SWITCHING TIME FOR LETTER SIZE AND INTENSITY

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PREFACE

The experiments described in this dissertation involve major components from cognitive psychology, computer science, and physiology. The focus of the research is on perceptual adjustments to visual input. A switching time paradigm is the center of the methodology used to measure the time to make the adjustments.

I wish to express my appreciation to Dr. Robert J. Weber, who served as my Dissertation Adviser, for his continual guidance, encouragement and help. Dr. Robert Stanners, Dr. Larry Hochhaus, and Dr. Randall R. Reininger also, served as committee members, and I should like to express my appreciation and thanks to them for their thoughts and support.

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Next, I would like to extend a round of applause to my parents, Bob and Betty Brown, for their patience and support.

Finally, I would like to thank my wife, Amy, for her encouragement and patience.

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Introduction

The relevant literature from several different areas of psychology, physiology, and computer science are reviewed. First, the concept of the human operating system is put forth with a focus on the visual input mode. This is followed by a broad range of switching time studies. Then, the metaphor of a band-pass filter and the effect of expectancy on the filter are discussed. Two models of visual pattern recognition are examined. Finally, ties to priming and physiological structures which seem to support a feature priming model are presented.

Human Operating System

The information-processing language has been heavily influenced by computer models (Simon, 1969). Computer jargon even permeates everyday language, e.g., input, output, interface, and buffer. It is not surprising that cognitive psychologists draw many analogies between human information processing and digital computers. A conceptual reference point for the present study is the human operating system (Weber, 1982), an analogy to a computer operating system.

There is an extensive literature on computer operating systems (Calingaert, 1982; Kaisler, 1983; Zarrella, 1979), however, the vast majority is irrelevant to human information processing at both the hardware and software levels. The conceptual level on which a computer operating system is based does pertain to the concept of the human operating system. Simply stated, a computer operating system controls the input, output, memory allocation, and processing that goes on within a digital computer.

By analogy, the human operating system is a general, largely user transparent program that is constantly running. Generally, the human operating system allows for the setting of attention to different modes and the communication of information between input and output modalities and memory. The human operating system is certainly a conceptual leap from a computer operating system.

The ability to alter such things as output parameters (speech intensity, pitch level, writing size), output modalities (speak, write, image generation), to attend to different input attributes (color, form, foreground) and input modalities (visual, tactual, memory systems) would seem to presuppose the existence of a human operating system. Hence, the argument is made on logical grounds that there must be a human operating system to control and facilitate these processes.

The present study focused on one specific part of the human operating system, the "handler routines" for the perception of visual input. Since output parameters may vary and regulate the intensity of response systems such as speech production (Weber, Blagowsky, & Mankin, 1982), it is natural to expect that input parameters may be differentially set. The nature of the visual system is such that it must be able to set and reset itself to select from a variety of different signal parameters. One may conceive of this ability as involving a highly sophisticated filtering system (Harris, 1980). Thus, visually one might attend to only a certain type of font or a particular color of word. The important issue is how long it takes to change the input filter, i.e., the time it takes to make the switch from one font or color to another. Indeed, switching time procedures seem to offer a powerful way of investigating properties of such filtering systems.

Switching Time

The traditional switching time literature is only partially relevant to the methodology selected for the present study. The older literature was interested in simultaneous processing (Woodworth, 1938). More recently, the interest has been directed towards concurrent performance of verbal tasks and has required the individual to attend to two different sensory inputs at the same time.

The classic "shadowing" experiments, originated by Cherry (1953), required the individual to repeat a spoken message staying as "close behind" the passsage as possible. In the initial experiments, the subject's task was to shadow a voice presented to one ear while an unrelated message was presented to the other ear. Cherry found that the subjects could report back the primary (the shadowed message) passage. Very little of the unattended information was retained, although some of the features did get through. Subjects could determine if the voice was a normal human voice, could discriminate if it was male or female, and observed that reversed speech sounded queer. These results suggest that dichotic verbal stimuli cannot be processed simultaneously to any depth by the individual.

Another dichotic listening procedure involved the concurrent presentation of digit pairs to the two ears (Broadbent, 1954; 1971). Following the presentation, recall tended to group the presentation by ear rather than in temporal order of presentation. Broadbent concluded that the organization by ear occurred because of the substantial costs in time in switching from ear to ear. Unfortunately, any estimates of switching time would be very indirect, since the principal measure was based on accuracy and not time. Also, Broadbent found that subjects had great difficulty in reciting the list in temporal order when the rate of presentation was more than one pair every 1.5 sec. He concluded that the time to make the attention shift between ears was between 1 and 2 seconds. In another series of experiments, Broadbent (1958) presented a digit pair to two ears, but not at the same time. These results compelled him to revised his estimate of switching time of attention downward to approximately 250 msec. Apparently, simultaneously presenting different items to the auditory system causes some major processing problems resulting in inflated time estimates.

A much different approach to attentional switching was taken by Kristofferson (1968). His research was built on an important assumption that attention can be directed at stimuli in only one sensory channel at a time. As an example, if one is attending to a given channel such as vision, the allocation of attention to input arriving in an unattended channel, such as audition, is delayed by the amount of time needed to switch between channels. Several experiments based on this assumption (Kristofferson, 1967; Schmidt & Kristofferson, 1963) using pure tones and spots of light as stimuli have suggested that switching channels takes approximately 40 to 60 msec. This is considerably shorter that the time suggested by Broadbent. However, what Broadbent and Kristofferson refer to as "channel" is not the same. For Broadbent, a "channel" is two input places into the same system, such as two ears for the audition system. For Kristofferson, a "channel" is two input places into different systems, such as the visual and audition system. One would expect the control mechanism for the two different channels to also be different. Thus, the switching times associated with the different control mechanisms would be different.

Thus far, the review of the switching time literature has focused on selective attention and dual processing tasks. The experiments provide a foundation for the present study which was concerned with selective attention in a single task paradigm. The recent work of Navon and Gopher (1979) presented a convincing argument to avoid tasks requiring obvious concurrency. It is extremely difficult to determine how much two tasks are drawing on the same central capacity versus how much response resources overlap at the peripheral level. Klein (1976) noted that many so-called shared capacity cases are nothing more than a response incompatibility. For example, two response systems may slow down considerably when running concurrently. The assumption could be made that they shared a central capacity resulting in the decrement. However, if the two response systems were talking and chewing gum, probably the only shared capacity is at the most peripheral motor level (Weber, 1982). The switching time paradigm used in the present study involved only a single task, letter identification.

A more recent literature on single task processing using a switching time paradigm was examined. The majority of the studies were concerned with productive or generative rather than receptive attention or allocation. A series of experiments (Weber, Blagowsky, & Mankin, 1982) was concerned with measuring switching time between overt and covert (mouthed) speech. This is referred to as an intensity switching effect. In Experiments 1 and 2, intensity switching was shown to be characteristically different from the switches that occur between categories of materials because it was much larger and more resistant to practice effects. The intensity switching effect was also shown to be distinct from a memory load effect since it held even for perceptually available lists. In Experiments 3 and 4, the question of a peripheral versus a central origin of intensity switching was addressed. Evidence supported the central origin argument.

Filter Theory

The research on selective listening suggests that attention behaves like a filter. Some signals are passed for further processing while others are rejected. This concept is at the core of Broadbent's (1958) theory of recognition. His general theory of attention, memory, learning, and related phenomena was presented in terms of information theory and filtering. Broadbent assumed that the hypothetical filter can be "tuned" by the observer to any of a large number of channels. Only information that has passed by the filter can affect the subject's response. The filter spares the limited-capacity system from being overloaded. In essence, the filter model views the selective nature of attention as resulting from restrictions in the capacity of the nervous system to process information.

An important feature of the filter theory is the notion that selection does not take place at random.

Instead, Broadbent maintained that the filter biases its selection toward certain physical features of the stimuli. Thus, the band-pass filter provides a mechanism for the tuning hypothesis of expectancy. If the filter is set to receive input from one specific channel and input begins to arrive via another channel, then the filter must be reset or switched. One would expect a cost in time for the switch to take place.

Two general models of the representation of the switch were contrasted in previous work (Weber, 1982; Weber, Blagowsky, & Mankin, 1982). The symbolic parameter substitution model suggests that there is a time involved in switching, however, the difference between what the filter is set on and what the filter is changed to makes no difference in the switching time. For example, if the filter was set for small letters, then the switch to medium sized letters would take the same amount of time as the switch to large letters. A new parameter is substituted for the small letter parameter. Conversely, the analogic pointer model suggests that the greater the switch, the longer the time to make the switch. For example, if the filter was set for small letters, then the switch to medium letters would take less time than a switch to large letters. The further the pointer has to move, the longer the time to switch.

In considering the representation of the switch, one might ask how the switch is set or what sets it. One possibility is an all-or-none method such that the last input through the filter leaves the filter set for the subsequent input. Another possibility is an increment method such that the filter adjusts in a stepwise manner. What one has just experienced or expects to experience should have an impact on setting the switch.

Expectancy

When one is asked to attend to only one of several attributes of a stimulus, he is often able to report more accurately about that attribute than he would otherwise. Kulpe (1904) first documented this effect experimentally, and since then a number of investigators have replicated the finding (Chapman, 1932; Wilcocks, 1925). Typically, the experiments involved either instructing the subject about which attribute he should attend, or provide the subject with a set of alternatives from which the stimulus was drawn. More importantly, the same process is implied by implicit instructions coming from the subject himself.

At least two basic and dissimilar interpretations have been suggested to explain the effects of set on perception (Haber, 1966). The older one is favored by Kulple and most of the investigators following him including the "New Look" theorists in perception. This is perceptual enhancement or "tuning" hypothesis (Dember, 1960; Postman, 1963) whereby attending to a particular attribute of a stimulus results in a clearer and more vivid perception of that attribute.

By the same token, the incidental attributes are not as clear and do not stand out. Thus, the perceptual tuning hypothesis places the locus of the effect of set in the perceptual system, while the stimulus is being viewed.

The alternative hypothesis is that set has no effect on perception itself, but only on some aspect of the memory trace or on responses to that perceptual experience. The locus of the effect of set is still a disputed issue with the expectancy theorists. Though it is not in the scope of the present study to make a determination for the locus, the tuning hypothesis is quite compatible with the feature extraction model, especially if one considers a mechanism such as a band-pass filter that precedes the feature extraction process.

One of the central components of the methodology was the concept of the perceptual set. Simply stated, when someone has the same experience several times, always the same way, he begins to expect it to happen that way in the future. As the expectancy relates to the present set of experiments, when a subject saw letters of one size or intensity for several trials, he expected to see the same condition on a subsequent trial. This was the reason that several control letters were viewed before a target letter was presented, to set the subjects expectancies. The role of expectancy is usually thought to affect an early stage of human information processing.

Stage Models

There are several models which can be used to explain and predict the results from a visual letter-identification task. To begin with, a general model for human information processing will be presented. This will provide a framework to consider different pattern recognition models.

In 1969 Sternberg introduces a reaction time model to study stages of information processing. The additive factors method, says Sternberg, shows additive contributions to mean reaction time if the independent variables affect independent stages of processing. If the variables show interactive effects, then they are assumed to influence the same stage of information processing (Sanders, 1980; Sternberg, 1969). Also, for the additive factor method to apply, subjects should be well practiced and operate at a high skill (accuracy) level.

Since the introduction of the additive factors method, researchers have proposed several stage models based on the results of character recognition and reaction time experiments (Hunt, 1978; Salthouse, 1981; Williams, 1984;). A recent line of research (Everett, Hochhaus, & Brown, 1984) investigated the effects of stimulus intensity, stimulus degradation, and stimulus-response compatibility in a letter-naming task. The data indicate support for a three-stage model of visual character recognition in which intensity, degradation and compatibility affect non-overlapping, serial stages. The three stimulus variables appear to affect independent operations in human information processing. At the level of cognitive psychology, the stages may correspond to preprocessing, feature extraction and response choice operations. The three stage model presented here should provide a suitable framework to compare different models of letter identification in the following sections.

Pattern Recognition

The present study is concerned with the problem of pattern recognition. Since the task in all three experiments of the present study involved letter identification, it is appropriate at this time to present two main theoretical approaches of pattern recognition. The first is template-matching in which new input is compared to a standard. The second is feature-analysis in which the presence of particular parts or particular properties are decisive.

The simplest process by which pattern recognition can take place is template-matching (Gibson, 1963; Reed, 1975). According to the theory, a large number of internal representations (templates) are stored in long-term memory. Meaning is associated with each of the representations. When an external stimulus is presented, comparisons are made with various templates until a match is found. The meaning associated with the template is then assigned to the stimulus. However, the uniformity of something as simple as the letter "A" is so low that problems quickly arise. A given letter can appear in an almost endless series of variations based on orientation, style, size, and brightness. A simple template-matching system fails unless it has the stored configuration that exactly matches the external stimulus.

Rather than requiring a template to exist for every possible stimulus, a second solution is to insert a level of analysis to take place before the template matching. Neisser (1967) has suggested that this preprocessing stage can consist of two types of operations. First, local operations serve to cleanup or embellish the input. This sort of step is almost essential for artificial systems (Barr & Feigenbaum, 1981) because they nearly always start with an image which contains numerous small imperfections. A simple cleanup program fills in small holes and eliminates isolated points. Also, a cleanup program embellishes the image if the contrast or intensity is too low. These are extremely local precesses, and the transformation they produce is independent of the gross form or actual identity of the letter. Local processes which are similar to these certainly operate in human vision to help overcome disturbances created by nystagmus, scattered light, and intraoccular irregularities.

A second preprocessing operation applied after the cleanup operation would be normalizing operations. These would consist of rotating, adjusting to some preset height and width, and centering the image. Once these operations were completed, template matching could begin. This approach has been used in various computer recognition systems and has proven quite powerful (Arbib, 1964).

A second main theoretical approach to pattern recognition presented here is feature analysis (Gibson & Gibson, 1955, 1969; Reed, 1973). In examining the letters of the alphabet, one thing that is readily evident is many different patterns share a number of subpatterns in common. Visual objects generally consist of combinations of vertical lines, horizontal lines, curved lines, right angles, acute angles, light and dark areas and such. Perhaps it is these smaller units that are extracted during the pattern detection stage. That is, perhaps the pattern recognition system contains analyzers that function to detect the subunits or features that are common to visual stimuli. When visual stimuli enter the system, a list of features would be extracted and compared with lists stored in memory. If an exact match did not occur, then the meaning associated with whatever had the most features in common would be used. An important consideration to note here is that the same perprocessing or normalization operations suggested by Neisser would occur when the stimulus first entered the system before the features were extracted.

Feature analysis is not completely different from template matching. Features and templates are not different in any absolute sense, rather they are two ends of a continuum. Template matching has a unique internal representation for each stimulus that it recognizes. A feature system makes use of a general set of features common to many stimuli. Certainly the feature system would require less memory than the template system. Template-matching and feature-extraction are not the only two possible explanation of how letters are perceived and identified. However, they do provide two viable approaches to a complex problem.

Physiological Mechanisms

There already exists a powerful physiological mechanism to support the concept of feature analysis in the work of Hubel and Wiesel (1962, 1965, 1968, & 1970). The pioneering work in the discovery and mapping of cortical receptive fields was done using electrophysiological procedures with cats and monkeys. A number of investigators have demonstrated the existence of similar mechanisms in humans (Gardner, 1975). Seven million ganglion cells form the basic photoreceptor structure in the retina. Ganglion cell receptive fields are nearly all concentric in shape, with the center excitatory and the surrounding area inhibitory, or vice versa. An optimal response from a ganglion or geniculate cell, the next level in the visual system, usually depends only on size, intensity, and location of a spot of light on the retina. If the spot is too large, the threshold for response increases. The specificity of the coding at these levels is not too great. Because of the spatial-frequency response function, the retinal ganglion and lateral geniculate cells are often referred to as band-pass cells (Maffei & Fiorentini, 1973).

Most of the work of Hubel and Wiesel has been with recordings of the receptive fields of cortical cells. With these, the patterns of coding are quite different, Cortical cells are generally described as simple, complex and hyper-complex depending on the properties of their receptive fields.

The simple cortical cells have antagonistic regions like the geniculate and ganglion cells, but their shapes are elongated rather than circular. They are most responsive to an elongated stimulus, e.g., a bar or edge, which is in parallel with the axis of the receptive field of the cell. Thus, a given cell may have a maximal excitatory response to a narrow lighted bar rotated at 45 degrees to the right, whose width matches the width of the on-center area. So, these simple cortical fields appear to be edge detectors and line detectors. They are sensitive to lines of specified widths and orientations, and edges of specified orientations.

The complex cortical receptive fields show a major difference from the simple cells. While they are generally sensitive to the same kinds of features as the simple cells, it does not matter where in the receptive field the feature is placed. Thus, a field might be selective for a narrow line at a 45 degree orientation, but that line produces a large response when presented anywhere within the field. Such a field therefore remains a feature detector, but can specify only within a large latitude where the line appeared on the retina.

The hypercomplex cortical cells look as if they are the output of combinations of complex cells, in that they code combinations of stimulus features. For example, cells have been found that respond to the angles that two intersecting lines form rather than to the lines alone. These cells are also sensitive to the length of the stimulus since the response is often reduced when the line exceeds a certain length. If a line is too short, the cells are activated more slowly and true response is again reduced. Cells at this level have been found to be so stimulus specific that they hardly respond except to an equilateral triangle with sides of 2.0 degrees and rotated 15 degrees to the left (Kaji, Yamane, Yoshimura, & Sugie, 1974) In summary, it appears that a feature may excite a particular location of the brain. This in much the same notion that has been extended in the priming literature with word associations.

Priming

The traditional priming literature is based on decreased latency for a response in a lexical-decision task. A lexical-decision task is a procedure in which a subject is presented with a string of letters and asked to determine if it is a word or not. The decrease in response time is due to the facilitating effects of a word in a preceding trial. Several different types of priming have demonstrated processes which are both quantitatively and qualitatively different.

Semantic priming (Meyer & Schvaneveldt, 1971) takes place when an associated word, such as DOCTOR, precedes a target word, such as NURSE, in a lexical-decision task. Typically, the decision that NURSE is a word takes place some 50 to 80 msec faster than if DOCTOR has not been presented. The rate of decay is such that the effect lasts about 15 seconds (Neiser, 1979). Repetition priming (Forbach, Stanners, & Hochhaus, 1974; Scarborough, Cortese, & Scarborough, 1977) is similar to semantic priming. However, instead of associated words as primes, a word is primed by itself, e.g., DOCTOR precedes DOCTOR. The facilitation from repetition priming is about 150 msec with the decay rate lasting 1 minute or longer (Forbach et al., 1974). Component priming (Brown, 1983) is demonstrated when a part or component of a compound word is used as a prime, e.g., if COW or BOY primed COWBOY. The facilitation for priming by the first component was about the same as that for semantic priming, 50 to 80 msec, but the decay rate was on the order of that found in repetition priming, 1 minute.

In a line of research prior to the popularized notion of priming, a subject was shown a letter and required to determine if a second letter was the same or different (Posner & Boies, 1971). The information about the first letter accrued and a strong facilitation was shown for "same" over "different" response. This finding suggests an automatic increase in the ability to reactivate an associative connection following activation. Though the effect was not referred to as priming, certainly a strong argument could be made for repetition priming for letters.

To summarize the review of priming, words can prime themselves, semantically related words can prime each other, components of a word can prime the word, and letters can prime themselves. With what has been put forth in the reviews of the feature extraction process and facilitation, could priming of letters by features be possible?

Summary

The switching time paradigm used in the present study involved a single task but with receptive rather than generative attention. The letter identification task is considered an automatic process in older, literate subjects (Keele, 1972). Presumably, graphically presented letters invoke the visual input mode of the human operating system and required receptive attention. Context letters (1,2, or 4) were presented one at a time and preceded a target letter. The context and target letters were one of three sizes (Experiment 1) or one of three intensities

(Experiments 2 & 3). For simplicity, only the size variable from Experiment 1 is used in the following examples. A pure condition was defined as the same size context letters as target letter in a given trial. Switching time was the extra time taken to perceive a target letter when it was a different size from the context letters. For example, a small letter following a small letter, denoted by small:small, was a pure condition as was meduim:medium and large:large. A medium or large letter following a small letter was a switching condition. To calculate the switching time, simply subtract the average time for a pure condition from the average time for a switch condition:

switch condition RT - pure condition RT = switching time

Note that the correct pure condition is the one in which the target size is the same as the switch condition. Thus, if the mean reaction time for the medium:small condition was 400 msec and the mean reaction time for the small:small pure condition was 350 msec then the switching time for the medium:small condition is 50 msec.

The present studies are exploratory in nature. Two of the four major questions addressed are: (1) is there a switching time for the change of letter sizes, and (2) is there a switching time for the change in letter intensities? If so: (3) what is the nature of the switch for size, and (4) what is the nature of the switch for intensity?

EXPERIMENT 1: SWITCHING TIME FOR LETTER SIZE

Experiment 1 was designed to test the generality of the switching time phenomenon, which in the work of Weber and collegues (Weber, Blagowsky, & Mankin, 1982; Gowdy, 1983; Noll, 1984) has so far concentrated on output systems. The present focus was on the visual input mode. At issue is whether there is a switching time for the perceptual adjustment to letters of different sizes. Furthermore, there is the issue of whether the switch is analog or symbolic in nature. Finally, at issue is whether the setting of the switch is an all-or-none or incremented process.

Method

Subjects. The subjects were 24 undergraduate students, 12 male and 12 female, recruited from introductory psychology classes at Oklahoma State University. From self-report, only those subjects with English as a primary language and good eyesight were used. The subjects ranged from 19 to 33 years of age. All subjects received extra credit for their participation in the experiment.

Design and Procedure. The apparatus included an Apple II microcomputer, a 17" Sony Trinitron (model CVM 1750) video monitor, a Ralph Gerbrand (model 160) electronic voice key, and a software clock (Price, 1982). The apparatus was responsible for stimulus presentation and data collection.

Stimulus items were three sizes of Franklin gothic styled capital letters. The small, medium, and large letters were 1 cm, 4 cm, and 16 cm tall respectively. At 50 cm from the screen, the visual angles were 1.15, 4.6 and 18.4 degrees respectively. All letters were presented as black letters on a white background.

The design employed was a 3 x 3 x 3 x 5 factorial design with 5 blocks. The four primary independent variables were: (1) size of context letter (small, medium, large), (2) size of target letter (small, medium, large), and (3) number of context letters preceding the target letter (1,2,4), and (4) 5 blocks of testing. All independent variables were within-subjects and had three levels, except for the five levels of blocks. Two dependent variables were recorded: (1) response time between target letter presentation and verbal response and (2) errors of identification.

The experiment consisted of 1 block of 27 practice trials followed by 5 blocks of 27 experimental trials or 135 total experimental trials. Each block was completely orthogonal in that it contained each level of the three primary independent variables crossed with each level of the other two. The order of presentation was randomized for each subject.

During a typical trial, the subject might have experienced the following sequence of events (see Figure 1): The subject was seated, facing a video monitor about 50 cm away, and was holding a microphone. The screen had just gone blank from a previous trial. It stayed blank for 2.5 sec, then a large "N" appeared almost covering the screen. The subject quickly responded "N" into the microphone. The letter was on the screen for a total of 750 msec, the screen blanked for 600 msec. Now, a large letter "B" appeared for 750 msec and the subject identified the second context letter as quickly as possible. The screen again blanked for 600 msec. Following, a medium sized "T" appeared in the center of the screen. When the subject responded "T", the screen blanked, the bell rang, and the phrase "LETTER ?" appeared at the bottom of the screen. The subject then keyed in the last letter said, a "T". The screen blanked again and after a 2.5 sec delay another trial begined. The response time between the presentation of the target letter "T" and the verbal identification was recorded. The keyed letter is compared to the actual letter for errors. This was an example of a trial which consisted of two large context letters followed by a medium target letter.

Insert Figure 1 about here

A trial can have of 1, 2, or 4 context letters followed by a target letter (see Figure 2). Having different numbers of context letters preceding a target letter was included to determine if the degree of set varied with the number of context letters. It also served as a control variable. Pilot data indicated that without this control variable, subjects might develop a strategy of knowing when the letter size is about to change and adjusting their attentional processes. Instructions to subjects are given verbatim in Appendix A. Subjects were shown the Apple II microcomputer and the microphone connected to the voice key. After reading the instructions, the practice trials were started. The experimenter stayed with the subject through the 27 practice trials. During this time, the experimenter answered any questions or explained any part of the instructions that were unclear. At the end of the practice trials, the experimenter asked if the subject was comfortable with the task. If the subject replied affirmatively, the 135 experimental trials were started. The experimenter left the subject in the experimental room until the experiment was concluded.

Insert Figure 2 about here

After each block, the subject was given information about his speed and accuracy. Depending on the cumulative accuracy, subjects were given different feedback: greater than 97.5% correct they were asked to speed up; less than 95% correct they were asked to slow down; and between 95% and 97.5% correct they were told was just right. At the end of the experiment, the subject was debriefed and the session ended.

Results

The following analysis is divided into two sections, preanalysis and analysis. Blocks and number of context letters were analyzed first. This was done to determine if they significantly contributed to the results, and if not, to collapse the data over blocks and number of context letters to provide a more powerful test for the remaining variables (Winer, 1971).

Preanalysis. Data were analyzed for the two control variables, blocks and number of context letters. The analysis of variance (see Appendix B) confirms that neither blocks nor number of context letters was a significant factor in the results. Also, none of the higher order interactions with either variable was significant.

Analysis. The following analysis on the remainder of the factors was collapsed over blocks and number of context letters. Data were analyzed for two independent variables, size of context letter and size of target letter, and two dependent variables, reaction time and errors. The reaction time means are depicted in Appendix B. The mean reaction times for context and target letter size have the same order, medium sized letters were responded to fastest, followed by large letter size, and the slowest response time was for the small letters. Finally, Figure 3 displays the means for the interaction between context letter size and target letter size.

Insert Figure 3 about here

The analysis of variance summary table (see Appendix B) indicates that size of context letter was significant, $F(2,46) = 15.16$, $p < .0001$. The size of target letter was also significant, $F(2,46) = 57.19$, $p < .0001$. Finally, the size of context by size of target letter interaction was significant, $F(4,92) = 17.35$, $p < .0001$.

Tukey multiple comparison tests were performed on both the context and target variable. The Tukey Honestly Significant Difference (HSD) test calculates a critical value which is used to determine whether the differences between two means is a significant difference or not. For example, the means for the context letter size, collapsed across all other variables were: small = 416.4, medium = 405.1, and large = 410.0 msec. The calculated HSD = 4.97, $p \le .05$. Therefore, the difference between the small and medium context letter group, 11.3 msec, is significant at $p < .05$. The difference between the small and large context letter group, 6.4 msec, is also significant, $p < .05$. However, the difference between the medium and large context letter group, 4.90 msec, is not significant. Tests of significance for the size of target letter show that all three target letters were significantly different, HSD = 6.70, $p < .05$. The order of times from fastest to slowest was:

medium < large < small.

The error rate for the 24 subjects ranged from .7% to 5.9% errors with 2.6% as the average. Error rate had a small positive correlation with reaction time, $\underline{r} = .019$, and therefore was contrary to speed-accuracy tradeoff. An analysis of variance for the context by target interaction using the error data was nonsignificant.

Switching time. The test for switching times was accomplished by analyzing for partial effects. A summary for switching times is portrayed in Table 1. A pure condition was defined as the same size for context letter and for target letter, e.g., a small target letter following a small context letter. The pure condition provides a reference or zero point to compare switches.

Insert Table 1 about here

Comparisons should be made by holding the size of the target letter constant and varying the size of the context letter. It is important to see why this is the correct perspective. By holding the target size constant and varying the size of context letters preceding it, a substantial amount of variance is controlled because all the target letters are the same size. The alternative perspective, holding the context letter constant and varying the size of the target letter, confounds the results with the fact that medium sized letters are simply perceived faster than large letters. Also, large leters are perceived faster than small letters. The pure condition with the same sized target letter is the correct zero point for the switch condition. For example, the mean reaction time for the small:small, pure condition was 417 msec and the medium:small, switch condition was 424 msec. Therefore, it took a switching time of 7 msec to identify a small letter when it was preceded by a medium letter rather than another small letter.

Results for those conditions which had a small target letter show that the pure condition (small:small) had the fastest reaction time. The medium:small switch condition produced a nonsignificant switch of 7 msec. However, the large:small switch was a substantial 19 msec switch, HSD = 12.22, $p < .05$. The results for the medium target letter conditions indicate that the medium:medium pure condition was faster than either switching condition. The small:medium switch was only 5 msec, but the large:medium switch was a significant 19 msec, HSD = 12.22, $p < .05$. Finally, the large:large pure condition had the fastest reaction times for the large target. The medium:large switch was 2 msec, but the small:large switch was the largest for Experiment 1, 22 msec, HSD = 12.22, $p < .05$.

Discussion

A substantial switching time effect for perceptual adjustment to letters of different sizes was demonstrated. For the small target letter group, the stepwise increase of context letter from small:small to medium:small and then to large:small occurred in a curvilinear function. The slightly depressed center of the curve (see Figure 3) may be an artifact of the fast response times for the medium sized targets. The function may truly be more linear than it appears. This suggests that the perceptual adjustment downward for smaller sized letters is an analog process, i.e., the smaller the letter, the longer the switching time.

For the medium target letter group, the medium:medium pure condition was the fastest condition for the entire experiment. There is a noticeable asymmetry with the relations between the switching conditions and the pure condition. The switch downward from large context letters to a medium target letter did not require as much time as the switch upward from small context letters to a medium target letter. This could be due to the way the normalization process functions.

For the large target group, the stepwise decrease of context letters from large:large to medium:large and then to small:large is also curvilinear. Again, the overall fast times for the medium sized target letters may account for the depressed center.

In considering the asymmetry within the medium target letter group, the normalization process appears to be faster to zoom in to an image rather than to pan out from an image. This could be interpreted as support for the concept of a selective band-pass filter. If the filter was set for large letters, and a medium sized letter was presented, features would still be extracted because the whole letter would be visible through the band-pass window. However, if the window was set small and a medium letter was presented, only a few of the central features would pass through the window. Thus, the normalization process would have to reset the filter taking extra time.

The reviewed literature would explain the increased time to make a switch in size in two ways. First, if context letters and a target letter were the same size, the selective filter would be "tuned" and the normalizing process would not be needed. If the context letters and target letter were different sizes, the switching time could be the measurement of the time required to reset the band-pass filter, thus increasing response time. Of course, the notion of a band-pass filter is a metaphor only. It does, however, provide a productive way of conceptualizing the process at work. Second, line size probably functions as a distinctive feature. With context and target letters of the same size, the pathway between the feature extraction stage and letter identification would be facilitated or primed for lines of a particular size. This would reduce the time in letter identification resulting in a faster overall response time. Thus, the second explanation is based on physiological structures.

The number of context letters preceding the target letter had a minimal effect on reaction times. It is apparent that using just one context letter has the same effect as using four context letters. This is an interesting finding in itself, suggesting that setting the filter is an all-or-none action. The first letter is all that is needed to set the filter, and the subsequent context letters have no real effect on the process. Since error rates were low and the correlation between response time and errors was almost zero, speed-accuracy trade-offs had no obvious effect on results.

EXPERIMENT 2: SWITCHING TIME FOR LETTER INTENSITY

The previous experiment demonstrated a switching time phenomenon in the visual input mode. Experiment 2 further tested the generality of the switching time paradigm with a focus on changes in letter intensity. At issue, is whether there is a switching time for the perceptual adjustment to letters of different intensities. Furthermore, there is the issue of whether the switch is analog or symbolic in nature. Finally, at issue is whether the setting of the switch in an all-or-none or an incremented process.

Method

Subjects. Subjects were 24 undergraduates students, 14 male and 10 female, recruited from psychology classes at Oklahoma State University. From self-report, only subjects with English as a primary language and good eyesight were used. The subjects ranged from 19 to 33 years of age. All subjects received extra credit for their participation.

Design and Procedure. The apparatus was similar to that used in the previous experiment except for the addition of a software-controlled device designed to manipulate CRT intensity (Hochhaus, Carver & Brown, 1983).

Stimulus items were all medium sized capital letters

(4 cm tall), Franklin gothic style, and presented in three different intensities. The intensities used were partially dependent on hardware limitations. Intensities were set using the following procedure. The normal screen intensity was used as the bright intensity condition. The dim conditon was adjusted as low as possible without losing the horizontal synchronization part of the video signal. If the signal became too low and syncronization was lost, a letter would "wash" across the screen making it illegible. Finally, the middle intensity condition was set at a position where three independent judges agreed was halfway between the bright and dim condition. Because the intensities between the second and third experiments were changed, the intensities for the second experiment were not measured with an illuminometer. All letters were presented as black letters on a white background.

The completely orthogonal design was identical to that used in the first experiment, 3 x 3 x 3 x 5 factorial design. There were 27 practice trials and 5 blocks of 27 experimental trials or 135 total experimental trials. The four primary independent variables were: (1) intensity of context letter (low, medium, high), (2) intensity of target letter (low, medium, high), (3) number of context letters preceding the target letter (1, 2, 4), and (4) 5 blocks of testing. All three variables were within-subjects. The two dependent variables, were: (1) response time (RT) and (2) errors in identification. The remainder of the experimental procedure was identical to Experiment 1, except that letter intensity was varied and letter size was held constant.

Results

Preanalysis. The data for blocks and number of context letters, were analyzed with an analysis of variance procedure (see Appendix B). Though the number of context letters did not significantly effect the results, $F(2,46) = .27$, $p > .05$, the blocks variable unexpectedly did, $F(4,92) = 2.54$, $p < .05$. A practice effect appeared to be at work. The following analysis deviated from the planned analysis because of the blocks factor.

Analysis. Since the blocks variable could not be dropped, it will appear in the analysis section. Data were analyzed for three independent variables: blocks, intensity of context letter and intensity of target letter. Two dependent variables, reaction time and errors, were used in the analysis. Figure 4 displays the means for the context by target interaction. As depicted, the pure conditions were the fastest condition for each target group. However, the times generated from the medium and high intensity conditions appear very similar. Ideally, all the intensities would have been more distinct.

Insert Figure 4 about here

The analysis of variance (see Appendix B) revealed the following: Context letter intensity was not significant, $F(2,46) = .76$, $p > .05$. Target letter intensity was highly significant, $F(2,46) = 36.70$, $p < .0001$. For the second order interactions, blocks by target was significant, $F(8,184) = 2.44$, $p < .02$. The remainder of the interactions, including the blocks by context by target interaction, were not significant.

Multiple comparison tests using the Tukey method were conducted for both context and target conditions (see Appendix B). The results suggested that the intensity of the context letter did not effect the reaction time of a target letter. However, the dim target letter condition was significantly slower than both the medium and bright target condition, $HSD = 6.65$, $p < .05$.

The error rate ranged from 0.0% to 4.8% with an average of 3.2%. The error rate was positively correlated with reaction time $r = .031$, and therefore, was contrary to speed-accuracy tradeoffs. An analysis of variance for the context by target interaction using the error data was nonsignificant.

Switching time. Partial effects tests were used to assess the magnitude of the switching times. A pure condition for Experiment 2 was defined as having the same intensity for both context and target letters in a given trial. A summary for the switching time results can be found in Table 2. No significant switching times occurred.

Insert Table 2 about here

Discussion

The findings for Experiment 2 were not as expected. There seemed to be two basic problems with the methodology. First, blocks was a significant factor when it was not supposed to be. Second, the medium and bright conditions were virtually the same for both context and target letters.

Experiment 2 failed to demonstrate a significant switching time effects for perceptual adjustment to letters of different intensities. As predicted, pure conditions for all three target letter intensity groups was the fastest condition for that target intensity. All of the switching conditions were slower than their corresponding pure condition.

For the low intensity target group, the stepwise change in intensity of context letter was not a linear function (see Figure 4). The one step increase in context letter intensity (medium:low) took longer to switch than the two step change, high:low.

For the medium intensity target letter group, both switches, low:medium and high:medium, took slightly longer than the medium:medium pure condition. The literature would indicate that both switch conditions would be slower because of the extra time taken in the local processing stage (Neisser, 1967).

For the high intensity target group, the pure condition, high:high, had the fastest response time. Again, the two step condition (low:high) was faster than the one step (medium:high). This was an unexpected finding.

The results suggest that a switching time may exist for perceptual adjustment to letters of different intensities. However, because of two problems, not enough practice trials and intensities not different enough, the results were inconclusive. This may be more of a methodological problem than a negative finding. Experiment 2 suggests the need for a third experiment with two major changes. First, additional practice trials should be prefixed. Second, hardware or software adjustments should be made so that all three intensities are more distinguishable from one another.

EXPERIMENT 3: SWITCHING TIME FOR LETTER INTENSITY REVISITED

The previous experiment attempted to test the generality of the switching time paradigm by focusing on letter intensity rather than letter size. Because of two methodological problems, a block effect and small intensity differences between conditions, the results were difficult to interpret. Furthermore, Experiment 2 did not fully answer questions about switches between letter intensities. Experiment 3 was a refinement of Experiment 2 in that it used an additional set of 27 practice trials to reduce the learning effect across trials, and it used intensities whose differences were much more distinctive. At issue, again, is whether there is a switching time tor the perceptual adjustment fo letters of different intensities. Furthermore, there is the issue of whether the switch is analog or symbolic in nature. Finally, at issue is whether the setting of the switch is an all-or-none process.

Method

Subjects. Twenty-four subjects, 13 male and 11 female, were either students or employees of Oklahoma State University. From self report, only those subjects with English as a primary language and good eyesight were tested. Subjects ranged from 22 to 35 years of age. None of the subjects received any compensation for their participation in the experiment.

Design and Procedure. The apparatus for the present experiment was identical to that used in Experiment 2. However, a different software approach to the presentation of the letters allowed for greater reduction in the intensities.

The stimulus items for the previous two experiments used a graphics package for presenting the medium and large letters. The small letters were the regular Apple characters. The graphics package had video problems when trying to adjust the intensity to an extremely dim state. Because of this, the present experiment used the small letters (1 cm tall) presented as white letters on a black background for all intensities. This allowed for more differentiation in the three intensities used.

The three intensities were empirically set based on response times rather than by using judges as in Experiment 2. Normal intensity was used as the bright condition. The dim intensity condition was adjusted as low as possible without losing the synchronization signal and distorting the letter image. The medium intensity was set in such a manner that for pilot data the medium target response time mean was halfway between the measured response time means for the dim and bright targets. A few test subjects were run on a preliminary basis and the medium intensity adjusted via a potentiometer (Hochhaus, Carver & Brown, 1983) until it appeared to meet the above criterion. All the adjusting was accomplished before any experimental subjects were run.

After the intensities were set, they were measured using a Macbeth Illuminometer (model 6800). The low intensity letters measured 41.2 cd/m, the medium intensity letters were 52.1 cd/m, and the high intensity letters were 132.5 cd/m. The letters were presented on a black background measuring 30.6 cd/m. The design employed was a 3 x 3 x 3 x 5 factorial design, identical to the previous experiment, except that an additional block of 27 practice trials was used. The four primary independent variables were (1) intensity of context letter (low, medium, high), (2) intensity of target letter (low, medium, high), (3) number of context letters preceding the target letter (1,2,4), and (4) 5 blocks of testing All variables were within-subjects. Two dependent variables were collected, (1) reaction time and (2) errors. The remainder of the experimental procedure was similar to that of Experiment 2.

Results

As in Experiments 1 and 2, the variables for blocks and number of context letters were preanalyzed so the remainder of the data could be collapsed in the analysis section.

Preanalysis. Data were analyzed for the two variables, blocks and number of context letters. The analysis of variance summary (see Appendix B) indicates that neither the blocks nor the number of context letters variable was significant. Furthermore, none of the higher order interactions involving the two control variables was significant. The subsequent analysis was performed on the data collapsed over the two control variables. The adjustments in the metholology from Experiment 2 seemed to correct the problems encountered there.

Analysis. The data were analyzed for two independent variables, intensity of context letter and intensity of target letter. Figure 5 displays the means for the interaction between context and target letters. As depicted, for the medium and high intensity target groups, the pure condition was the fastest time. The high intensity targets were noticeably faster than the medium intensity targets. Also, the medium intensity target letters were generally faster than the low intensity target letters.

Insert Figure 5 about here

The analysis of variance (see Appendix B) indicates the following: Context letter intensity was significant, $F(2,46) = 89.51$, $p < .0001$. Target letter intensity was significant, $F(2,46) = 210.13$, $p < .0001$. Also, the context by target letter interaction was significant, $F(4,92) = 54.51$, $p < .0001$.

Multiple comparison tests were performed on both the context and target variables. All three context letter intensities were significantly different from each other, HSD = 8.71, $p < .05$; so were all three target letter intensities HSD = 15.47, $p < .05$ (see Appendix B).

The error rate ranged from 0.9% to 5.7% with an average error rate of 3.1% for the entire experiment. The small, negative correlation between reaction time and errors was not significant, $r = -.045$. An analysis of variance for the context by target interaction using the error data was nonsignificant.

Switching time. Switching time was tested for significance by analyzing partial effects. The difference at which a switch was considered significant was HSD = 23.68, $p < .05$. A summary of switching times is presented in Table 3.

Insert Table 3 about here

For low target letters, medium context letters provided the fastest reaction times (note the negative value). The pure condition was 21 msec slower, but not statistically different. The low:high switch took 80 msec and was significant. The pure condition was the fastest condition for medium intensity target letters. The low:medium switch was minimal, 3 msec. However, the high:medium switch was a significant 69 msec difference.

For the high intensity target condition the pure condition (high:high) was the fastest condition. None of the switches to the high intensity target letter was significant. The low:high and medium:high switches were 20 and 10 msec respectively.

Discussion

A switching time effect for perceptual adjustment to letters of different intensities was demonstrated for at least some conditions. A minor problem with the results was found with the low target letter group. The low:low pure condition was slower than the medium:low switch condition, however, the difference was not significant.

The pure condition for the medium and high intensity target letter was the fastest condition for the respective target letters. The switching conditions for the medium and high intensity letters were slower than their corresponding pure condition.

The results can be generally explained with the switching time paradigm, with the exception of the low:low pure condition. When the context letters and target letter were the same intensity, the selective filter is "tuned" and the local process in the model is not needed to adjust the image, thus resulting in faster response times. When the context and target letters are different intensities, the band-pass filter has to be reset, morphologically speaking. From a process approach, the local processing which Neisser (1967) indicates is responsible for embellishing a dim image would account for the increased response time. This does not account for a major portion of the results.

A second explanation, utilizing arguments from the first experiment would suggest a priming by intensity argument. However, this does not explain a negative switching time or the lack of results with the high intensity target.

An alternative explanation comes from the masking literature (Sperling 1960; Erikson, 1966). Forward masking is the interference in perception of a visual field from some preceding visual field. It is interesting to note that the only two significant switching times were the result of high intensity context letters. Could the high:low and high:medium effects have been produced by masking? A high intensity display would more effectively mask a low or medium one than another high intensity display. Hence, the lack of an effect on the high target condition. The masking explanation suggests that intensity is not represented as a feature detector, but rather as the number of neurons activated. Intensity, thus, might not be primable.

GENERAL DISCUSSION

The experiments presented in this dissertation demonstrate that the switching time phenomenon is a general effect that occurs within the visual input system. This is consistent with the previous work with switching times and output systems.

Experiment 1 showed significant switches for the perceptual adjustments to letters of different sizes. The switch appears to be analog in nature rather than symbolic. Also, the switch appears to be set in an all-or-none fashion rather than incremental.

Two explanations were proposed for the switching time phenomenon, e.g., the difference in response time for the adjustment to letters of different sizes. The first, the increase was due to a normalization process prior to feature extraction. Though this is a powerful approach in the computerized pattern recognition field, it does not seem viable from a cognitive standpoint. Some of the problems are that the system does not know when to normalize or when to stop. Also, the system has no physiological mechanism underlying it. The second would explain the decrease in response time as priming by features. This approach has a strong supporting literature and explains the results well. Also, feature priming has a physiological foundation, a tie that cognitive approaches are sometimes lacking. Therefore, it appears that size is a primable feature.

Future research question might be more directed toward the feature priming argument. Presenting angles, curves, or specific sized lines just prior to a letter identification task would be an obvious starting point.

For Experiment 2, probably the most important point is that subjects seemed to learn to perceive the lower intensity letters, hence the significant block effect. Since the results were inconclusive, it would be speculative to discuss interpretation at this point. However, the second experiment was useful in eliminating some of the methodological problems when dealing with an intensity variable.

Experiment 3 demonstrated significant switching for the adjustment of the perception of letters of intensities in only two of the six switching conditions. Both switches were from a high intensity context letter to a less intense target letter.

Three explanations were proposed. The first, the switching time is attributed to a local process in a preprocessing stage (Neisser, 1967). The local process embellishes an image if the intensity or contrast is too low. The second, the switching time is attributed to feature priming, with intensity as the feature. Neither sufficiently account for the results. Thus, it appears that intensity is not "primable".

An third argument explained the difference in response time as forward masking. This approach explains the results well and has a solid conceptual and physiological foundation.

Further research directed toward the masking argument is in order. An experiment in which the interstimulus interval between the context and target letters is manipulated would address the issue of forward masking. The effect from masking is greatly diminished after after .8 to 1 sec. If the interstimulus interval were set at 1.5 sec and the significant switches from a high intensity context condition dissappeared, one could conclude that the effect found in Experiment 3 was due to masking. However, if the significant switches still exist, an explanation other than masking would be in order.

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APPENDIXES

APPENDIX A

INSTRUCTIONS TO SUBJECTS

INSTRUCTIONS TO SUBJECTS

This is a relatively simple task. First, I want you to sit down and relax. Letters of different sizes will be presented on the video monitor. What I want you to do is to identify the letter as quickly and as accurately as you can. The letters will be presented one at a time, always at the center of the screen.

About every 2 or 3 or 4 letters, you will hear a "beep" as the word "LETTER" appears on the bottom of the screen. You are to key in the last letter that you said. This is for an error check.

The only part of the experiment that is timed is from the moment the letter appears on the screen until you identify the letter. Everything else can be done at your own rate.

At four different times during the experiment you will be given feedback on your speed and accuracy. I want you to try to say the letter as fast as you can. So fast that you even make a few mistakes. I would like to see you make between 2.5 and 5 percent errors. If you are not making any errors, the computer will assume that you are going too slow and tell you to speed up. If you make too many errors, the computer will assume you are going too fast, and tell you to slow down. Otherwise, it will tell you that you are going just right.

Again, your job is to identify the letters as fast and accurately as you can. Do you understand the instructions? Now we will start the practice trials.

APPENDIX B

TABLES

Table 1

Switching Times (msec)

Experiment 1. Letter Size

	Context Letter		
	Small	Medium	Large
Target Letter			
Small	Pure	7	19*
Medium	19*	Pure	5
Large	22*	2	Pure

HSD = 12.2, df = 184

*Significant difference, $P < .05$

Table 2

Switching Times (msec)

Experiment 2. Letter Intensity

	Context Letter		
	Low	Medium	High
Target Letter			
Low	Pure	5	2
Medium	10	Pure	4
High	4	7	Pure

HSD = 12.82, df = 184

Table 3

Switching Times (msec)

Experiment 3. Letter Intensity Revisited

	Context Letter		
	Low	Medium	High
Target Letter			
Low	Pure	-21	80*
Medium	3	Pure	69*
High	20	10	Pure

HSD = 23.68, df = 184

*Significant difference, $p < .05$

Table 4

Analysis of Variance Summary Table

Experiment 1. Letter Size

Source	df	MS	F	P
Blocks	4	9006.0	1.46	NS
Number of Context Letters	2	715.2	.21	NS
Context Size	2	32150.9	15.16	.0001
Target Size	2	220472.0	57.19	.0001
Context x Target	4	41567.6	17.35	.0001

NS - Not Significant, $p > .05$

Table 5

Analysis of Variance Summary Table

Experiment 2. Letter Intensity

Source	df	MS	F	P
Blocks	4	51054.5	2.54	.05
Number of Context Letters	2	358.9	.27	NS
Context Intensity	2	2019.0	.76	NS
Target Intensity	2	130339.9	36.70	.0001
Blocks x Context	8	936.1	.38	NS
Blocks x Target	8	3951.7	2.44	.02
Context x Target	4	5807.7	2.36	NS
Blocks x Context x Target	16	3256.4	1.39	NS

NS - Not Significant, p > .05

Table 6

Analysis of Variance Summary Table

Experiment 3. Letter Intensity Revisited

Source	df	MS	F	P
Blocks	4	10102.1	1.02	NS
Number of Context Letters	2	21191.0	1.84	NS
Context Intensity	2	580755.1	89.51	.0001
Target Intensity	2	4292869.1	210.13	.0001
Context x Target	4	394785.8	54.51	.0001

NS - Not Significant, p > .05

Table 7

Mean Response Time (msec) for Context and Target Letters

Experiment 1. Letter Size

Size	Context		Target	
	M	SD	M	SD
Small	416.4	46.9	425.6	50.1
Medium	405.1	46.6	396.0	42.2
Large	410.0	49.5	410.6	57.4

Table 8

Mean Response Time (msec) for Context and Target Letters

Experiment 2. Letter Intensity

Intensity	Context		Target	
	M	SD	M	SD
Low	376.4	51.7	388.6	52.4
Medium	375.7	52.6	368.8	50.6
High	373.7	50.8	368.7	50.0

Table 9

Mean Response Time (msec) for Context and Target Letters

Experiment 3. Letter Intensity Revisited

Intensity	Context		Target	
	M	SD	M	SD
Low	446.5	78.9	520.9	98.1
Medium	435.7	76.8	461.7	76.9
High	482.2	113.5	389.8	66.2

APPENDIX C

FIGURES

Figure Captions

Figure 1. Experiment 1, Letter size. Illustration of the temporal sequence for a given trial.

Figure 2. Experiment 1, Letter size. Illustration of the possible sequences for 1, 2, and 4 context letters.

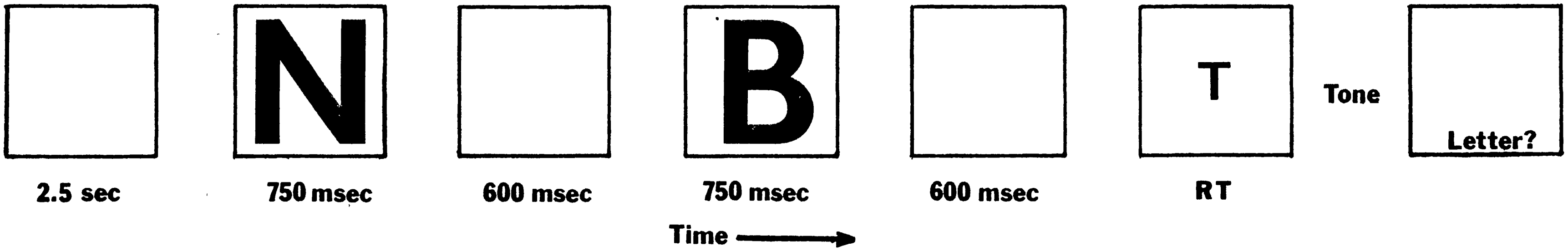
Figure 3. Experiment 1, Letter size. Mean response times for context by target interaction.

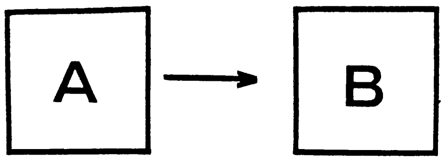
Figure 4. Experiment 2, Letter intensity. Mean response times for context by target letter interaction.

Figure 5. Experiment 3, Letter size revisited. Mean response times for context by target letter interaction.

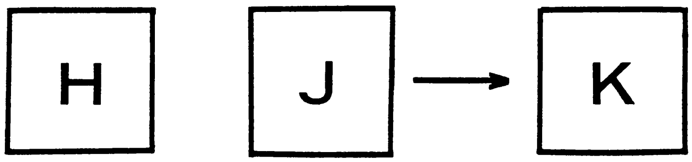
Figure 6. Experiments 1, 2, and 3. Mean response times for blocks of testing.

Figure 7. Experiments 1, 2, and 3. Mean response times for number of context letters.

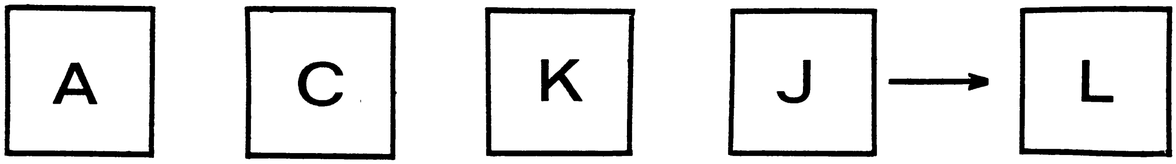

N
B
T
Tone
Letter?
2.5 sec
750 msec
600 msec
750 msec
600 msec
RT
Time



One Context Letter

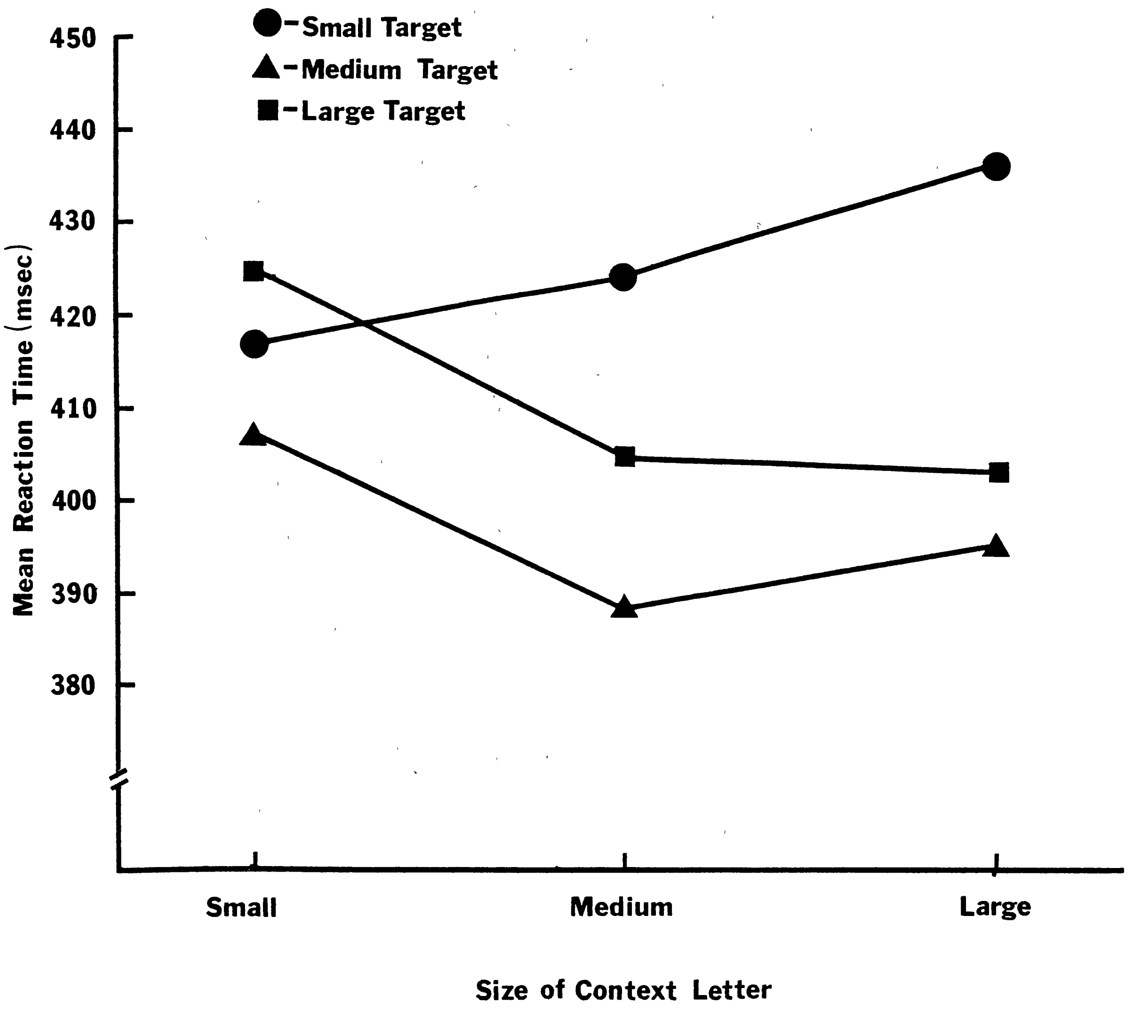


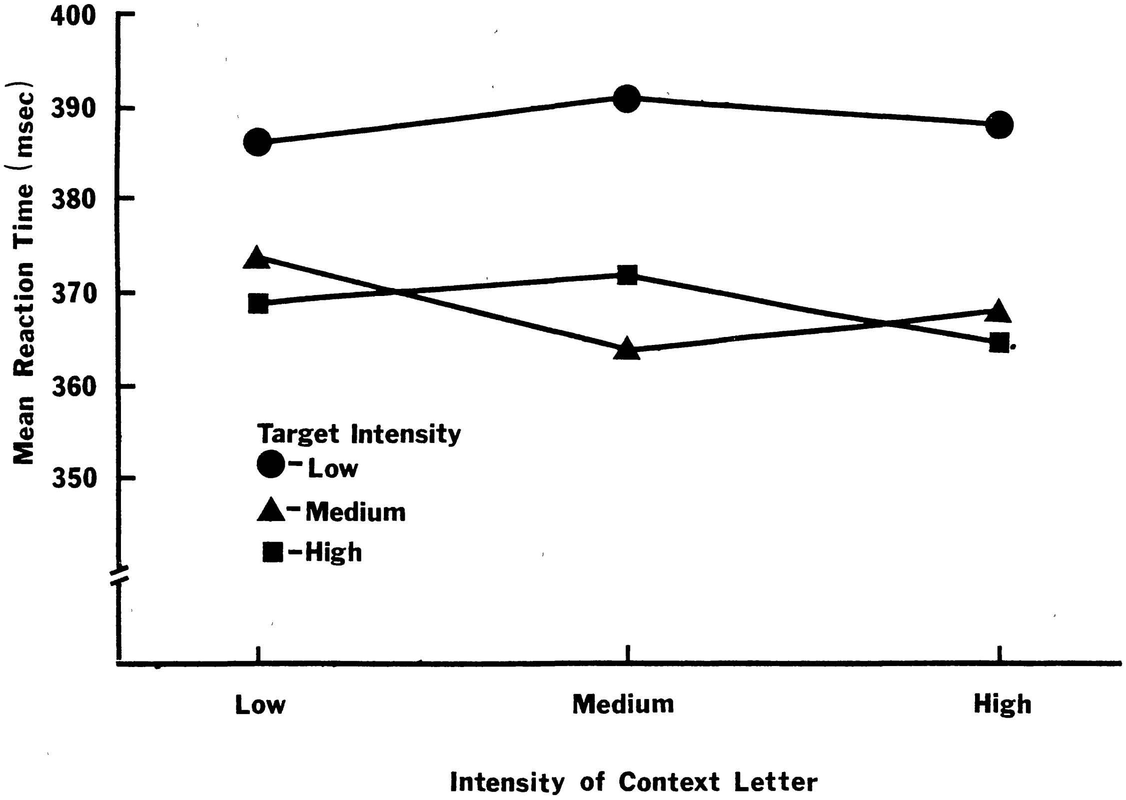
Two Context Letters

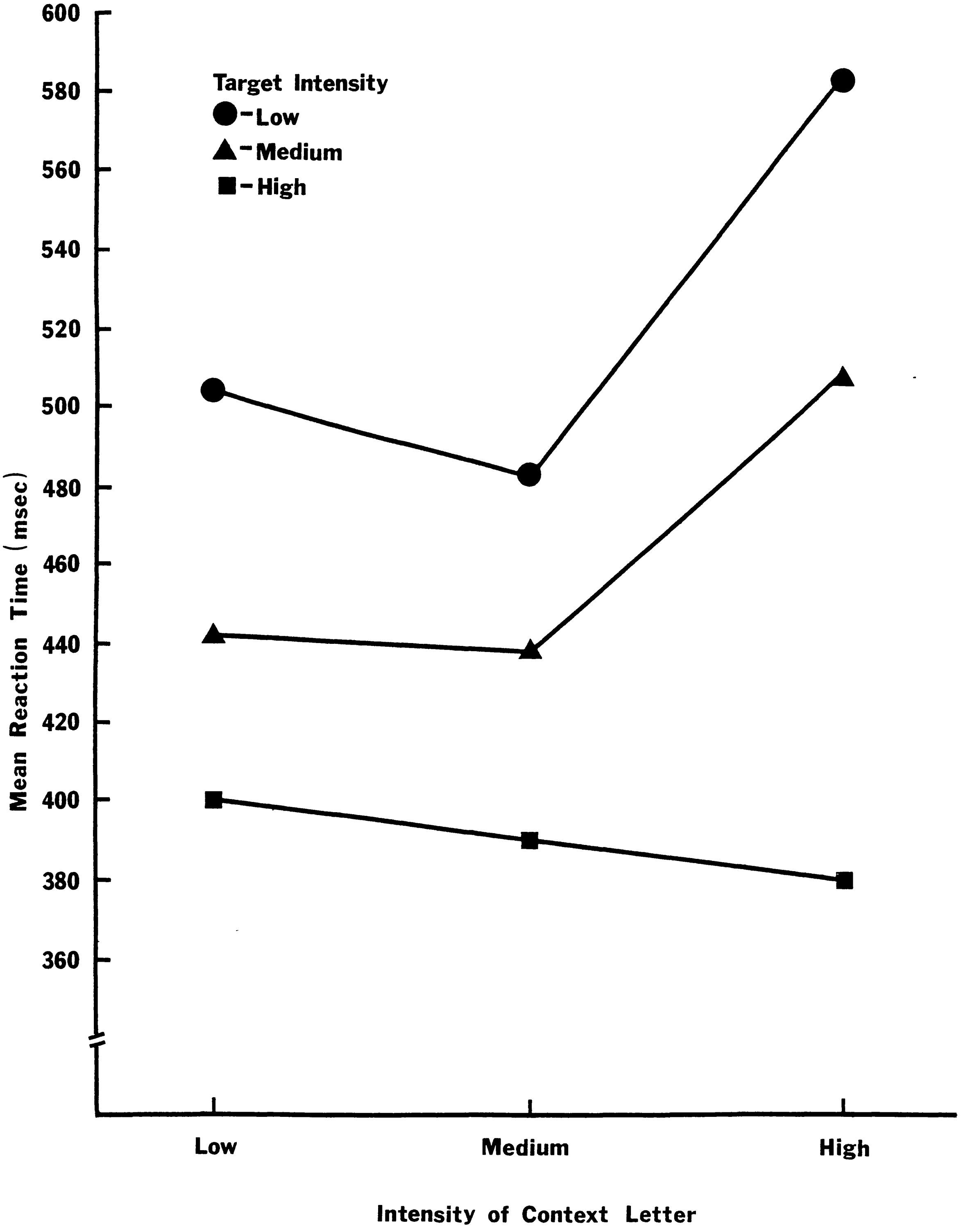


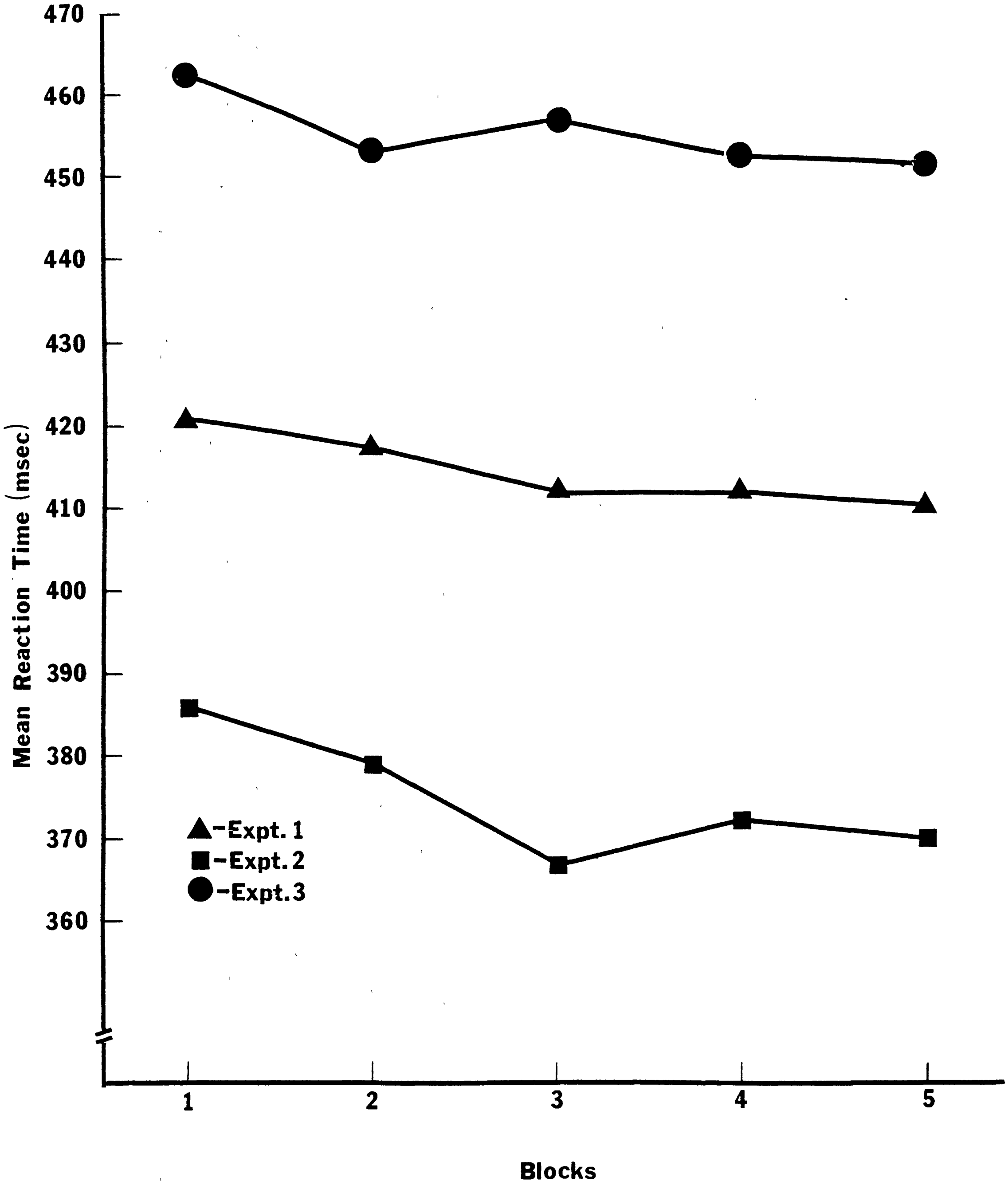
Four Context Letters

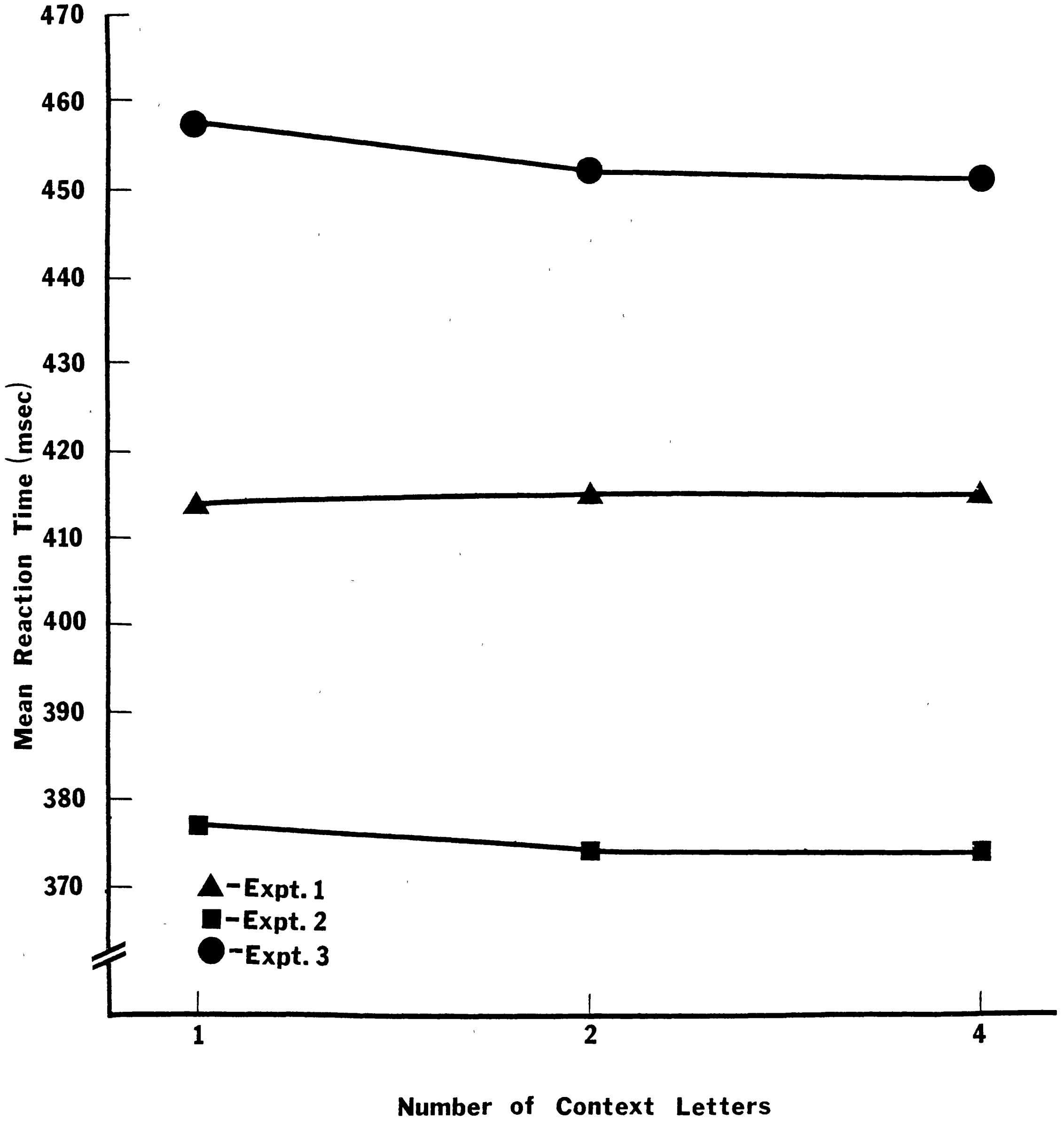
TIME →


●-Small Target
▲-Medium Target
■-Large Target
450
440
430
420
410
400
390
380
Mean Reaction Time (msec)
Small
Medium
Large
Size of Context Letter


400
390
380
370
360
350
Mean Reaction Time (msec)
Target Intensity
●- Low
▲- Medium
■-High
Low
Medium
High
Intensity of Context Letter

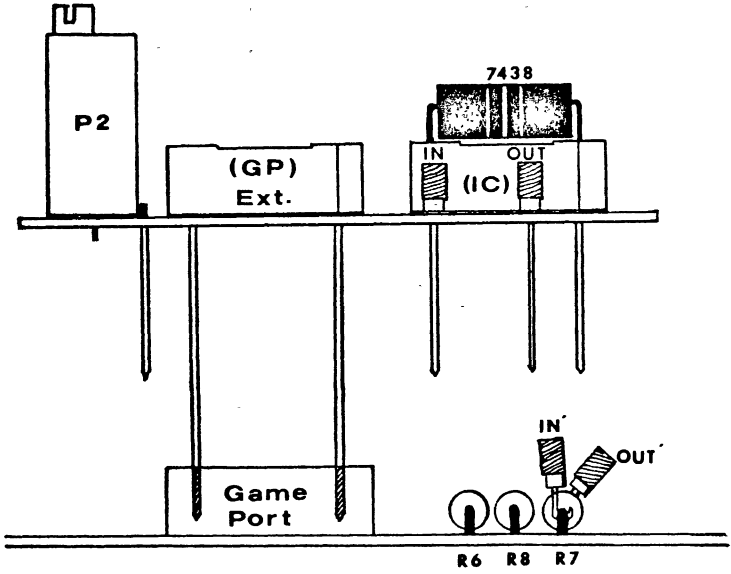

Mean Reaction Time (msec)
600
580
560
540
520
500
480
460
440
420
400
380
360
Target Intensity
● - Low
▲ - Medium
■ - High
Low
Medium
High
Intensity of Context Letter


470
460
450
440
430
420
410
400
390
380
370
360
Mean Reaction Time (msec)
▲-Expt. 1
■-Expt. 2
●-Expt. 3
1
2
3
4
5
Blocks

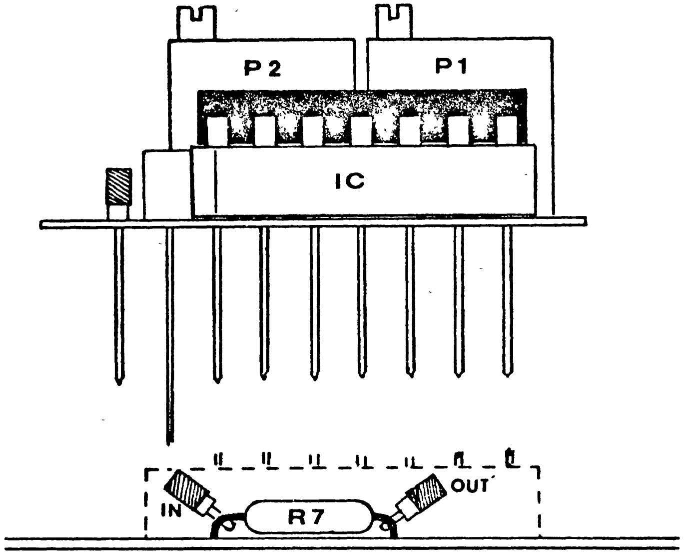

470
460
450
440
430
420
410
400
390
380
370
Mean Reaction Time (msec)
▲-Expt. 1
■-Expt. 2
●-Expt. 3
1
2
4
Number of Context Letters

APPENDIX D

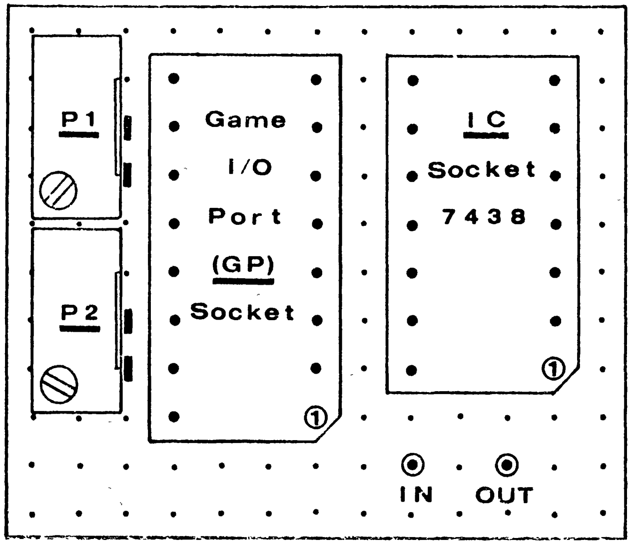
APPARATUS



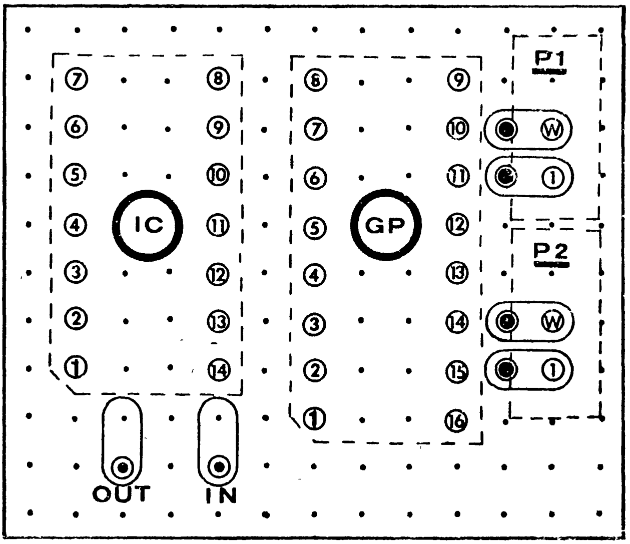
FRONT VIEW



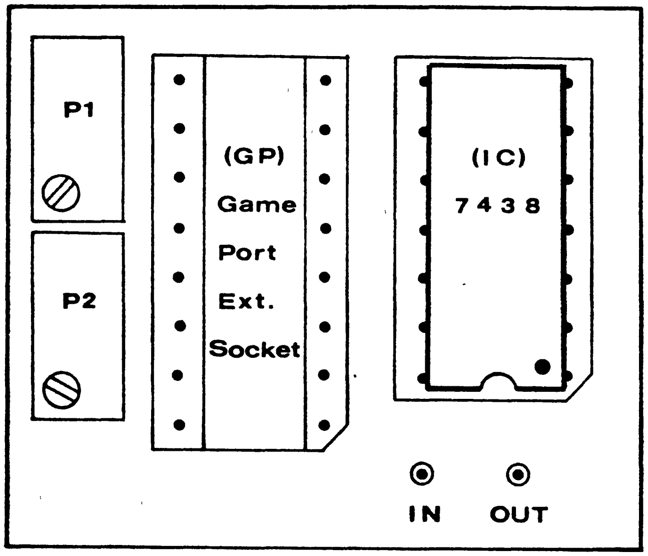
SIDE VIEW



COMPONENT SIDE



WIRE WRAP PIN SIDE



TOP VIEW

2

VITA

Joe Ray Brown

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