color naming response is governed by the relative meaningfulness of the words (with respect to the correct response). Many studies have shown that when an attribute and attribute name are consistent the interference effect does not occur (Dyer, 1971b; Hintzman et. al., 1972; Ridley, Johnson & Braisted, 1978). If the interference between two modes were occurring, one dimension would interfere with the other dimension (as seen in response latencies) regardless of whether or not the two dimensions represented consistent information. Hintzmen et. al. felt that the delay exhibited with an interference effect of this sort represents response competition and that the consistency effect occurs because there is no competition when the two dimensions (responses) are the same.

Hintzman (1978) later revised his position and stated that the Stroop effect shows that encoding is automatic, or effortless, that we cannot turn off the retrieval of highly familiar information even if we want to, and that because interference is selective (different words produce different levels of interference), it is probably the meanings of the words that are being retrieved. Hasher and Zacks (1979) use the Stroop effect to demonstrate the automaticity of learning. They feel that the word meanings are automatically activated and explain the effect by stating that the difficulty in reading the ink colors comes from the interfering reading responses made to the incongruent color words.

It is this assumption that the meanings of the printed words are encoded "automatically" that is relevant to the current discussion. That some information cannot be ignored (that subjects cannot selectively attend to some information), but will be processed automatically, without effort or intent, is a very important finding with respect to selective attention. The idea of "automatic processing" may be very important to the discussion of processing of unattended information and will be further discussed below.

Recent evidence for processing unattended visual information: Automatic processing. Although the majority of the research on selective attention has been concerned with the auditory modality (probably due to the conveniences discussed earlier) some studies have also utilized the visual modality. In addition to the research dealing with Stroop phenomena discussed above, some studies have been classified as dealing with Stroop like phenomena, that is, studies similar to the Stroop studies, but that do not meet the criteria for a true Stroop test.

One such article, dealing with the precedence of global dimensions in visual perception, is that of Navon (1977). Navon proposed that perception proceeds from a general, global analysis to a more and more specific, local analysis, and that his findings demonstrated the "inevitability of global processing". These claims were based on the results of an experiment in which he used stimuli composed of letters made up of smaller letters, as shown in Figure 1. These stimuli, as originally suggested by Kinchla (1974),

GLOBAL DIRECTED CONDITION

```
H         H    S         S    0         0
H         H    S         S    0         0
H         H    S         S    0         0
H H H H H H    S S S S S S    0 0 0 0 0 0
H         H    S         S    0         0
H         H    S         S    0         0
H         H    S         S    0         0

  H H H H        S S S S        0 0 0 0
H         H    S         S    0         0
H              S              0
  H H H H        S S S S        0 0 0 0
          H              S              0
H         H    S         S    0         0
  H H H H        S S S S        0 0 0 0
```

LOCAL DIRECTED CONDITION

```
H         H      H H H H      H H H H H H
H         H    H         H    H         H
H         H    H              H         H
H H H H H H      H H H H      H         H
H         H              H    H         H
H         H    H         H    H         H
H         H      H H H H      H H H H H H

S         S      S S S S      S S S S S S
S         S    S         S    S         S
S         S    S              S         S
S S S S S S      S S S S      S         S
S         S              S    S         S
S         S    S         S    S         S
S         S      S S S S      S S S S S S
```

Figure 1. Stimulus set used by Navon (1977).

were used such that the identified properties of the global and local dimensions could be equated (i.e. the set of identified global features - the large letter, was identical to the set of identified local features - the small letters).

Subjects were shown the stimuli described above under two different conditions. In the global directed condition the subject was asked to indicate whether the global character (the large letter) was an H or an S. In the local directed condition the subject was asked to indicate whether the local characters (the small letters making up the large one) were Hs or Ss. The results indicated that the global pattern was responded to faster than the local characters, and more importantly, subjects were able to voluntarily attend to the global dimension without being affected by the local dimension, but they were not able to attend to the local dimension without being affected by the global dimension (i.e. under the global directed condition it made no difference whether the two levels of structure were consistent or conflicting; under the local directed condition consistent stimuli were responded to more rapidly than were conflicting stimuli). Navon's results are shown in Figure 2.

That global attributes were processed more quickly

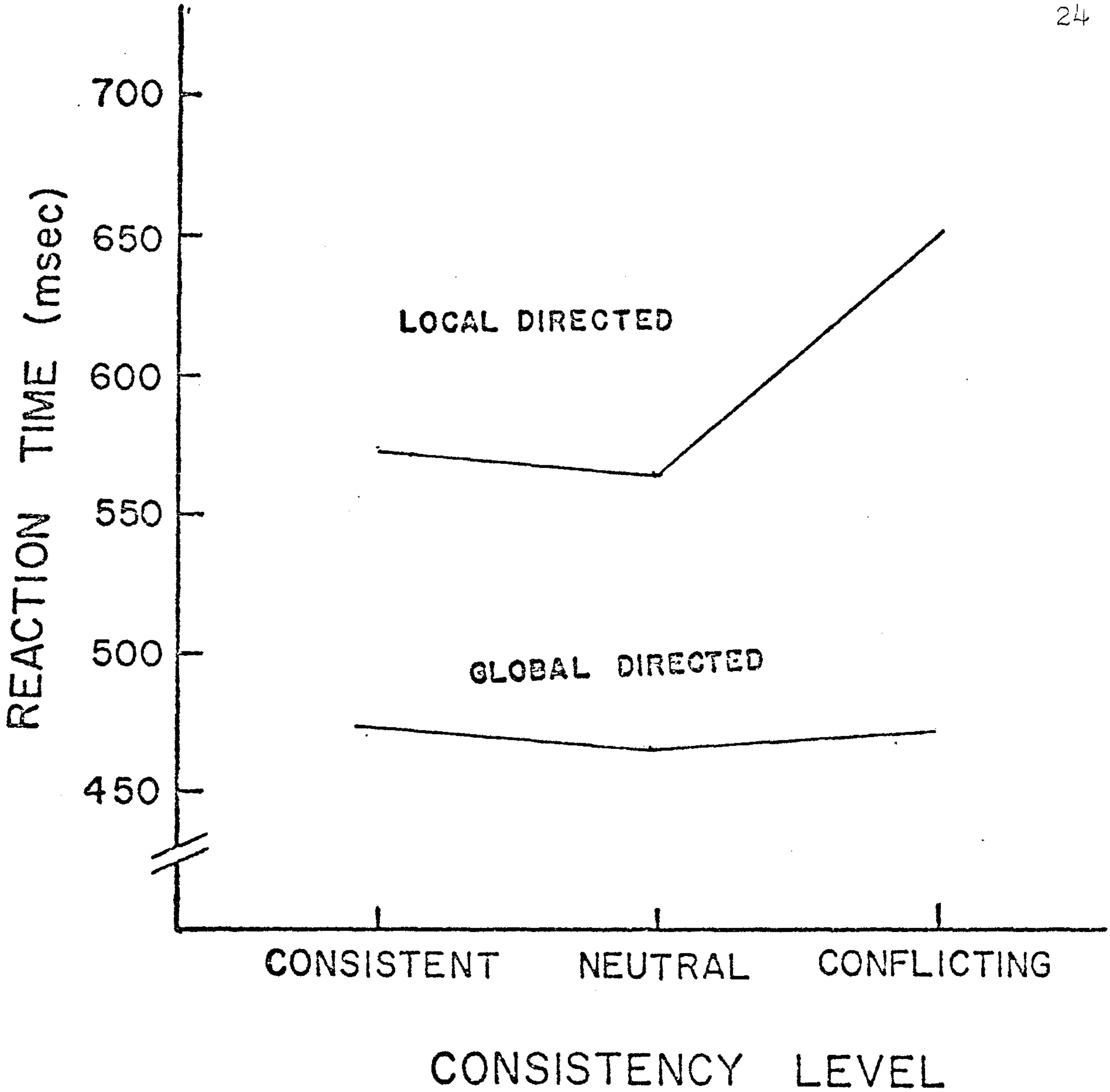

Figure 2. Mean response latencies as a function of consistency level and attentional condition (Navon, 1977).

in Navon's study was perhaps not surprising. There is evidence (Lupp, Hauske & Wolfe, 1976) that subjects respond rapidly to low spatial frequencies and progressively more slowly to higher frequencies, which in itself would predict Navon's findings. There is also considerable evidence that single letters are easier to perceive than letters flanked by other letters (Townsend, Taylor & Brown, 1971; Wolford & Hollingsworth, 1974). This phenomenon is called a lateral masking effect and would appear in Navon's stimulus set only on the local level, which also may have made letters within the local level more difficult to perceive. What is surprising, however, was the finding that the local dimensions did not interfere with the processing of the global dimensions, while the global dimensions did interfere with the processing of the local dimensions. It was this finding that led Navon to conclude that processing on the global level was inevitable; it seemed that subjects had to process the large (global) letter first in both conditions.

In response to Navon's results, Kinchla and Wolfe (1979) again addressed the problem of the order of visual processing. The stimuli used were similar to those used by Navon, however, the overall size of the stimuli was varied over a much larger range of visual angle. Navon presented stimuli at a visual angle of approximately $3^{o}12'$;

Kinchla and Wolfe presented stimuli in which the height of the large letter subtended, with equal probability on each trial, 4.8°, 6.7°, 8.0°, 10.3°, or 22.1° visual angle. Subjects heard a target letter defined and were then shown a stimulus letter. Their task was to respone "yes" if the target letter corresponded to either the large letter or the small letters in the stimulus letter and "no" if it did not. It was found that "no" responses generally took longer than "yes" responses and that there was a crossover interaction between the speed of a "yes" response to large and small targets and the visual angle of the display, as shown in Figure 3. At smaller visual angles the large letter evoked the fastest "yes", while at the larger visual angles the small letters did. These results suggested neither an invariant global to local process (which Navon had proposed as inevitable) nor an invariant local to global process (as a feature analytic model would predict).

Another series of studies was conducted by Martin (1979), again in direct response to Navon's findings. Martin used stimuli similar to those used by Navon, letters made up of smaller letters. As in Navon's study, stimuli were presented in one of four possible quadrants of the stimulus field, immediately adjacent to the field's central and vertical axes. The global shape subtended 2.8° to the left or right of the center point of the field and

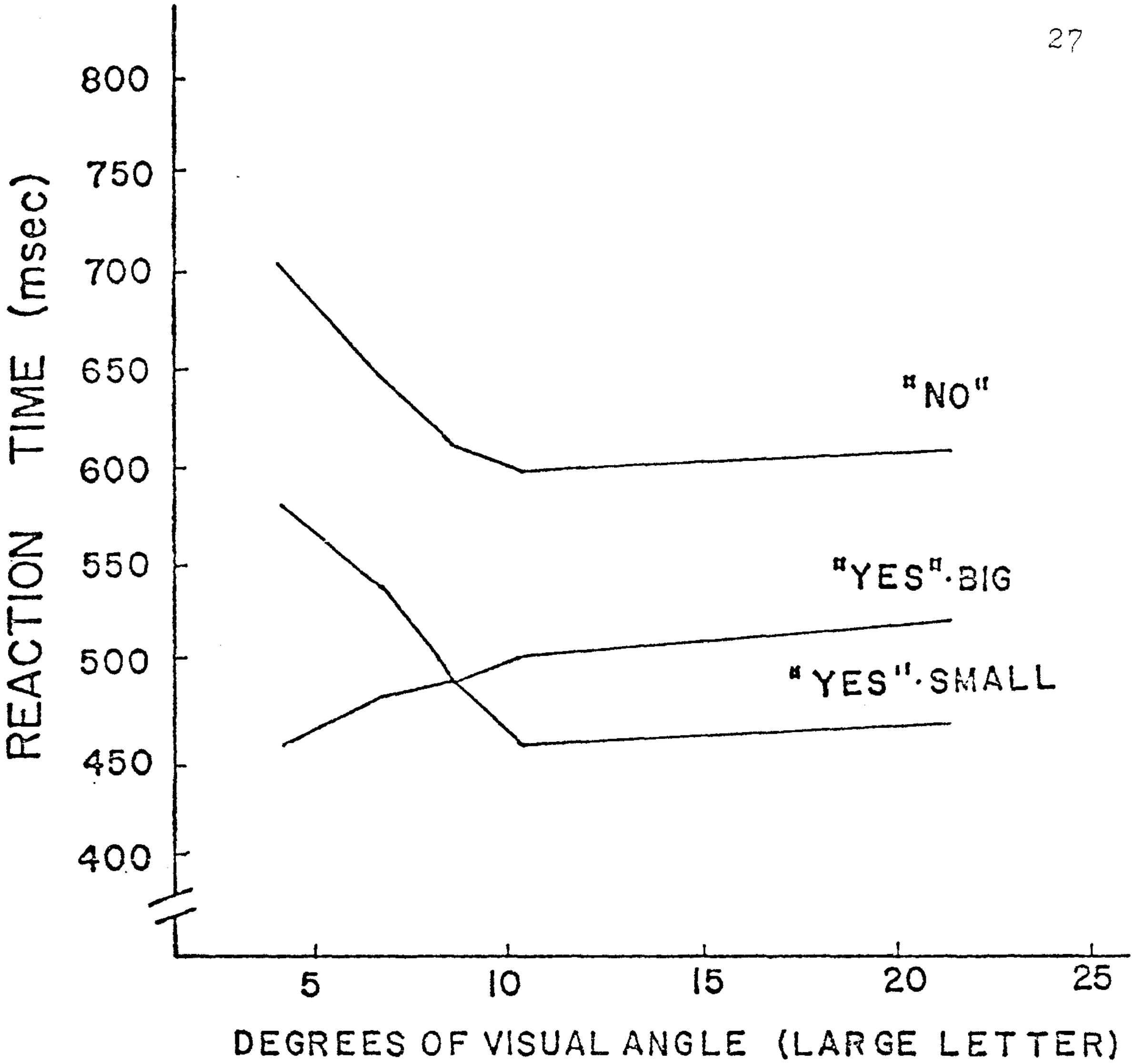

Figure 3. The average time to respond "yes" at each angular display size when a large letter was the target, when small letters were the targets, and to respond "no" when neither was the target (Kinchla & Wolfe, 1979).

4.1° above or below it. Her research addressed two assumptions: The first was that global processing preceeds local processing, and the second was that when two conflicting types of information are processed, perception of a secondary (more slowly available) type is impaired by the primary type.

In Martin's main experiment, subjects were shown a global letter composed of several smaller, local letters. The sparsity of each stimulus was varied by having each global aspect be comprised of either many or few local ones, such that the global to local size ratio was varied. The task of the subject was to identify either the global or local letters (as instructed) as rapidly as possible.

A two way interaction between sparsity and attentional instructions was found. Depending upon conditions, either the global aspects or the local aspects of the stimuli were responded to more rapidly, as shown in Figure 4. Although global processing was significantly faster than local processing for stimuli with many local elements, it was significantly slower than local processing for stimuli with few local elements. The results of her series of four experiments consistently demonstrated a global processing priority only for many-element stimuli, a local processing priority appeared for few-element stimuli.

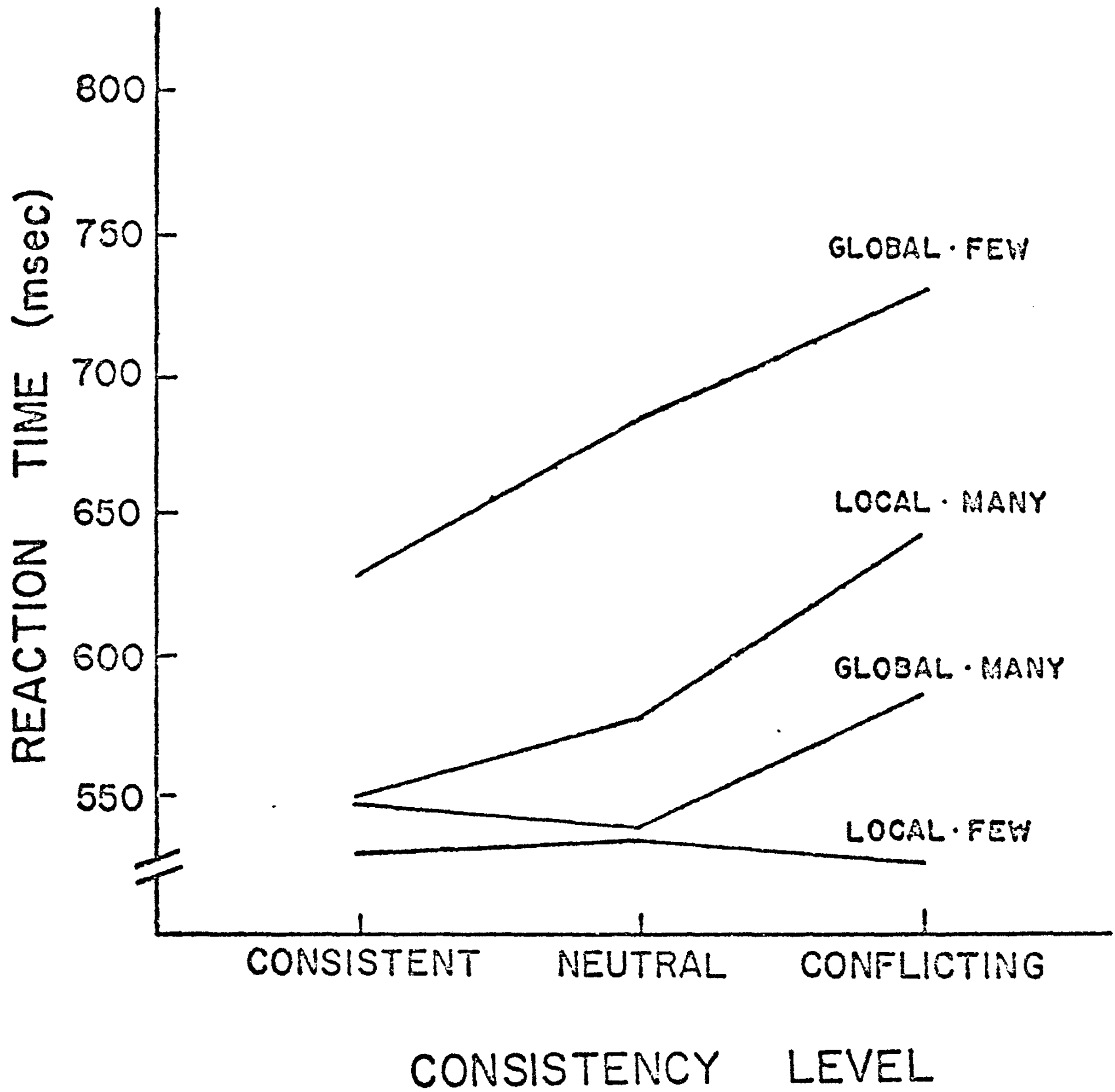

Figure 4. Latencies for reporting local and global aspects of many element and few element stimuli, as a function of the level of consistency of the secondary aspect (Martin, 1979).

Hoffman's (1980) research also investigated the processing of levels of structure, utilizing a paradigm that combined elements of Navon's (1977) interference paradigm and Kinchla and Wolfe's (1979) target search task. Each of his trials began with the presentation of a memory set of one, two, or four letters. A stimulus pattern was then presented consisting of a large letter made up of smaller letters. A letter was considered positive if it was a member of the memory set and negative if it was not. The experiment was divided into a "large only" condition in which the target letter might appear at the global level, a "small only" condition in which the target letter might appear at the local level, and a "both" condition in which the target letter might appear at either level. In one experiment (using the letters L,X,T,Y,H,N,F, and Z), it was found that in the focused attention conditions subjects were unable to attend to only the instructed dimension. Reaction times were faster when the two dimensions (large and small letters) were in agreement than when they conflicted, and the magnitude of the interference provided by the to-be-ignored dimension was approximately the same in both the global directed and the local directed conditions. In the divided attention, or "both" condition, reaction time was the same for targets located at either the global or local level, and generally slower than for the corresponding focused attention condition.

In a second experiment Hoffman distorted the quality of information at the local and/or global levels by changing the position of a randomly chosen element of a letter (at the appropriate global or local level) from its correct position to a new randomly chosen position within the letter matrix. An example of Hoffman's stimuli is shown in Figure 5. When the small letter was distorted, a global precedence pattern was obtained: Subjects could not ignore the large letter when told to attend only to the small, and the identity of the small letter was irrelevant when subjects were attending to the large letter. It is important to note that these results are in accordance with those which would be predicted by Navon's precedence model. When the large letter was distorted however, a corresponding local precedence pattern was obtained, implying that both the large letters and the small letters were proceeding through a pattern recognition process simultaneously, and that the relative quality of information at each level determines the speed of recognition.

The results of the Stroop studies mentioned earlier and Navon's work mentioned above suggest that some processing is so automatic that it cannot be ignored: Subjects cannot attend to an instructed dimension of a stimulus if another available dimension is one which is processed automatically. These studies imply that certain elements are

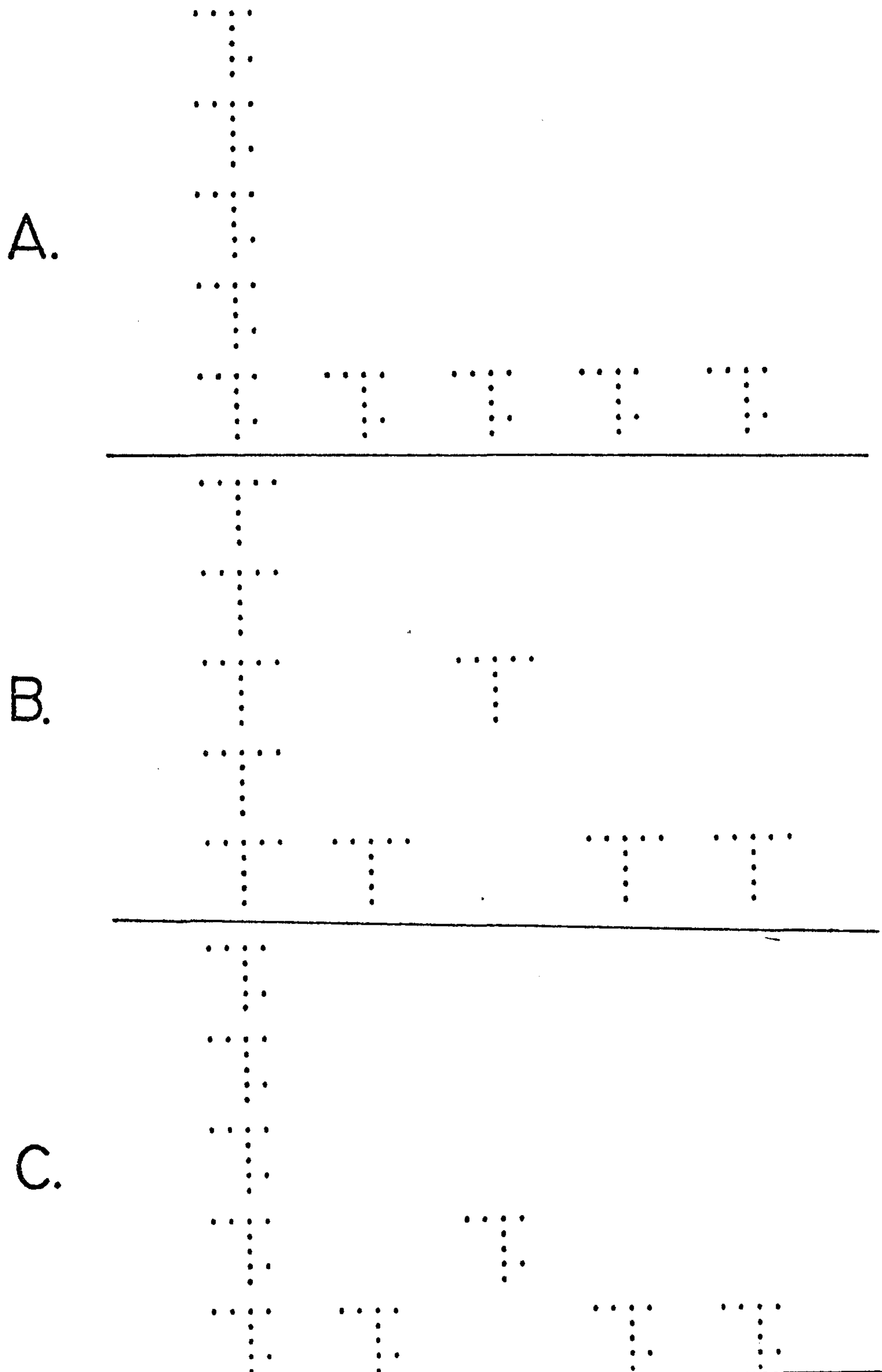

Figure 5. Distorted stimuli used by Hoffman (1980).
A. Distortion on the local level.
B. Distortion on the global level.
C. Distortion on both levels.

always processed automatically, in an invarient manner. Later work (Hoffamn, 1980; Kinchla & Wolfe, 1979; Martin, 1979) has shown that the ease (automaticity) of processing of different dimensions is variable, and contingent upon the quality of information available at those different dimensions.

In a more direct investigation of unattended visual information Neisser (Note 1) demonstrated what he called selective reading. Subjects were presented with text in which the lines were printed in alternate colors. Subjects were instructed to selectively attend to half of the material, that is, they were instructed to read the text printed in one color and to ignore the text printed in the other color. For the most part, subjects were unaware of the unattended information (the lines of text which they were not instructed to read). They were aware of highly familiar items however, such as their own names.

Although the above study was considered a visual analog to the auditory selective attention studies discussed earlier, it has been argued that the results may have been seriously confounded, due to the fact that the unattended visual information was located somewhere in the periphery of the retina. Recognition of the unattended material may have been inferior to that of the attended material simply because the attended information was located at the subject's fovea (where acuity is quite high) while the unattended information was located in the periphery (where acuity is deficient).[1]

In an effort to account for this rather serious confound, Wolford and Morrison (1980) designed a new paradigm in order to study the processing of unattended visual information. A pair of digits was presented to subjects on the face of a CRT seperated by five degrees of visual angle, with a word centered between the two digits. Subjects were instructed to judge whether the two digits were of the same parity (both odd or both even) or of different parity (one odd and one even) and to ignore the centered word. It was found that no processing capacity was used to moniter the centered word (response latencies were the same with or without a centered word, as shown in Figure 6). Although subjects were generally unaware of the centered words and performance was at chance level on a subsequent two alternaternative forced choice recognition test, they were aware of a highly salient centered word, such as their own name, and performance was well above chance level on the subsequent recognition test.

As mentioned earlier, an explanation which would account for this phenomena is the concept of automatic pro-

[1]It has been shown that visual acuity is superior for stimuli presented at the fovea (Cornsweet, 1970).

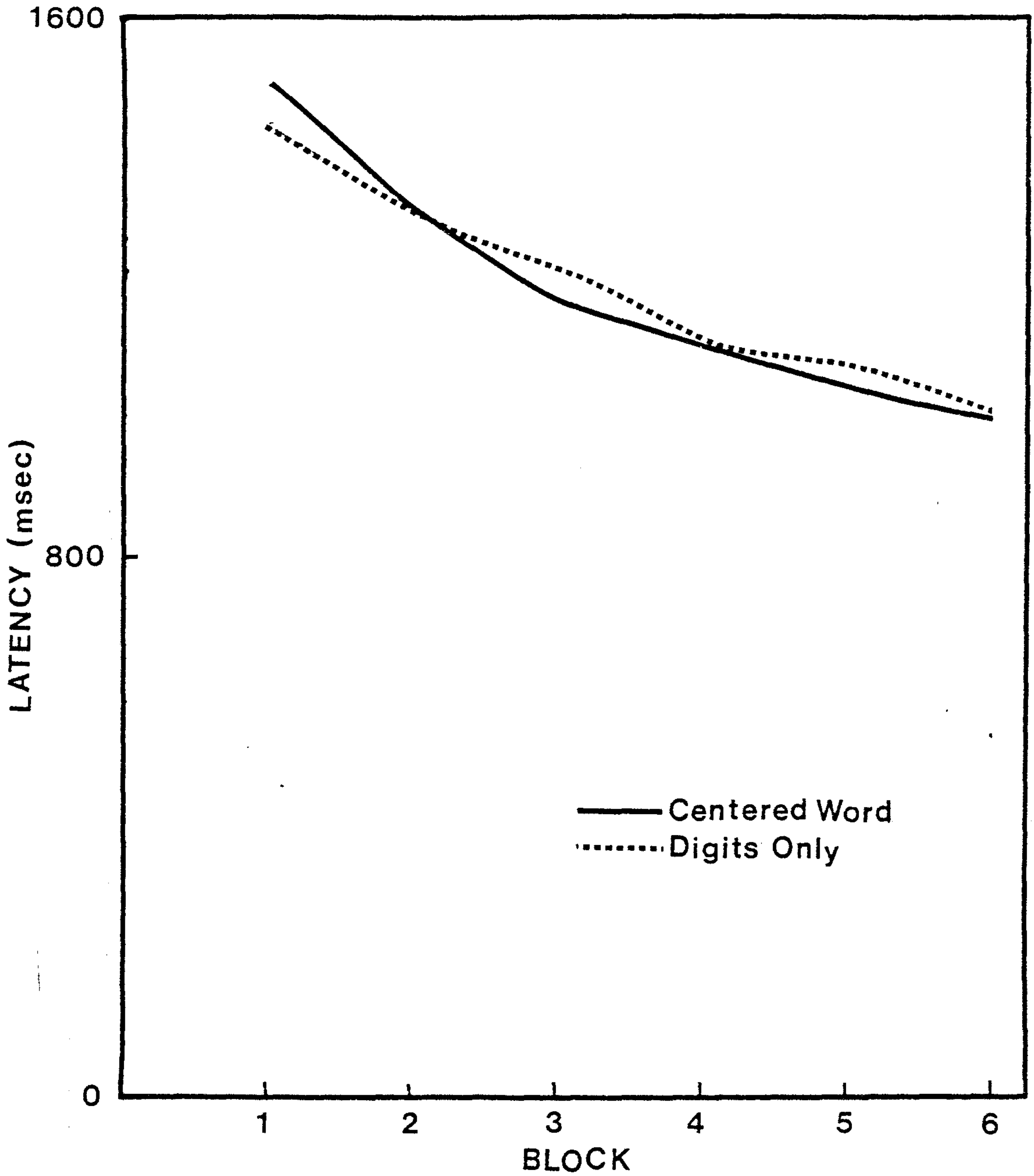

Figure 6. Response latencies as a function of block and experimental group (Wolford & Morrison, 1980).

cessing. It is contended that some material is processed so often that it becomes increasingly practiced and familiar until that information is processed automatically, without effort or intent (e.g. one's own name).

In an experiment in which subjects were instructed to write dictated words while reading it was shown that subjects became increasingly more efficient at this task (Hirst, Spelke, Caharack & Neisser, 1980). The results were interpreted such that it was shown that attention is a skill that improves with practice: While at first subjects found reading and writing (simultaneously) very difficult, with practice the task became very easy. The more a task has become practiced, the less attention it requires; highly practiced processes require no attention (capacity) at all. Such highly practiced processes are referred to as automatic (Anderson, 1980). Automatic processes are said to operate continually. They do not require awareness or intention and drain minimal amounts of energy from attentional capacity (Hasher & Zacks, 1979).

A comparison of recognition threshold and automaticity explanations of processing unattended information. As mentioned earlier, in an effort to accomodate results which suggested that unattended information is sometimes processed (Gray & Wedderburn, 1960; Moray, 1959; Treisman, 1960,

1964) an attenuation model of selective attention has been proposed (Treisman, 1960, 1964). It was suggested that all incoming stimuli activate hypothetical "dictionary units" that have thresholds that must be exceeded for perception to occur. The thresholds for highly significant stimuli, such as one's own name, are permanently low, while the threshold for a stimulus that context makes highly probable is temporarily lowered. Because of these variations of thresholds, a stimulus of high significance or high probability that is presented in an unattended channel can be perceived. The posited threshold mechanism is described as follows:

> It may be that the channel filter attenuates messages rather than blocks them completely. If so, words which were highly important or relevant to the subject could be picked out when the threshold for identifying them was permanently or temporarily lowered within the word-identification system itself, in spite of their reduced signal-to-noise ratio. A possible system for identifying words is a hierarchy of tests carried out in sequence and giving a unique outcome for each word or other linguistic unit. The decision at each test point could be thought of as a signal detection problem: A certain adjustable cut off or criterion point is adopted on the word being discriminated, above which signals are accepted and below which signals are rejected as noise. The criterion determining the results of the test would be made more liberal for certain outcomes favored by context and probabilities, by recent use, or by importance. Messages attenuated by the filter would pass the test only if the criterion had been lowered in their favor and, if not, would pass no further through the hierarchy. (p. 14, 1964)

In a recent set of articles, Schneider and Shriffin

(1977) and Shiffrin and Schneider (1977) distinguished between automatic and controlled processes in human information processing. Automatic processing was defined as the activation of a learned sequence of elements in long term memory initiated by appropriate inputs. This activation proceeds automatically, without subject control, without any capacity allotments, and without demanding attention. Controlled processing was defined as an activation of a sequence of elements that requires attention, is capacity limited, and is controlled by the subject. In a series of studies the ways in which subjects scan visual arrays and the role of automaticity in that activity were investigated.

Subjects were given a target letter or number and were instructed to scan a series of visual displays for that character. The display consisted of 20 different frames flashed on a screen. Subjects were to report if their target occurred in one of those frames. Two factors were varied: The frame size (each frame had one, two, or four characters on it), and the relationship between the target items and the search items (in the same-category condition, both the target and the search characters were either letters or numbers; in the different-category condition, the target was a number and the search characters were letters). Performance was dramatically different between between the different- and same-category conditions. In the different-category condition, frame size had no effect, but in the same category condition performance changed dramatically as a function of frame size (as frame size increased, performance decreased).

Schneider and Shriffrin argued that subjects were so practiced at detecting a number amoung letters (before the start of the experiment - due to everyday experience) that this process was automatic. In contrast, when subjects had to distinguish a letter from other letters a more effortful process was required. To support this view, another experiment was conducted in which the target letter was always from one set of letters (B,C,D,F,G,H,J,K,L) and the search letters were always from another set of letters (Q,R,S,T,V, W,X,Y,Z). After 2,100 trials, subjects were at the same level of performance as in the different-category condition of the previous experiment. Subjects needed extensive practice, but eventually became as efficient in this condition as in the letter/number search condition, implying that automatic processing follows consistent mapping of stimuli to responses (practice).

As a result of these findings, Schneider and Shiffrin proposed that in novel situations or situations requiring moment to moment decisions, controlled processes are used in order to perform accurately, if slowly. As situations become familiar, always requiring the same sequences of processing operations, automatic processing develops - such that attention demands are eased and control processes can be carried out in parallel. When stimuli are presented to be processed that do not cause automatic attention responses, a controlled attention response begins. In the case of selective attention, the processing organism carries on attention demanding controlled processing on the attended message, with only minimal controlled processing of the unattended information - just enough to establish which information is to be given deeper processing. If automatic attention responses have been attached to stimuli, these stimuli will be processed and remembered even when they are present at an unattended source of information (or an ignored channel).

While the two aforementioned theories (namely, those of low recognition threshold processing and automatic processing of information) suggest very different processing systems, it should be noted that both theories account for "effortless" processing of the same material. The attenuation model (low recognition threshold theory) holds that highly familiar or highly meaningful material is processed even with a very small attentional allotment due to low recognition thresholds for that material. Automatic processing theory holds that highly familiar material is processed even with a very small attentional allotment due to a practiced response pattern. In both cases it is very familiar material (such as one's own name) that is processed easily or effortlessly (i.e. processed even when that information is present at an unattended source or channel). To this degree, both theories are very similar; both accounting for the same phenomena.[2] Accordingly, the adequacy of both theories can be examined simultaneously (with respect to this particular aspect of the theories), as they will be in the following series of experiments.

Clustering effects.

In a free recall task, subjects view (or hear) a list of words and then attempt to recall them. The form the recall takes suggest ways in which information is organized by the subjects. A very general fact about free recall is that although there are no restrictions on recall order,

[2] It should be noted that the attenuation theory also accounts for some effortless processing of less familiar material, in the case when a given situation makes the probability of occurance of that material unusually high. This phenomena is not accounted for in the automatic processing theory. This situation is not considered in the present body of research however, and thus will not be discussed here. The following series of studies will investigate the processing of unattended single words and will not offer attended contextual conditions which might affect the probability of occurrance of any given single word.

the actual order in which the items are recalled reflects some order. Bousfield (1953) was the first to demonstrate this. He presented a list of 60 nouns to subjects which fell into four categories: Animals (such as, giraffe, chipmunk, camel), male names (such as, Gerald, Owen, Simon), professions (such as, milkman, chemist, dancer), and vegetables (such as, parsnip, spinich, mushroom). Although the presentation of the words was in a random order, the recall was not. Subjects tended to recall items from the same categories together - a practice Bousfield termed "clustering". If recall were random, it would be expected that a word would be followed by another word from the same category 25% of the time; this happened 40% of the time however, too often to be attributed to chance.

In response to Bousfield's study, Cohen (1963, 1966) conducted a series of studies investigating the effect of categorization on word recall. Two types of categories were examined: Exhaustive and non-exhaustive. Exhaustive categories were ones in which three or four words represented all the words in that category (such as, North, South, East, West). Non-exhaustive categories were ones which contained a large number of items, only a few of which were used in the experiment (such as, dog, lion, horse). The results indicated that the words were categorized by the subjects and that this increased recall. Moreover, recall was greater for words in exhaustive categories than in non-exhaustive categories.

In an experiment conducted by Bower, Clark, Lesgold and Winzenz (1969), the organizational variables in recall were investigated. Several conceptual hierarchies were constructed. An example of a conceptual hierarchy for the word "minerals" is shown in Figure 7. The list of to-be-recalled items contained both members of a category and the category label itself. The presence of the category name was assumed to serve as a potent retrieval cue if the subjects used the category name as an encoding tool. The word list included nested categories (such as "metals"), such that a high level category might serve as a superordinate for lower level instances. Words were presented all at once for prolonged study (rather than presenting the words one at a time for a brief duration). Subjects who had verbal material presented in an accurate nested fashion had higher free recall than those who had seen inaccurate hierarchies formed by randomly assigning category labels. Bower et. al. concluded that if subjects encoded words by means of organizational structure and used that structure in recall, the ability to recall words was greatly enhanced.

The ability to integrate information into single ideas or concepts will greatly increase the amount of information

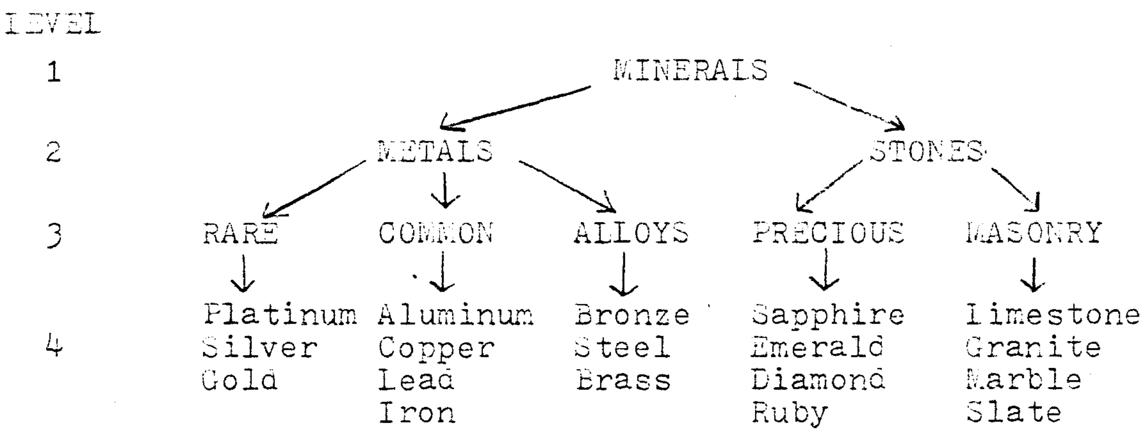

Figure 7. A conceptual hierarchy of words for the word "minerals" (Bower et. al., 1969).

one can process. That is, the ability to integrate several encodings, or bits of information at one level, such that they represent a single encoding or bit of information at a higher level, greatly increases processing capacity. The process of integrating several encodings into one is called chunking; the higher level units formed in this way are called chunks (Miller, 1956). The ability to chunk information greatly increases one's capacity for information processing. Chunking cannot occur, however, without familiarity with the incoming material and the chunk itself. Previous knowledge and information must be activated in order for chunking to take place (previous knowledge and information must be activated in order to integrate new information within that system). The extensive bulk of knowledge that is activated can impose a structure on seemingly unrelated material once a match occurs between that incoming information and stored previous information (Solso, 1979).

The link between stored previous information and chunking was illustrated in an experiment by Bower and Springston (1970) in which subjects were read a letter sequence and later asked to recall those letters. In one condition the letters were presented to the subjects so that they formed no known group (such as, FB...IPH...DTW...AIB...M). In the other condition the letters were dictated to the subjects so that they did form well known groups (such as, FBI...PHD...TWA...IBM). As expected, the letters presented in meaningful groups were recalled much more successfully than were the letters presented in random groups.

The research reviewed in this section suggests that memory is structured in an organized way. The ability to recode information into higher levels of structure will greatly enhance processing capacity. It appears that a consequence of clustering and chunking is an organized system in which processing capacity, and hence, memory span, for information is greatly increased.

Recall of concrete versus abstract stimuli.

In an early study, Brener (1940) demonstrated that the memory span for concrete words is significantly greater than that for abstract words. Another study (Gorman, 1961) using recognition memory as the dependent measure, demonstrated a similar superiority in short term retention scores for concrete over abstract stimuli. Paivo (1963) investigated the learning of adjective-noun paired associates as a function of adjective-noun word order and noun abstractness. He found that the adjective-noun paired associates were most effectively learned when the noun in the pair was concrete.

Dukes and Bastran (1966) studied the recall of concrete and abstract words equated for meaningfulness. A list of ten abstract and ten concrete nouns were presented to subjects one at a time. Half of the abstract words were high in frequency and half were low. The concrete nouns were equated for frequency in a similar manner. Immediate free recall was tested. Again, significantly more concrete words were recalled than abstract words. There was no significant effect for word frequency.

Paivo, Yuille and Rogers (1969) have shown that the concreteness of stimuli is an important determinant of the difficulty of recall. Concrete words (for example, elephant, grass, magazine, tomahawk) are more easily recalled than are abstract words (for example, history, anxiety, profession, virtue). The effect of concreteness appears to be due to the fact that concrete words arouse vivid mental images while abstract words do not, and that imagery makes learning easier.

The original work on imagery was conducted in a paired associates learning context by Paivo, Yuille and Madigan (1968). A group of college students was asked to rate nouns for their capacity to arouse an image. The results confirmed the fact that some words were consistently considered more imaginal than others (elephant, orchestra, church versus contact, deed, virtue). The influence of imagery on paired associate learning was examined (stimulus words were matched for frequency and meaningfulness). Subjects were given stimulus and response words of a paired associate that were either high or low in imagery. The results showed that recall was the greatest when both the stimulus and the response words were high in imagery, and recall was the poorest when both words were low in imagery. It was concluded that high imagery (concrete) words were easier to recall than low imagery (abstract) words.

The influence of imagery on free recall has now been firmly established. Words high in imagery are much more successfully recalled than those low in imagery (Postman, 1975). Richardson (1975a, 1975b) has shown that although concreteness is usually linked to imagery, within the category of concrete words, some can be ranked high in imagery, some low. In one of his experiments, in which the recall of concrete words either high or low in imagery was compared, it was found that there was no difference between imagery conditions thus, although concrete stimuli were also usually high imagery stimuli, it is the concreteness that is the determinant of recall.

In a very recent study, Christian, Bickley, Tarka and Clayton (1978) established norms for the recall of 900 English nouns. The probability of recall for each noun was correlated with the noun's imagery, concreteness, meaningfulness and frequency. This study again confirmed that concreteness is a potent predicter of recall.

RATIONALE FOR THE CURRENT STUDY

It has been established that unattended information is occasionally processed. Most research dealing with this phenomena has utilized the auditory modality, probably due to the methodological conveniences associated with audition and selective attention (as was outlined in a previous section of this paper). Recently, a paradigm was designed which would permit well controlled investigations of processing of unattended information utilizing the visual modality (Wolford & Morrison, 1980). This present series of studies was designed to utilize the visual modality, taking advantage of Wolford and Morrison's paradigm.

The study by Wolford and Morrison was considered a visual analog of auditory selective attention paradigms. Results paralleled auditory selective attention results in that subjects were generally unaware of the unattended information (as was first found by Cherry in 1953), but were aware of their own name when that was present in the unattended information (as was first found by Moray in 1959) The goal of this series of investigations was to extend those findings. While there has been a great deal of work done with the auditory modality, very little has been done with the visual modality. It was hoped that additional similarities would be found.

It seems that unattended auditory information is probably processed semantically. Studies conducted by Treisman (1960) and Gray and Wedderburn (1960) support this fact. Additional evidence for semantic processing comes from studies conducted by Lackner and Garrett (1972) and MacKay (1973). Subjects were presented ambiguous sentences to their attended ear and, simultaneously, information to their unattended ear which would disambiguate those sentences. Subjects were later asked to paraphrase the sentences or select a sentence that was close in meaning (to the presented sentence) from a set of alternatives. Although subjects reproted no awareness or memory of the unattended information, that information significantly affected the direction in which the attended sentences were disambiguated. The present set of studies investigated whether or not unattended visual information is processed semantically. Three studies were conducted which investigated the clustering effect, the concrete superiority effect, and the Stroop interference effect. If, at the level of unattended information, the facilitative effects of clustering, a superiority of recognition for concrete versus abstract words, or a Stroop interference effect could be demonstrated, semantic processing would be implied.

Traditionally, there are two explanations which have been offered to account for processing of unattended information. As described in a previous section, these two explanations are: 1) that some words have a very low recognition threshold and are thus recognized very easily, even without attention delegated to them, and 2) some information is so familiar and processing so practiced that such processing becomes automatic - the processing of highly familiar items is accomplished without attention. Both of these explanations adequately account for the processing of very familiar unattended information, such as one's own name. The low recognition threshold theory states that recognition thresholds for certain words may be temporarily lowered when the probability of occurance of a given word is high. This would account for processing which is classified as semantic in the case of Treisman's and Gray and Wedderburn's results. Neither theory would account for the semantic processing of the type described by Lackner and Garret (1972) and MacKay (1973), however, although it may be argued that their results were not as strong as implied. Newstead and Dennis (1979) presented evidence that MacKay's results held only under certain specific conditions. This series of studies was designed in order to investigate semantic processing of unattended information in conditions which control for expectancy effects, or the probability of occurrance of given words, and which therefore cannot be accounted for with the current explanations.

Three studies were conducted using a paradigm similar to Wolford and Morrison's (1980): The unattended information was presented foveally and the unattended stimulus was always the only verbal stimulus present (in order to avoid expectancies). Single words were flanked by two single digits. The only word presented in each trial was the unattended word so that it would never be the case that recognition thresholds were temporarily lowered due to high probabilities of given words occurring (as was the case in Treisman's and Gray and Wedderburn's studies).

The first experiment investigated the effect of clustering on processing of unattended information. Previous research has shown that subjects are better able to recall words when they are from a consistent category or chunk (such as, animals or professions), than when they are unrelated. This effect was tested with unattended information. If the information were truly unattended and not processed, presenting words from a consistent category would not aid recall. If words were processed, specifically semantically processed, subjects would notice that the unattended information is from a consistent category and thus, recall should be facilitated. Following the experimental tasks (add the two single digits from a series of trials), subjects were given a surprise two alternative forced choice recognition test. If they were aware of the fact that the unattended words were from one category or cluster (if they processed that information semantically), they should perform significantly better on the recognition test than if they were unaware of that fact (even if they did not remember specific words, awareness of the category of words would permit them to make "educated guesses").

If the unattended words were processed and subjects were aware of the word category, it would show a need to revise current explanations of unattended processing, as neither explanation described above can account for such an effect (the unattended words were not highly practiced or meaningful to the subjects, and there was no attended information which would have lowered the recognition thresholds for such words). If subjects were not aware of the word categories it would strenghten current explanations as it would imply that unattended information is processed only when it is highly familiar and/or meaningful.

The second experiment examined the effects of concrete versus abstract words at the level of unattended information. Research has shown that, at the level of attended information, concrete words are much easier to recall than are abstract words. Subjects were presented with either concrete stimuli or abstract stimuli (again flanked by single digits). Following the experimental task (adding the digits) subjects were given a surprise recognition test of the unattended information (the centered words). If that information were processed, concrete words should be remembered more often than abstract words. The results of this study will again be used to measure the adequacy of current explanations of unattended processing.

The final study in this series investigated Stroop type effects. Previous research has shown that if two dimensions of a stimulus are present, one representing an attribute and one representing an attribute name, interference will occur when a subject is asked to respond to that attribute and to ignore that attribute name, if those two dimensions are conflicting (i.e., if the attribute and the attribute name represent two different things). Using the same paradigm as in the previous two studies, this effect was tested with unattended visual information. Subjects saw a word flanked by two single digits and were instructed to find the sum of the digits and to ignore the centered word. Sometimes the centered word was unrelated to the digits, sometimes it was equal to the sum of the digits (in which case the attribute and the attribute name were consistent), and sometimes it was a number that was equal to the sum of the digits, plus or minus one (in which case the attribute and the attribute name were inconsistent). Interference effects were tested by measuring response latencies (the time the digits were presented to the subjects until the time they reported the sum). Recall of the centered words was later measured with a surprise two alternative forced choice recognition test, as in the previous studies. The types of words recalled (if any) would again suggest ways in which the stimuli were processed (if at all) and ways in which current explanations of unattended processing should be revised (if necessary).

EXPERIMENT I

Method

Subjects. Sixty subjects participated in this experiment. All subjects were enrolled as students at Loyola University of Chicago at either the graduate or the undergraduate level. All subjects were screened for normal or corrected-to-normal vision using a Snellen eye chart.

Design. There were five groups in this experiment. All groups received six blocks of twenty trials each. On each trial the stimulus consisted of two single digit numbers seperated by five degrees of visual angle. All subjects were instructed to add the two digits as quickly and as accurately as possible. In four conditions there was a word positioned between the two digits. Subjects in these conditions were instructed to ignore that centered word. After the sixth block of trials subjects were given a surprise two alternative force choice recognition test (for the appropriate four conditions).

Condition 1 represented a control condition, in which subjects were simply asked to find the sum of the two single digits, without the presence of a centered word. The centered words in Condition 2 were from one category of words. The words in Condition 3 were from two categories (ten words from each category) and in Condition 4 were from four categories (five words from each category). Words in Condition 5 were unrelated semantically.

There were 12 subjects in each condition. Response latencies were measured in all conditions Recall of the centered words was tested in Conditions 2-5.

Apparatus and materials. Stimuli were presented to the subjects on a Scientific Prototype Tachistoscope, Model N-1000. An Erling Counter Timer Frequency Meter was interfaced to the tachistoscope and used to measure reaction times.

The stimuli for all trials, for all conditions, were two single digit numbers positioned on a screen at a distance of approximately five degrees of visual angle. The digits that were used were selected randomly, with the constraint that the sum of the digits would be less than ten. In Conditions 2-5 there was a word centered between the two digits. Examples of stimuli with and without centered words are shown in Figure 8. For each word condition the stimuli were either from one category, from two categories, from four categories, or from no discernible category. Appropriate words and categories were chosed from Cohen, Bousfield and Whitmarch's Cultural Norms for Verbal Items (1957).

A. 5 1

B. 6 WORD 2

Figure 8. Examples of stimuli used in Experiment I. A. A stimulus item used in Condition 1. B. A stimulus item of the type used in Conditions 2-5.

For each word condition two sets of stimulus words were chosen such that one set could be used as stimulus (test) items and one set as foil items in a subsequent two alternative forced choice recognition test. All stimulus words used for each condition are shown in Appendix A.

Following all experimental trials was a surprise two alternative forced choice recognition test in which subjects were asked to identify the centered words that they had seen. On this recognition test, stimulus (test) items were paired with foil items (the other set of stimulus words) matched for length and frequency (on the basis of Kucera and Francis' 1967 norms). In Condition 2, all stimulus items were either articles of clothing or animals; one set of words was used as test items and one set as foil items. In Condition 3, all stimulus items were either types of fruit and parts of the body or pieces of furniture and animals; one set of words was again used as test items and and one set was used as foil items. In Condition 4, all stimulus items were either metals, articles of clothing, parts of the body, and animals or types of fruit, modes of transportation, vegetables, and pieces of furniture; again one set of words was used as test items and one set as foil items. In Condition 5, two sets of words were selected which did not represent any discernible category; one set was used as test items and the other as foil items. In each of the above conditions the set of words used as test items and the set used as foil items were counterbalanced across subjects.

In order to avoid the possibility that subjects might not ignore the centered words on the first few trials, the first two blocks of trials utilized a list of 20 unrelated words, test items were not introduced until the third block of trials. All test items and foil items were randomly paired in the subsequent recognition test. The recognition tests used are shown in Appendix A, as are the initial 20 words used in Blocks 1 and 2 for Conditions 2 - 5.

Procedure. As a subject arrived he was tested for normal (20/20) vision using a Snellen eye chart. Assuming he had normal or corrected-to-normal vision (those who did not were not used as subjects), the experiment began. The subject sat in a dimly lighted room and viewed the tachistoscope screen binocularly.

At the start of each session the subject was told that he would see two digits separated by a word (except in Condition 1). He was to initiate each trial by pushing a button in front of him. When he pushed the button he would see the two digits and the word (or just the two digits in the case of Condition 1). His task was to add the digits as quickly as possible and to ignore the centered word, if present. When the digits appeared on the screen a clock started, as soon as he knew the sum he was to push the button again, stopping the clock, and report the sum to the experimenter. It was further explained that the purpose of the task was to see how quickly subjects were able to perform a simple task (adding the digits) in the presence of interference (the centered word) which was why he was to respond as quickly and as accurately as possible. He was told that his strategy should be to try to focus on the digits and ignore the centered word, if he started to read the centered word it would interfere and slow him down, and he should be trying to proceed as quickly as possible. Subjects in Condition 1 were told that the purpose was to see how quickly subjects could perform a simple task. When the subject initiated each trial a display appeared following a 1000 msec foreperiod. Each display was presented for a duration of 50 msec.

Each testing session was divided into six blocks of 20 trials each. In Conditions 2-5 the first two blocks used an initial set of centered words (as these blocks were considered practice trials where subjects might not be adequately ignoring the centered words). Response latencies for the first two blocks were not scored for any of the experimental conditions. The stimulus words of interest (the test items) were introduced in the third block of trials. Following all trials subjects were given a two alternative forced choice recognition test and asked to identify the centered words that they had seen (the words from Blocks 1 and 2 were not present).

Results.

An analysis of variance yielded no significant differences between response latencies for Blocks ($F(3,165=0.4613$, $p>.05$) or Conditions ($F(4,55)=0.330$, $p>.05$) and no significant Blocks by Conditions interaction ($F12,165=0.04178$, $p>.05$). Figure 9 shows the mean response latencies as a function of Blocks and Conditions. Performance did not improve with practice, as the experiment progressed from Blocks 3 through 6, reaction times did not change significantly (as mentioned above, because Blocks 1 and 2 were considered practice trials, responses for those blocks were not scored.

There was a significant difference between conditions for words recalled on the subsequent recognition test ($F(3,44)=3.23$, $p<.05$) as shown in Figure 10. Subjects recalled more words when they were from consistent categories than when they were from no discernible category.

Discussion.

There were no significant differences between response

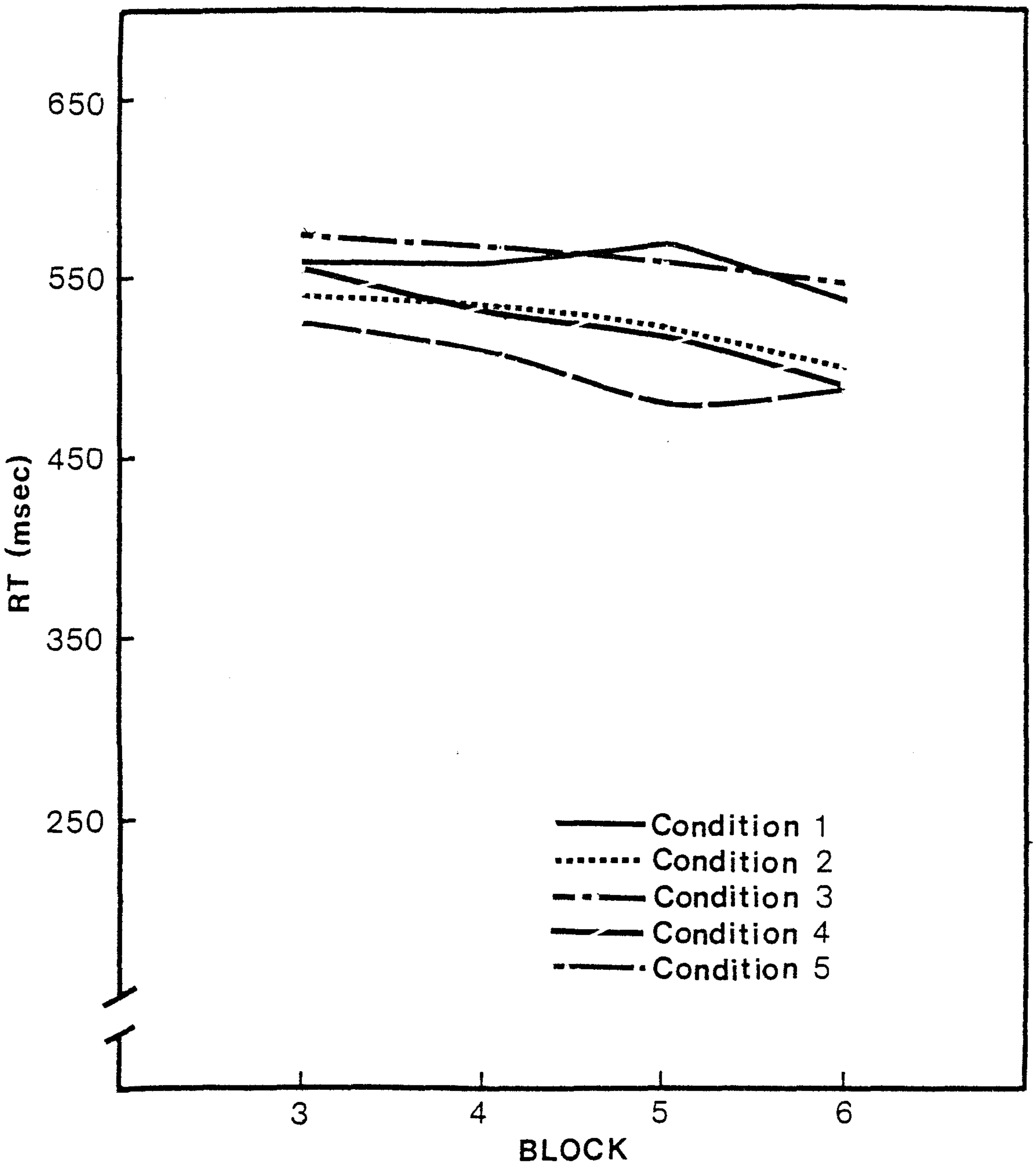

Figure 9. Mean response latencies as a function of block and condition (Experiment 1).

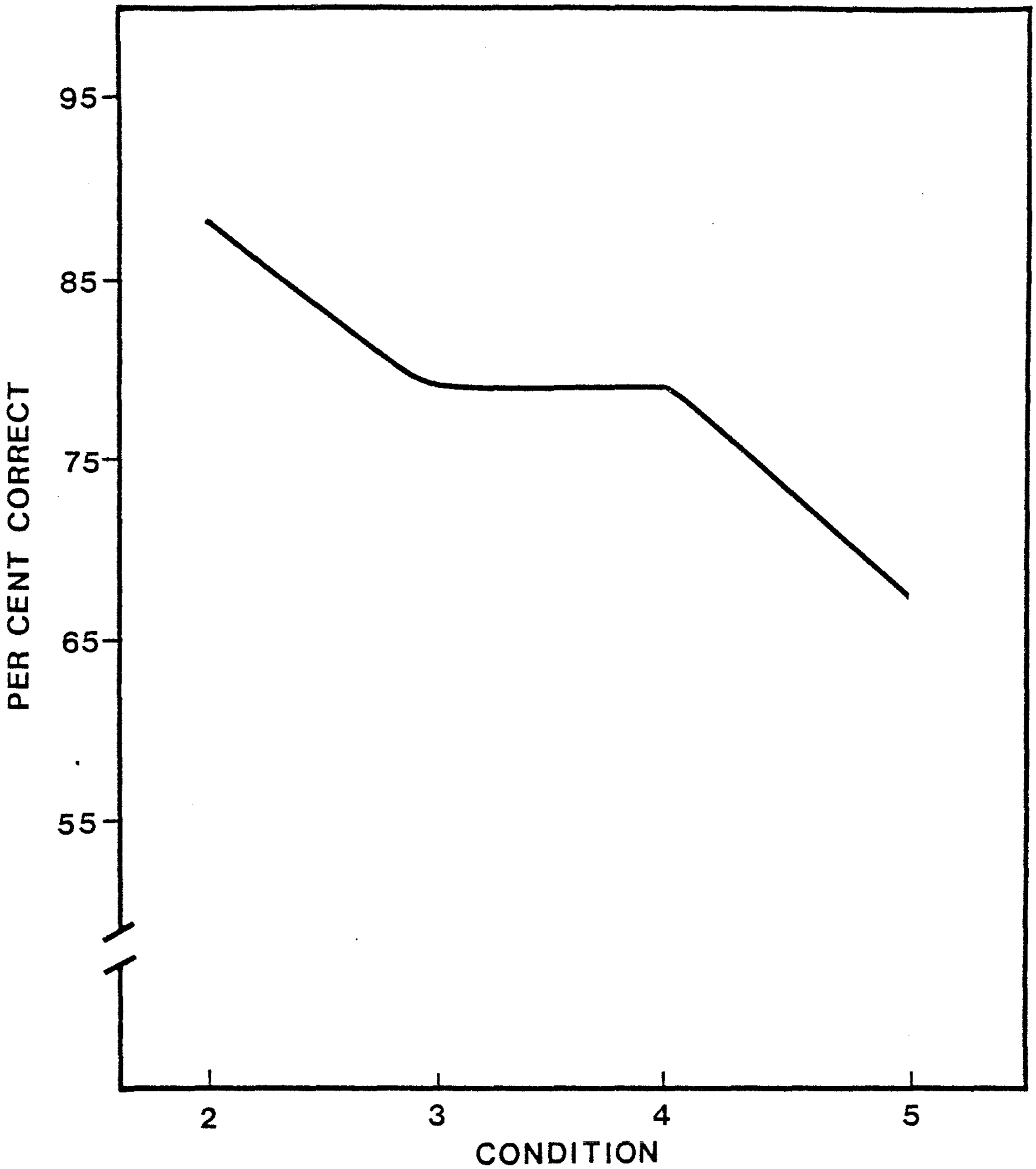

Figure 10. Percentage of words correctly recognized as a function of condition. Condition 2 - One category; Condition 3 - Two categories; Condition 4 - Four categories; Condition 5 - No discernible categories (Experiment 1).

latencies across conditions. Subjects did not display a practice effect for the last four blocks of trials (the trials of interest) and did not show any difference in response times across conditions. Both of these results reflect a very improtant foundation for the rest of this discussion. Since no practice effects were shown, it can be assumed that the initial practice trials (Blocks 1 and 2) were of sufficient number and served to bring subjects up to an adequate level of performance at the onset of the experimental trials. The fact that there were no differences across subjects shows that subjects were performing at the same speed regardless of whether or not there was a centered word present in the displays they saw (Condition 1 versus Conditions 2-5) and regardless of any characteristics of those centered words (Conditions 2-5). If those centered words were being processed in any way, it was without any extra time alloted to that processing function.

There was a significantly different number of words recalled on the subsequent recognition tests across conditions. Subjects recalled the most words under Condition 2 where all the test words were from the same category, and the least under Condition 5 where the test words were from no discernible category. As mentioned earlier, unless the subjects were processing the centered words semantically, they would never know that those words were of consistent categories and thus, there should be no difference across category conditions. Since there was a difference, it must suggest that subjects were aware of the category factor and were processing the material semantically.

It should be noted that one possible flaw in the design of this experiment is that subjects may have been able to correctly guess the appropriate words when tested in Condition 2. Because the test words were all from the same category and because the recognition test consisted of words from that category and from one other, subjects might have guessed that the presented words were all from the same category. There appeared to be no simple solution to this problem (it was decided that a recognition test was preferable to a recall test, and a recognition test where the foil items were all of different categories would have confounded the problem further), although it may indeed be a problem. It is suggested that this be born in mind when interpreting the results. It still appears that this effect is a strong one however; even if this condition is not considered, there is still a large difference between recognition rates for the other three conditions (although not quite significant).

Contrary to expectations, the recognition rate for the centered words was above chance in all conditions.

Even in Condition 5 (where the centered words were from no discernible semantic category), subjects correctly identified an average of 13.5 words on the subsequent recognition test. If only chance was operating, which was expected as a result of previous studies, subjects would have correctly identified and average of 10 words. That recognition was above chance in all conditions implies that subjects processed the centered words in all conditions, at least to some minimal degree.

EXPERIMENT II

Method.

Subjects. Forty eight subjects participated in this experiment. All subjects were enrolled as students at Loyola University of Chicago at either the graduate or the undergraduate level. All subjects were screened for normal or corrected-to-normal vision using a Snellen eye chart.

Design. There were four groups in this experiment. All groups received six blocks of 20 trials each. The overall design of this experiment was similar to the previous one in that all subjects saw two digits positioned at a distance of 5° of visual angle (from each other). In three conditions there was a word positioned between the digits which the subjects were instructed to ignore. After the sixth block of trials, subjects were given a surprise two alternative forced choice recognition test (for the appropriate conditions).

Condition 1 represented a control condition in which subjects were asked to compute the sum of the two digits, without the presence of a centered word. The centered words in Condition 2 were all concrete nouns. The words in Condition 3 were abstract words, and the words in Condition 4 were comprised of both concrete nouns and abstract words

(50% of each type). As in Experiment I, there were two sets of stimulus words selected for each condition such that one set was used as test items and one set was used as foil items in the subsequent recognition test (the use of words as test or foil items was counterbalanced across subjects). The stimulus words for each set (and each condition) were matched for length and frequency.

There were 12 subjects in each condition. Both response latencies and recall of the centered words were measured.

Apparatus and materials. The apparatus and materials used were virtually the same as in Experiment I. The only difference was that the stimulus words (test items and foil items) were changed. Initial stimulus words (those used in the first two blocks of trials), all subsequent stimulus words, and all subsequent recognition tests are shown in Appendix B. All stimulus items (test and foil items) were matched for length and frequency and randomly paired in the recognition test.

Procedure. The procedure utilized was the same as in Experiment I.

Results.

An analysis of variance yielded no significant differences between response times across conditions ($\underline{F}(3,44)=0.914$, $p>.05$) or across blocks ($\underline{F}(3,132)=0.1767$, $p>.05$), nor a significant interaction effect for Blocks by Conditions ($\underline{F}(9,132)=0.2259$, $p>.05$). Figure 11 shows the mean response latencies as a function of Block and Condition. It appears that response latencies did not change to a significant degree as the experiment progressed from block to block, or between the different experimental conditions.

An analysis of variance yielded no significant difference between the number of words recalled for each condition ($\underline{F}(2,33)=1.009$, $p>.05$). It should be noted, however, that although a significant difference was not found, more concrete words were recognized than abstract words, as shown in Figure 12 (recognition rates for the condition in which test items were ten concrete words and ten abstract words fell directly between the concrete only and the abstract only conditions). The trend for recognition rates was in the predicted direction.

Discussion.

No differences in response latencies as a function of Block or Condition were found. These results suggest that no practice effects were exhibited (performance did not change as the experiment progressed from Block 3 through Block 6) and that the time alloted to process the

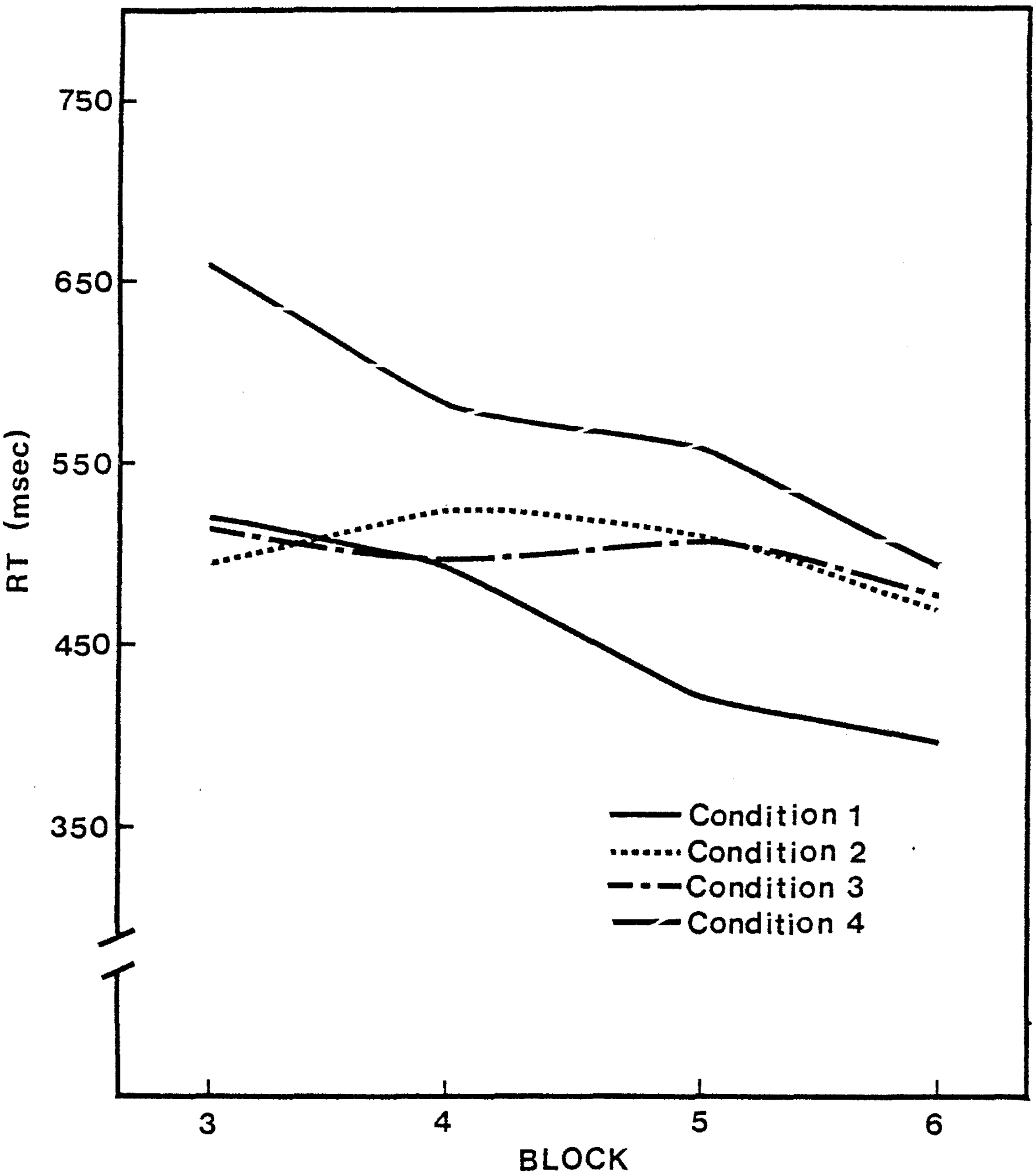

Figure 11. Mean response latencies as a function of block and condition (Experiment 2).

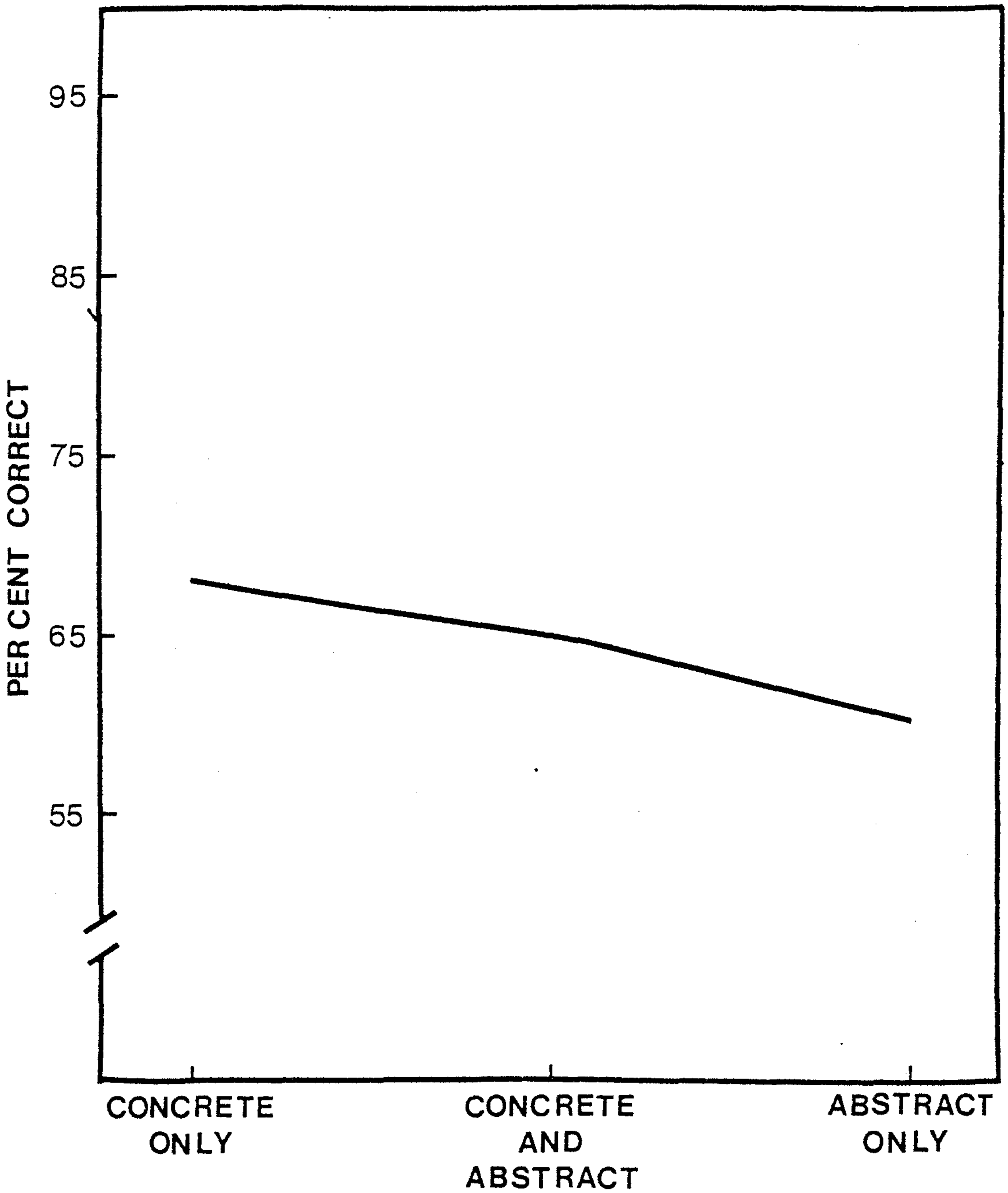

Figure 12. Percentage of words correctly recognized as a function of condition. Condition 2 - Concrete only; Condition 3 - Abstract only; Condition 4 - Concrete and Abstract (Experiment 2).

displays was the same regardless of the experimental condition (processing time was the same when there was no centered word present, when the centered word was concrete, when the centered word was abstract, and when the centered words were either concrete or abstract).

The lack of a difference between conditions for word recognition was surprising. It was predicted that concrete words would be remembered more successfully than abstract words and that recall for the condition which consisted of both concrete and abstract words would fall between the concrete only and abstract only recall rates. It should again be noted that the results were in the direction predicted, but that the differences were not large enough to reach significance. There are two possible explanations for this result.

First, the fact that the differences in this experiment did not approach significance was probably due to the fact that the number of subjects participating in this experiment was relatively small. The fewer the number of measurements taken in an experiment, the greater the differences must be in order to be considered significant. If the differences noted here remained consistent (thus, not due to chance) over a larger number of subjects they would have been considered significant.

Second, it was established in the first experiment that recognition memory for a list of 20 unrelated words was poor (although significantly greater than chance). In all conditions within the present experiment the word lists consisted of unrelated words. The weak effect exhibited in this experiment was probably due in part to a floor effect. The differences might have been larger if this floor effect had been avoided. One way in which this problem might be overcome in a future experiment would be to present words from consistent categories for all conditions.

Moreover, as mentioned eariler, when selecting the stimulus items care was taken to select items that could be classified as either concrete or abstract and to match all test and foil items for frequency and length. In a future study, the effects suggested here might be strenghtened if the stimulus words were selected such that (in addition to the constraints mentioned above) the concrete words were highly concrete and the abstract words were very abstract (this could be done by checking the stimulus words against the Christian et.al. 1978 norms).

EXPERIMENT III

Method

Subjects. Thirty six subjects participated in this experiment. All subjects were enrolled as students at Loyola University of Chicago at either the graduate or the undergraduate level. All subjects were again screened for normal or corrected-to-normal vision using a Snellen eye chart.

Design. There were three groups in this experiment. All groups again received six blocks of 20 trials each. The overall design of this experiment was similar to that of the previous two experiments. Subjects saw similar types of stimuli under the same instructions. Condition 1 was a control condition in which subjects saw only digits with no centered words. Condition 2 was a condition similar to the above conditions in that the centered words were a set of unrelated nouns. Of the words in Condition 3, 80% were unrelated nouns, 10% were words equal to the sum of the digits (for any particular trial), and 19% were words equal to one plus or minus the sum of the digits for any particular trial (half were equal to one plus the sum, half were equal to the sum minus one). As in the previous studies, for each word condition two sets of stimulus words were selected such that one set was used as test items and one set as foil items in the subsequent recognition test (words used as test or foil items was counterbalanced across subjects).

Again, there were 12 subjects per condition. Response latencies and recall of the centered words were measured.

Apparatus and materials. The apparatus and materials used were virtually the same as in the previous experiments. The only difference was that the stimulus words (test items and foil items) were changed. All stimulus items were again matched for length and frequency and randomly paired in the recognition test. Initial stimulus words (those used in the first two blocks of trials for all word conditions), all subsequent stimulus words, and all subsequent recognition tests are shown in Appendix C.

Procedure. The procedure utilized was the same as in Experiments I and II.

Results

An analysis of variance yielded no significant differences between response latencies across blocks ($F(3,99)$= 0.4603, p .05) or across conditions ($F(2,33)$=0.9247, p .05). There was no significant difference found for the Blocks by Conditions interaction ($F(6,99)$=0.1502, p .05). Figure 13 shows the mean response latencies as a function of Block by Condition. It appears that reaction time to the stimuli did not change to a significant degree as the experiment progressed from block to block, or between the different experimental conditions.

As it was felt that the Stroop type stimuli might alter the reaction times in Condition 3, data for that condition was analyzed alone. Response latencies for the Stroop type stimuli where the attribute was the same as the attribute name (the centered number word was equal to the sum of the two flanking digits), and where the attribute was not equal to the attribute name (the centered number word was not equal to the sum of the flanking digits), and response latencies for non-Stroop type stimuli (the centered word was unrelated to the flanking digits) were compared. There were no significant differences found ($\underline{F}(2,33)=0.0928$, $p>.05$). These results are shown in Figure 14.

The mean number of words recognized for Conditions 2 and 3 were compared. The results did not reach significance ($\underline{t}(22)=1.22$, $p>.05$). It should be noted that more words were correctly recognized in Condition 3 (Stroop) than in Condition 2 (unrelated words), as shown in Figure 15.

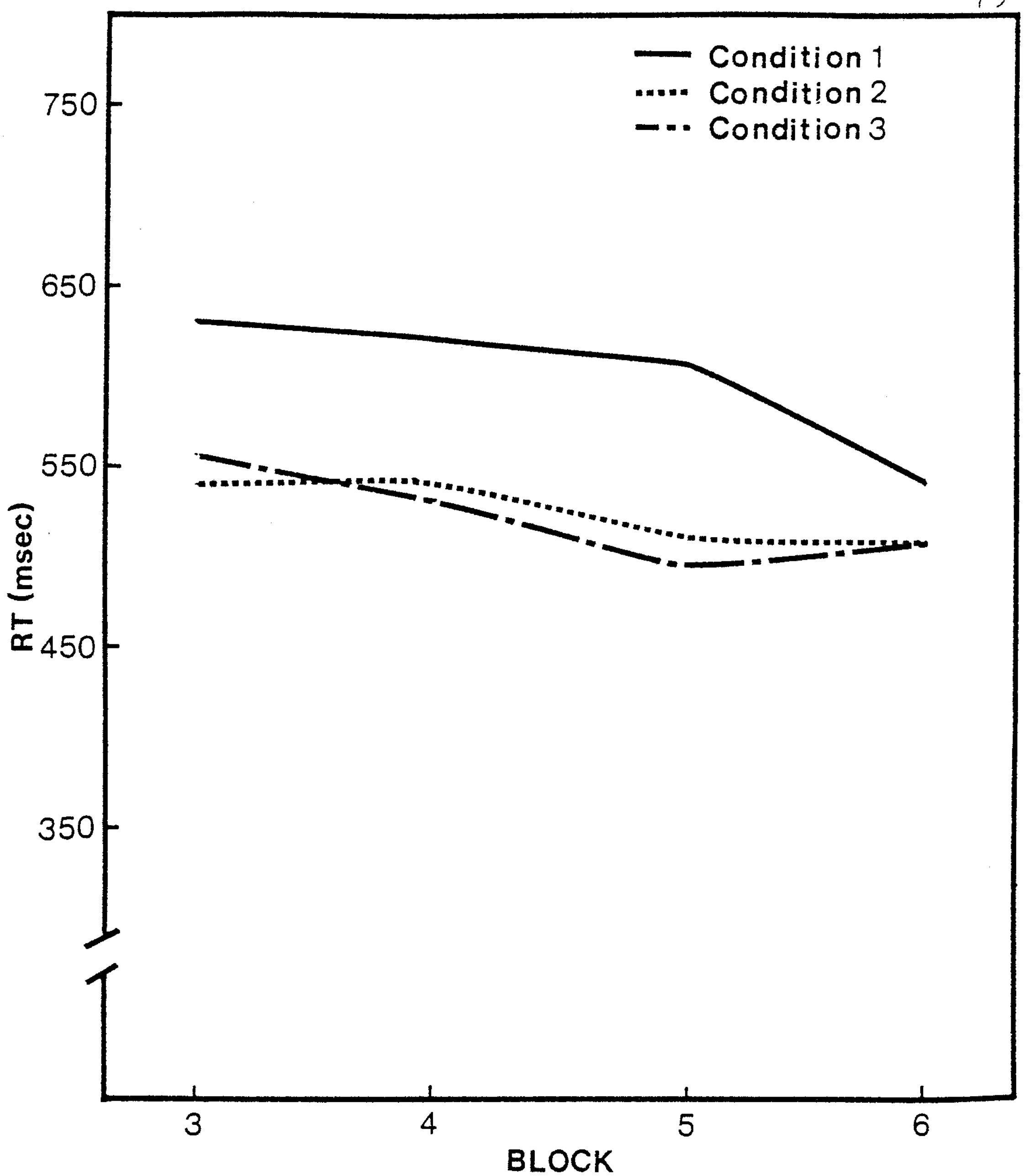

Figure 13. Mean response latencies as a function of block and condition (Experiment 3).

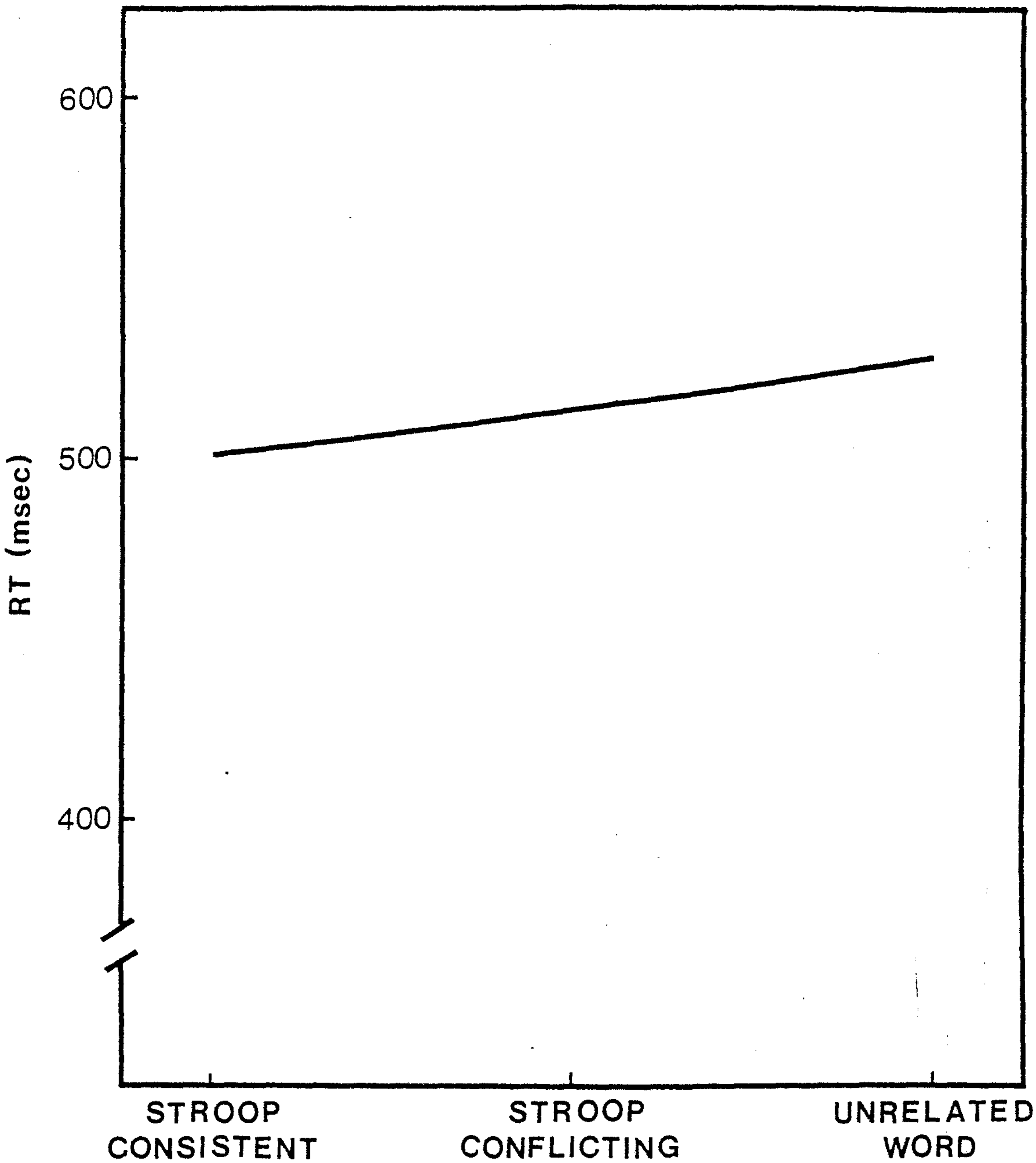

Figure 14. Mean response latencies as a function of the category of the centered words (Experiment 3; Condition 3).

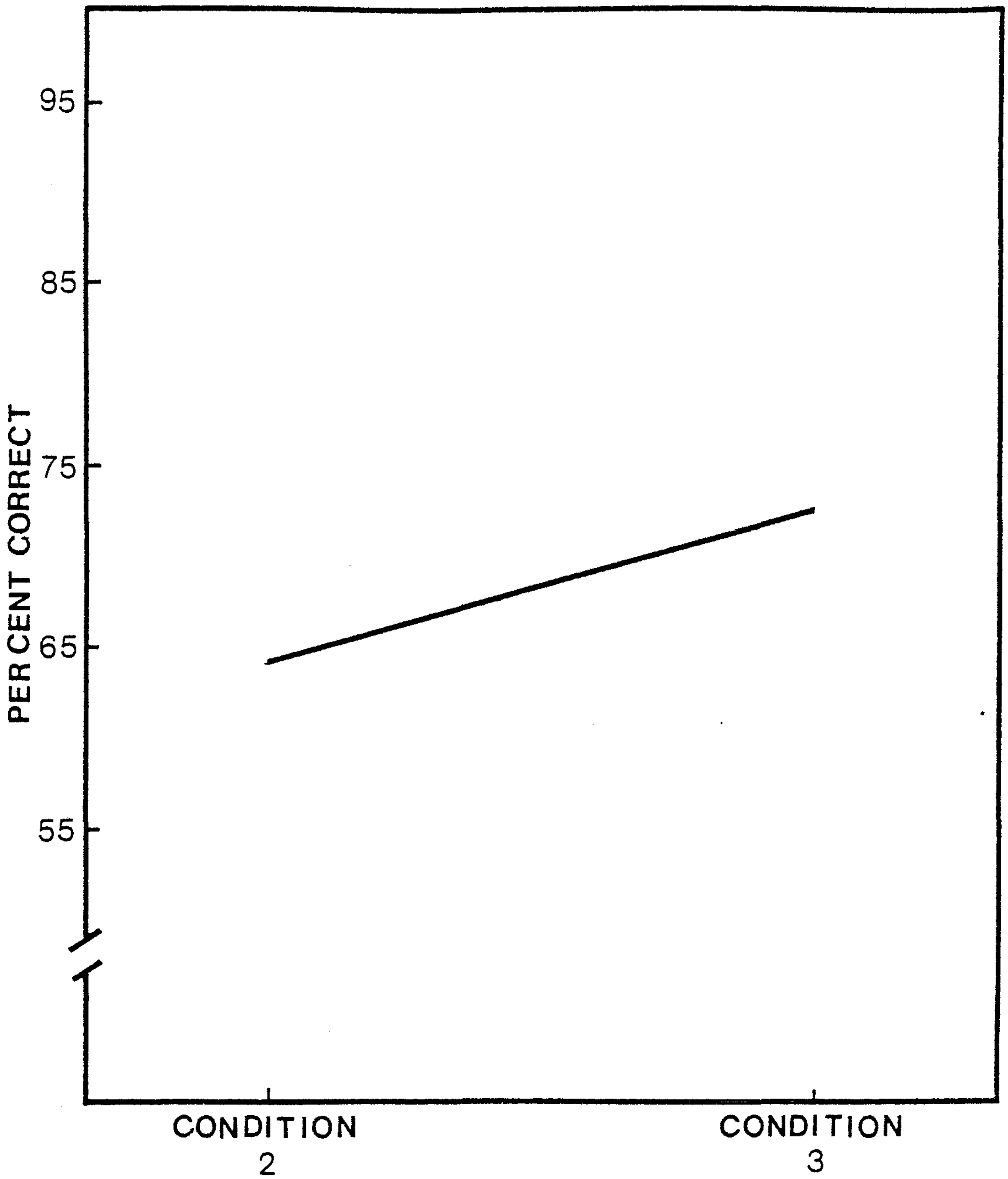

Figure 15. Percentage of words correctly recognized as a fuction of condition. Condition 2 - Unrelated words; Condition 3 - Stroop type stimuli (Experiment 3).

A further analysis was done on the number of words correctly recognized in Condition 3. Words correctly recognized when they were consistent Stroop types, conflicting Stroop types, and unrelated to the flanking digits were compared. No significant differences were found ($\underline{F}(2,22) = 1.942$, $p > .05$). These results are shown in Figure 16.

Discussion

As in the previous two experiments, no differences in response latencies as a function of Blocks or Conditions were obtained. These results suggested that no practice effects were exhibited and that the time alloted to process the stimulus displays was the same regardless of the experimental condition.

It was very surprising that the Stroop type stimuli did not alter reaction times in Condition 3, as this is contrary to the classical Stroop findings. There are two possible explanations for this. As mentioned in the previous literature review, it has been suggested that Stroop interference occurs when one process (usually reading a color word) is faster than another process (usually naming the color of the ink). In this case, the two processes examined were reading (the centered words) and adding (the flanking digits). In this case, it may be that the interference did not occur because reading may not be faster

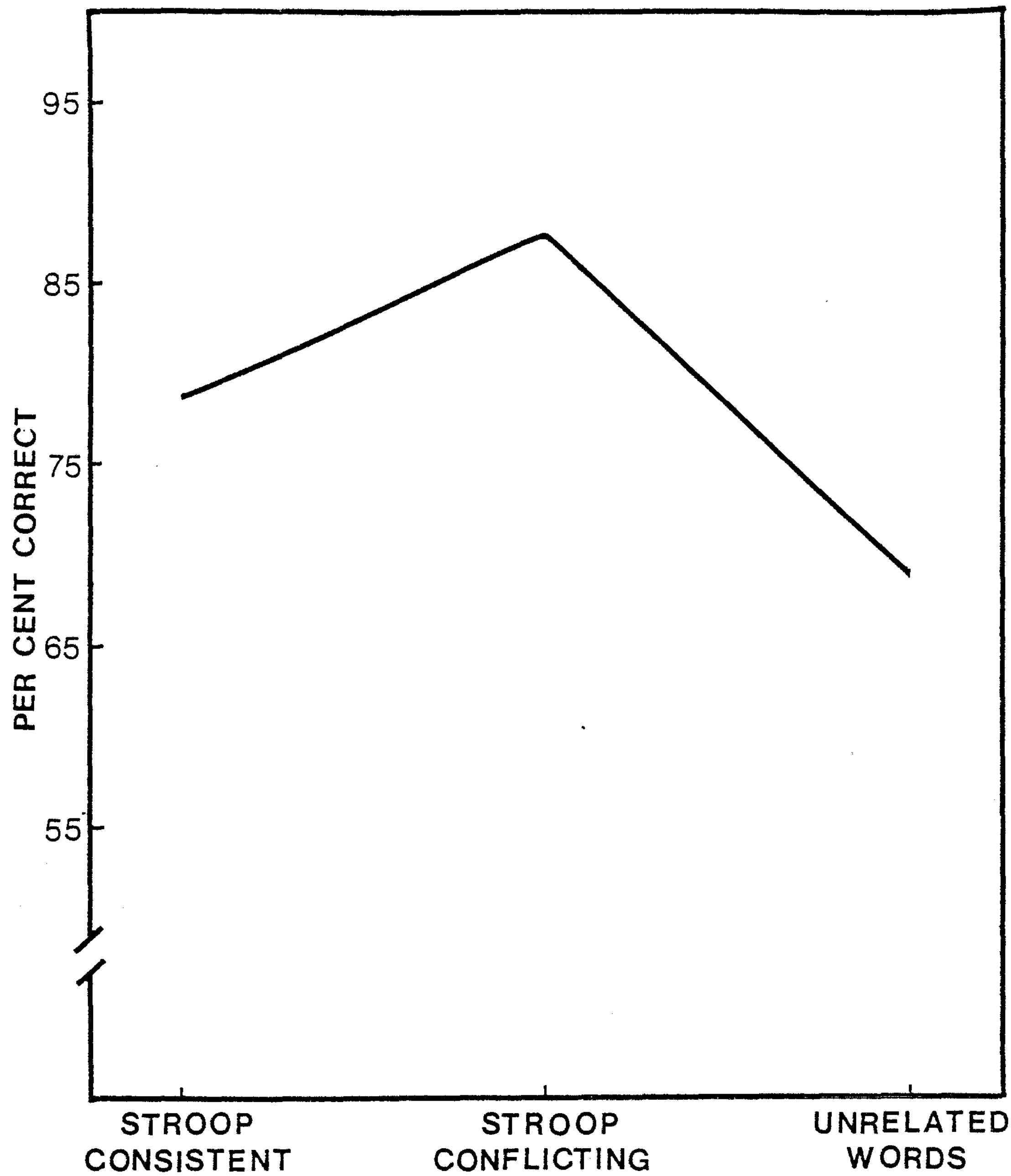

Figure 16. Percentage of words correctly recognized as a function of the category of the centered words (Experiment 3; Condition 3).

than adding (at least under these conditions, when the sum of the two digits was always less than ten).

In classical Stroop studies, subjects view a number of Stroop type stimuli in succession and identify the instructed attribute of those stimuli. In this experiment, only 20% of all stimuli could be classified as Stroop type, with only 10% conflicting Stroop stimuli. This was due to the fact that a subsequent surprise recognition test was used to test subjects' recall of the centered words. Obviously, only a few numbers could have been used or it would have rendered the test invalid. It may be that, because only a small proportion of the stimuli were actually Stroop stimuli, subjects became more practiced at not alloting time to that interfering attribute (since it only actually conflicted once in a while) than they do under a more traditional Stroop paradigm.

No significant differences between the number of words correctly recognized for Conditions 2 and 3 were found. It was expected that more words would have been recalled in Condition 3, as the Stroop stimuli were expected to be more meaningful to the subjects than the unrelated words. This trend was evident (more words were recalled in Condition 3), but the differences were not large enough to be considered significant. As mentioned previously, this lack of significance was probably due, in part, to the relatively small number of subjects participating in this experiment.

Moreover, if the centered words were changed so that there was not such a poor overall recognition rate, the expected differences might be apparent. It is expected that if this floor effect were avoided, more words would have been recognized under the Stroop condition than under the unrelated words condition. Within the Stroop condition, it would be expected that the conflicting Stroop-type stimuli would be recognized the most successfully, followed by the non-conflicting Stroop type and the unrelated words.

GENERAL DISCUSSION

This series of studies was designed in order to see if visual selective attention was similar to auditory selective attention, if and when unattended information is "processed", what type of processing occurs at the level of unattended information, and finally, to evaluate the adequacy of two unattended processing explanations.

Perhaps the most consistent and striking finding in this research was the fact that response latencies did not change to a significant degree across all conditions in all experiments. Subjects completed the experimental task (adding the digits) at the same speed regardless of whether or not there was a word present between those digits and regardless of whether or not those centered words (across trials) were of the same category, were of different categories, were concrete, were abstract, or were Stroop type stimuli. It has previously been assumed that if no additional time was alloted to additional stimuli (RT without versus RT with centered words), those additional stimuli were not being attended to and were not being processed.

Shiffrin and Gardner (1972) have shown that, at least in the initial stages of visual processing, processing takes place without capacity limitations and without attentional control. In a letter detection task it was found that subjects were performing with equal success when they were asked to detect letters from a set of four letters displayed simultaneously and when asked to detect them from a series of four letters displayed sequentially. That response latencies did not change in the present experiments with or without the presence of a centered word does not necessarily imply anything about processing those words (bearing Shiffrin and Gardner's results in mind). The fact that no additional time was used to process the presented information does not necessarily reflect the fact that no additional processing occured.

Another common assumption when dealing with "unattended information" is that if subjects do not remember the presented information, it was not processed. It is easy to see how this assumption came about. Although it might be hard to imagine not seeing the centered words, after completing a series of trials of the type used in this experiment, subjects seem to become unaware of those words. For the first few trials the centered word is clearly seen between the two digits, but after a while the digits are focused on and the word is really not consciously attended to. Anyone who questions this should view a few trials of this type himself. After viewing a few trials, most people are quite certain that the centered words are not processed.

Following all trials, subjects were given a surprise recognition test. Judging from their reactions and comments this test was really a surprise, and to expect them to recognize words they never "saw" was about as reasonable as asking them to predict what words they would see before the start of the experiment. Subjects did not think they saw the words and felt quite certain that they could not recognize the words. Based on the subjects' reactions one would almost certainly assume that the words were never processed. On the basis of the results of this series of studies, however, this appears to be a faulty assumption.

Recognition memory was better than subjects thought it would be. While many subjects swore they had no idea what words were being presented, and that they were randomly indicating words in the subsequent recognition test, performance in all cases was better than chance (although only slightly). Moreover, even when subjects could not remember the words that were presented, this does not necessarily imply that they did not process those words. In previous studies the unattended information was always random and irrelevant to the experimental task, except in the cases where the unattended information was the subject's name, when it disambiguated the shadowed message, or when it completed a sentance started in the shadowed channel - and in all of these cases the unattended information was remembered! The fact that subjects did not retain contentless, irrelevant messages does not prove that they were completely unaware of them.

Under several conditions within this present series of studies the centered words were chosen such that they would be easier to remember than under other conditions (i.e. words of consistent categories versus no categories; concrete words versus abstract words). When words were selected that were easy to remember (i.e. words that were chunked into one category), subjects performed significantly better on the subsequant recognition test than they did when words were selected that could not be remembered as easily. The lack of significance amoung other conditions may be attributed to floor effects (due to the difficulty of remembering the stimulus words). It does not seem at all logical to assume that under some conditions the centered words were processed and under some conditions they were not when the same experimental procedure was used across all conditions. What is logical to assume however, is the fact that under some conditions the centered words were remembered more successfully than under other conditions. This differential recognition effect reflects the ease of recall of the centered words between conditions, it does not reflect a differential processing rate between conditions.

An assumption prevalent in the Stroop literature is that subjects cannot "turn off" the processing of highly familiar information even if they want to, and that this processing interferes with the processing of other information. This assumption has been formed on the basis of the interference effect of one attribute on the processing of another attribute of the stimuli being processed (when the attributes are of the same response class but represent conflicting attributes). This interference effect is very robust and has been shown in almost all Stroop studies. In all of those Stroop studies subjects are asked to respond to a long series of stimuli, all of which contain a conflict between the attributes. In the present experiment, Stroop type stimuli were only 20% of the total number of stimuli presented to the subjects (due to other experimental constraints). The interference effect was not exhibited. It seems that in an experiment in which conflicting attributes were rarely present (attributes represented the same response class for 20% of the trials - 10% were consistent and 10% were conflicting) subjects were able to "turn off" the interference effect of processing those attributes. When conflicting attributes rarely occurred subjects were able to train themselves to allot an equal amount of time to monitering those attributes as they did to moniter all other stimulus attributes.

On the basis of the results of this series of studies, it is believed that "unattended" visual processing is similar to "unattended" auditory processing. It seems that unattended (peripheral) information is processed even when it is not highly meaningful or highly familiar to the subjects. The critical distinction seems to be between the PROCESSING of unattended information and the later RECOGNITION of unattended information. It appears that unattended messages are processed, specifically semantically processed (with both auditory and visual stimuli), but unless those messages are meaningful or relevant to the subject or his experimental task, they aren't remembered (or at least not sufficiently for accurate recognition).

In the case in which a subject's name is presented, he remembers it because it is so meaningful to him. In the case of the presentation of a series of unrelated words, irrelevant both to the subject personally and to the task at hand, subjects would not be expected to retain that information. When unattended information is presented that is irrelevant but is very simple to remember (such as a series of types of fruit), subjects can be expected to retain that information without effort, at least temporarily.

Again, it cannot be assumed that because information is not remembered it was not processed. Processing of information and the subsequent recognition of information are very distinct processes which sometimes, but do not always go together. The explanations of processing unattended information discussed earlier account very nicely for the processed unattended information which is usually retained and recognized: Information which is very meaningful to the subjects. They do not account for information that is not necessarilly meaningful but is very easily retained and they do not even come close to accounting for all the unattended information which is processed but not retained.

It appears that only slight modifications of current explanations are needed to account for all unattended information that is retained. A model that accounts for all the unattended information that is processed, however, must be much more complex, much more sophisticated, and much more sensitive than any of the gross processing models suggested to date.

REFERENCE NOTES

1. Neisser, U. *Selective reading: A method for the study of visual attention.* Paper presented at the 19th International Congress of Psychology, London, 1969.

REFERENCES

Anderson, J.R. *Cognitive psychology and its implications*. San Francisco: W.H. Freeman and Company, 1980.

Bousfield, W.A. The occurence of clustering in the recall of randomly arranged associates. *Journal of General Psychology*, 1953, *49*, 229-240.

Bower, G.H., Clark, M.C., Winzenz, D. & Lesgold, A.M. Hierarchical retrieval schemes in the recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior*, 1969, *8*, 421-430.

Bower, G.H. & Springston, F. Pauses of recording points in letter series. *Journal of Experimental Psychology*, 1970, *83*, 421-430.

Brener, R. The experimental investigation of memory span. *Journal of Experimental Psychology*, 1940, *26*, 467-482.

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

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

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

Christian, J., Bickley, W., Tarka, M. & Clayton, K. Measures of the recall of 900 English nouns: Correlations with imagery, concreteness, meaningfulness and frequency. *Memory and Cognition*, 1978, *6*, 379-390.

Cohen, B.H. Recall of categorized word lists. *Journal of Experimental Psychology*, 1963, *66*, 227-234.

Cohen, B.H. Some or none characteristics of coding behavior. *Journal of Verbal Learning and Verbal Behavior*, 1966, *5*, 182-187.

Cornsweet, T.N. Visual perception. New York: Academic Press, 1970.

Dukes, W.F. & Bastion, J. Recall of abstract and concrete words equated for meaningfulness. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 455-458.

Dyer, F.N. A comparison of chromatic and achromatic versions of the Stroop color-word test. Psychonomic Science, 1971. 22, 235-237. (a)

Dyer, F.N. The duration of word meaning responses: Stroop interference for different preexposures of the word. Psychonomic Science, 1971, 25, 229-231. (b)

Fraisse, P. Why is naming longer than reading? Acta Psychologica, 1969, 30, 96-103.

Gorman, A. Recognition memory for nouns as a function of abstractness and frequency. Journal of Experimental Psychology, 1961, 61, 23-29.

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

Hasher, L. & Zacks, R. Automatic and effortful processes in memory. Journal of Experimental Psychology: General, 1979, 108, 356-388.

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

Hintzman, D.L. The psychology of learning and memory. San Francisco: W.H. Freeman and Company, 1978.

Hirst, W., Spelke, E., Reaves, C., Caharack, G. & Neisser, U. Dividing attention without alternation or automaticity. Journal of Experimental Psychology: General, 1980, 109, 98-117.

Hoffman, J.E. Interaction between global and local levels of form. Journal of Experimental Psychology: Human Perception and Performance, 1980, 6, 222-234.

James, W. Principles of psychology, New York: Holt, 1890.

Jensen, A.R. & Rohwer, W.D. The Stroop color-word test: A review. Acta Psychologica, 1966, 25, 36-93.

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

Kinchla, R.A. Detecting target elements in multidimensional arrays: A confusability model. Perception and Psychophysics, 1974, 15, 149-158.

Kinchla, R.A. & Wolfe, J.M. The order of visual processing: "Top-down," "bottom-up," or "middle-out". Perception and Psychophysics, 1975, 25, 225-231.

Klein, G.S. Semantic power measured through the interference of words with color naming. American Journal of Psychology, 1964, 77, 576-588.

Kucera, H. & Francis, W.N. Computational analysis of present day American English. Providence, R.I.: Brown University Press, 1967.

Lackner, J.R. & Garrett, M.F. Resolving ambiguity: Effects of biasing context in the unattended ear. Cognition, 1972, 1, 359-372.

Logan, C.D. & Zbrodoff, N.J. When it helps to be misled: Facilitative effects of increasing the frequency of conflicting stimuli in a Stroop-like task. Memory and Cognition, 1979, 7, 166-174.

Lupp, L.U., Hauske, G. & Wolf, W. Perceptual latencies to sinusoidal gratings. Vision Research, 1976, 16, 969-972.

MacKay, D.G. Aspects of the theory of comprehension, memory, and attention. Quarterly Journal of Experimental Psychology, 1973, 25, 22-40.

Martin, M. Local and global processing: The role of sparsity. Memory and Cognition, 1979, 7, 476-484.

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.

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

Navon, D. Forest before the trees: The precedence of global features in visual perception. Cognitive Psychology, 1977, 9, 353-383.

Newstead, S.E. & Dennis, I. Lexical and grammatical processing of unshadowed messages: A re-examination of the MacKay effect. Quarterly Journal of Experimental Psychology, 1979, 31, 477-488.

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

Paivo, A. Learning of adjective noun paired associates as a function of adjective noun word order and noun abstractness. Canadian Journal of Psychology, 1963, 17, 370-379.

Paivo, A., Yuille, J.C. & Madigan, S.A. Concreteness, imagery, and meaningfulness values for 925 nouns. Journal of Experimental Psychology Monograph Supplement, 1968, 76, Part 2.

Paivo, A., Yuille, J.C. & Rogers, T.B. Noun imagery and meaningfulness in free and serial recall. Journal of Experimental Psychology, 1969, 79, 504-514.

Palef, S.R. & Olson, D.R. Spatial and verbal rivalry in a Stroop like task. Canadian Journal of Psychology, 1975, 29, 201-209.

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

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 Associates, 1975.

Postman, L. Verbal learning and memory. _Annual Review of Psychology_, 1975, _26_, 291-335.

Richardson, J.T.E. Imagery, concreteness and lexical complexity. _Quarterly Journal of Experimental Psychology_, 1975, 27, 211-223. (a)

Richardson, J.T.E. Concreteness and imageability. _Quarterly Journal of Experimental Psychology_, 1975, _27_, 235,249.

Ridley, D.R., Johnson, D.E. & Braisted, P.D. The color-word connotative incongruity effect. _Perceptual and Motor Skills_, 1978, _46_, 939-946.

Schneider, W. & Shiffrin, R.M. Controlled and automatic human information processing: I. Detection, search and attention. _Psychological Review_, 1977, _84_, 1-66.

Seymour, P.H. Stroop interference in naming and verifying spatial locations. _Perception and Psychophysics_, 1973, _14_, 95-100.

Shiffrin, R.M. & Gardner, G.T. Visual processing capacity and attentional control. _Journal of Experimental Psychology_, 1972, _93_, 72-82.

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.

Shor, R.E. The processing of conceptual information on spatial directions from pictorial and linguistic symbols. _Acta Psychologica_, 1970, _32_, 346-365.

Solso, R.L. _Cognitive psychology_, New York: Harcourt, Brace, Jovonovich, 1979.

Stroop, J.R. Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643-662.

Townsend, J.T., Taylor, S.G. & Brown, D.R. Lateral masking for letters with unlimited viewing time. Perception and Psychophysics, 1971, 10, 375-378.

Treisman, A. Verbal cues, language, and meaning in selective attention. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.

Treisman, A. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16.

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

White, B.W. Interference in identifying attributes and attribute names. Perception and Psychophysics, 1969, 6, 166-168.

Wolford, G. & Hollingsworth, S. Retinal location and string position as important variables in visual information processing. Perception and Psychophysics, 1974, 16, 437-442.

Wolford, W. & Morrison, F. Processing of unattended visual information. Memory and Cognition, 1980, 8, 521-527.

APPENDIX A

STIMULUS WORDS USED IN THE FIRST TWO BLOCKS OF TRIALS

HUT

OAK

VENUS

PATHS

PEPPER

CONE

PIT

GROVE

COMPASS

SEATS

NAILS

CURE

CAKE

BOOT

LEVER

ARCH

RABBIT

COPPER

RAKE

PIE

TEST ITEMS USED IN CONDITION 2

SET A	SET B
TOPCOAT	DOG
COAT	GOAT
CAP	BEAR
PANTS	LAMB
SWEATER	DEER
SOCKS	TIGER
JACKET	CAT
BLOUSE	ELEPHANT
GLOVES	BULL
SHIRT	MOUSE
SLACKS	FOX
OVERCOAT	WOLF
SHORTS	LION
SKIRT	COW
SHOES	MONKEY
SCARF	PIG
GOWN	PONY
TIE	RABBIT
BELT	SHEEP
JEANS	BEAVER

RECOGNITION TEST USED IN CONDITION 2

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	GOWN	DOG
2.	TIE	GOAT
3.	BEAR	GLOVES
4.	LAMB	SHORTS
5.	SOCKS	DEER
6.	CAP	TIGER
7.	SCARF	CAT
8.	ELEPHANT	SKIRT
9.	JEANS	BULL
10.	OVERCOAT	MOUSE
11.	SLACKS	FOX
12.	COAT	WOLF
13.	LION	SHOES
14.	COW	BELT
15.	MONKEY	TOPCOAT
16.	PIG	SWEATER
17.	PONY	JACKET
18.	SHIRT	RABBIT
19.	SHEEP	PANTS
20.	BEAVER	BLOUSE

TEST ITEMS USED IN CONDITION 3

SET A	SET B
LIP	TIGER
EAR	RUG
THROAT	COUCH
WRIST	BEAR
ANKLE	PIG
FIG	STOOL
PEAR	PIANO
KNEE	MOUSE
LEMON	LAMP
TOE	BUFFET
BANANA	DEER
PEACH	BENCH
ORANGE	WOLF
CHERRY	MULE
APPLE	FOX
LIME	STOVE
ELBOW	COW
PLUM	SOFA
RIBS	MONKEY
TOOTH	ROCKER

RECOGNITION TEST USED IN CONDITION 3

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	TIGER	LEMON
2.	RUG	WRIST
3.	LIP	COUCH
4.	BEAR	LIME
5.	PLUM	PIG
6.	STOOL	TOE
7.	CHERRY	PIANO
8.	TOOTH	MOUSE
9.	BANANA	LAMP
10.	BUFFET	THROAT
11.	DEER	EAR
12.	ELBOW	BENCH
13.	WOLF	APPLE
14.	RIBS	MULE
15.	PEAR	FOX
16.	FIG	STOVE
17.	COW	ANKLE
18.	SOFA	PEACH
19.	KNEE	MONKEY
20.	ROCKER	ORANGE

TEST ITEMS USED IN CONDITION 4

SET A	SET B
ZINC	POTATO
TIN	LAMP
DEER	COUCH
BULL	STOOL
LIP	CABBAGE
JEANS	BEANS
FOX	JEEP
COPPER	PEPPER
WRIST	RUG
LION	LEMON
BRONZE	STOVE
SKIRT	SUBWAY
TEETH	ORANGE
TIRE	LIME
RIBS	JET
SLACKS	SAILBOAT
ELBOW	TAXI
BRASS	PENS
SWEATER	APPLE
MONKEY	PEACH

RECOGNITION TEST USED IN CONDITION 4

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	CABBAGE	LIP
2.	JEEP	FOX
3.	SUBWAY	SKIRT
4.	BRASS	PENS
5.	TAXI	ELBOW
6.	DEER	COUCH
7.	BEANS	JEANS
8.	BULL	STOOL
9.	ZINC	POTATO
10.	LAMP	TIRE
11.	MONKEY	PEACH
12.	BRONZE	STOVE
13.	RIBS	JET
14.	PEPPER	COPPER
15.	WRIST	RUG
16.	LIME	TIN
17.	SLACKS	SAILBOAT
18.	TEETH	ORANGE
19.	APPLE	SWEATER
20.	LEMON	LION

TEST ITEMS USED IN CONDITION 5

SET A	SET B
DRUM	JUICE
TANK	RIB
TIN	STEREO
BRONZE	PINT
TUB	BUBBLE
CLIFF	DOT
SODIUM	DOLLS
LEAF	PLOW
FERRY	GHOST
WIRES	GLOBE
DENTIST	CEMENT
LIME	ASH
SAIL	TOURIST
MAP	BLADE
STREET	RUG
ORGAN	SILK
BEE	CALF
BABIES	SHELF
BEDS	PUMP
ATLAS	COUCH

RECOGNITION TEST USED IN CONDITION 5

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	BEE	CALF
2.	WIRES	GLOBE
3.	BEDS	PUMP
4.	ATLAS	COUCH
5.	BABIES	SHELF
6.	DOT	CLIFF
7.	SILK	ORGAN
8.	ASH	LIME
9.	LEAF	PLOW
10.	PINT	BRONZE
11.	DRUM	JUICE
12.	SODIUM	DOLLS
13.	RIB	TANK
14.	TUB	BUBBLE
15.	TOURIST	SAIL
16.	CEMENT	DENTIST
17.	TIN	STEREO
18.	RUG	STREET
19.	BLADE	MAP
20.	GHOST	FERRY

APPENDIX B

STIMULUS WORDS USED IN THE FIRST TWO BLOCKS OF TRIALS

RIB

PINT

BLADE

RUG

GLOBE

JUICE

PUMP

GHOST

CEMENT

DOT

ASH

CALF

STEREO

SILK

SHELF

PLOW

TOURIST

DOLLS

BUBBLE

COUCH

TEST ITEMS USED IN CONDITION 2

SET A	SET B
PIE	SUNNY
RAKE	TANK
COPPER	BABIES
RABBIT	SODIUM
ARCH	BEDS
LEVER	ORGAN
BOOT	LEAF
CAKE	MAP
CURB	SAIL
NAILS	CLIFF
SEATS	FERRY
COMPASS	DENTIST
GROVE	ATLAS
PIT	BEE
CONE	DRUM
PEPPER	BRONZE
PATHS	LIME
VENUS	WIRES
OAK	TIN
HUT	TUB

RECOGNITION TEST USED IN CONDITION 2

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	ATLAS	GROVE
2.	BABBIES	COPPER
3.	ARCH	BEDS
4.	COMPASS	DENTIST
5.	LEAF	BOOT
6.	ORGAN	LEVER
7.	CURB	SAIL
8.	RABBIT	SODIUM
9.	TANK	RAKE
10.	OAK	TIN
11.	BEE	PIT
12.	BRONZE	PEPPER
13.	NAILS	CLIFF
14.	DRUM	CONE
15.	SEATS	FERRY
16.	WIRES	VENUS
17.	TUB	HUT
18.	PIE	SUNNY
19.	LIME	PATHS
20.	MAP	CAKE

TEST ITEMS USED IN CONDITION 3

SET A	SET B
AFFIRM	TON
APT	CONFIRM
CEASED	ATE
EGO	LEASE
COUNTS	GRIEF
NULL	RISEN
DEAF	NOTHING
WARN	FEE
OWNS	OWE
DESERVE	HERS
RELY	COMMIT
DIES	HUFF
DIMLY	BULK
EATEN	SURE
THY	MERGE
IRONY	THEFT
FREED	CORN
IMPLY	AIMS
HARSH	SEEKS
SHY	AMPLE

RECOGNITION TEST USED IN CONDITION 3

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	AFFIRM	TON
2.	CEASED	ATE
3.	GRIEF	COUNTS
4.	NOTING	DEAF
5.	HERS	DESERVE
6.	DIES	HUFF
7.	BULK	DIMLY
8.	SORE	EATEN
9.	FREED	EARN
10.	SEEMS	HARSH
11.	IMPLY	AIMS
12.	THEFT	IRONY
13.	THY	MERGE
14.	RELY	COMMIT
15.	OWNS	OWE
16.	FEE	WARN
17.	AMPLE	SHY
18.	NULL	RISEN
19.	EGO	LEASE
20.	CONFIRM	APT

TEST ITEMS USED IN CONDITION 4

SET A	SET B
TON	TOURIST
DENTIST	RIB
ORGAN	EGO
SAIL	SILK
HERS	WARN
TIN	DESERVE
BULK	ASH
BEE	GHOST
EARN	IMPLY
CLIFF	DOT
FERRY	EATEN
THEFT	JUICE
MERGE	IRONY
WIRES	THY
OWE	DEAF
STREET	OWNS
AMPLE	SHELF
RISEN	GLOBE
MAP	NULL
CONFIRM	BLADE

RECOGNITION TEST USED IN CONDITION 4

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	TOURIST	CONFIRM
2.	EGO	DENTIST
3.	NULL	RISEN
4.	SHELF	AMPLE
5.	WARN	SAIL
6.	OWNS	OWE
7.	ORGAN	SILK
8.	THY	MERGE
9.	IRONY	THEFT
10.	BEE	IMPLY
11.	TIN	ASH
12.	DOT	EARN
13.	EATEN	CLIFF
14.	BULK	GHOST
15.	FERRY	JUICE
16.	DESERVE	HERS
17.	DEAF	WIRES
18.	STREET	GLOBE
19.	MAP	BLADE
20.	RIB	TON

APPENDIX C

STIMULUS WORDS USED IN THE FIRST TWO BLOCKS OF TRIALS

FERRY

MAP

STREET

STEREO

DENTIST

SAIL

BUBBLE

TANK

DOLLS

JUICE

BRONZE

PLOW

LIME

ORGAN

CLIFF

SHELF

COUCH

PUMP

GLOBE

CALF

TEST ITEMS USED IN CONDITION 2

SET A	SET B
COUCH	CAKE
BUBBLE	PATHS
DOLLS	RAKE
TOURIST	OAK
PLOW	RABBIT
SHELF	HUT
SILK	CURB
STEREO	LEVER
CALF	COMPASS
ASH	VENUS
DOT	SEATS
CEMENT	ARCH
GHOST	PIT
PUMP	PEPPER
JUICE	COPPER
GLOBE	NAILS
RUG	GROVE
BLADE	PIE
PINT	BOOT
RIB	CONE

RECOGNITION TEST USED IN CONDITION 2

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	RIB	CAKE
2.	PINT	PATHS
3.	RAKE	BLADE
4.	RUG	OAK
5.	RABBIT	GLOBE
6.	JUICE	HUT
7.	PUMP	CURB
8.	GHOST	LEVER
9.	COMPASS	CEMENT
10.	DOT	VENUS
11.	SEATS	ASH
12.	ARCH	CALF
13.	STEREO	PIT
14.	PEPPER	SILK
15.	SHELF	COPPER
16.	NAILS	COUCH
17.	BUBBLE	GROVE
18.	PIE	DOLLS
19.	BOOT	TOURIST
20.	PLOW	CONE

TEST ITEMS USED IN CONDITION 3

SET A	SET B
RIB	GLOBE
NAILS	GROVE
BUBBLE	SEVEN
PIE	ONE
NINE	FOUR
BOOT	SIX
JUICE	CAKE
STEREO	CURB
TEN	OAK
RABBIT	POTATO
TWO	COPPER
PINT	CONE
ARCH	CEMENT
SEATS	BLADE
THREE	TOURIST
RAKE	SILK
PUMP	VENUS
COMPASS	PIT
PEPPER	CALF
PLOW	COUCH

RECOGNITION TEST USED IN CONDITION 3

In each of the following items there is one word which was present in the displays you just saw and one word which was not. Please circle the word which was present.

1.	PEPPER	COUCH
2.	CALF	COMPASS
3.	RAKE	VENUS
4.	CEMENT	PINT
5.	PIE	FOUR
6.	ONE	BUBBLE
7.	CONE	TWO
8.	RABBIT	COPPER
9.	SEVEN	NAILS
10.	POTATO	TEN
11.	RIB	GROVE
12.	NINE	SIX
13.	CAKE	BOOT
14.	PLOW	GLOBE
15.	JUICE	CURE
16.	BLADE	ARCH
17.	SEATS	TOURIST
18.	STEREO	OAK
19.	SILK	THREE
20.	PIT	PUMP

APPROVAL SHEET

The dissertation submitted by Susan Gelmini Tammaro has been read and approved by the following committee:

Dr. Mark S. Mayzner, Director
Professor, Psychology, Loyola

Dr. Deborah L. Holmes
Associate Professor, Psychology, Loyola

Rev. Daniel O'Connell
Professor, Psychology, Loyola

The final copies have been examined by the director of the dissertation and the signiture which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

July 23 1981
Date

Mark S. Mayzner
Director's Signature