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Effects of Interstimulus Interval (ISI), Practice, Gender and Sex Hormones on Visual Recognition

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EFFECTS OF
INTERSTIMULUS INTERVAL (ISI),
PRACTICE, GENDER AND SEX HORMONES
ON VISUAL RECOGNITION

by
Catherine Milord

A Thesis Submitted to the Faculty of the Graduate School of Loyola University of Chicago in Partial Fulfillment of the Requirements for the Degree of Master of Arts

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VITA

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CHAPTER I

INTRODUCTION

History

According to Robinson (1976), every idea or scientific paradigm is embedded, to some extent, in the prevailing cultural context or milieu of its era. The information processing approach to the study of psychological phenomena is no exception. The rise of a technological "Zeitgeist" and the emergence of sophisticated computer hardware led to a methodological revolution in the experimental attempts to understand the central nervous system mechanisms underlying human perception and thinking. The CNS became widely conceptualized as a data processing system designed to interpret and refine tremendous quantities of information (Lachman, Lachman, & Butterfield, 1979). Newly available hardware and computer programs often determined the selection of problems to be studied and influenced the direction of research in this area. Questions of information reception, encoding, filtering, storage and retrieval are among the key problems studied by
information processing investigators.

Certain epistomological assumptions (Lachman et al., 1979) seem to undergird the studies in this area; for example, 1) that some kind of objective, outer reality exists, apart from human perception of it; 2) that knowledge and information originate with sensory observation; 3) that humans cannot know real objects directly, but only processed and interpreted versions; and 4) that there exist sometimes marked individual differences in the perception of reality.

Many information processing paradigms are largely phenomenological/psychophysical in that the experimental procedures focus on and attempt to measure the perceptual experience of each subject and hypotheses are generated about what structures or mechanisms might account for each subject's responses. Links to the cognitive perspective are centered on the necessity for complex processing to transform and organize incoming stimuli into meaningful, symbolic information through encoding, storage, elaboration and so forth (Neisser, 1967). A "proper explication of thought processes must begin with perceptual behaviour" (Haber, 1969, p. 1). At a physical level, primary neurological mechanisms may be invoked to "explain", among other things, certain regularities or
commonalities among subjects and observed temporal limitations in processing.

Paradigms

Since the information processing approach is a relatively new area of inquiry, several working models or paradigms have evolved in the movement toward eventual formal theorizing. Historically, these models were derived from tenets of "Information Theory" in the late '40s and '50s (Lachman et al., 1979). Information theorists began to conceive of the central nervous system as comprised of several processing stages, diagrammatically represented as a series of blocks illustrating the flow of hypothetical events as information passed through.

Broadbent's (1958) flow diagrams influenced subsequent information processing models because they elucidated a way to conceptualize the information flow into channels and components. "A perceptual response is assumed not to be an immediate consequence of stimulation, but one which has gone through several stages or processes, each of which takes time to organize or traverse" (Haber, 1969, p. 2). Although some aspects of the system's organization were assumed to be genetically fixed, the extent to which the system could
be modified by environmental events was and is an open question. Issues are often raised about the flexibility and adaptability of the system and its ultimate neurological limits. "It is assumed that this processing is limited by the capacities of the information-handling channels, the information content of the stimulus and prior experiences and condition of the perceiver" (Haber, 1969, p. 2).

Sperling's (1963) investigations found that it takes a certain amount of time to process information and that presentation of a "mask" within a critical time after the onset of the stimulus seemed to interfere with processing of the initial stimulus. The nature of this "interruption" process was unclear. Sperling was not able to ascertain which processing subroutines were being disrupted or whether the problem was one of storage or retrieval. Sperling reported that, without a mask, the visual system takes approximately ten milliseconds to process a single letter (one of the frequently used inputs). He also discovered that as the interstimulus interval (ISI) increased between stimulus and mask, subjects could more readily identify the letter.

Since 1965, with the advent of cathode ray tube (CRT) technology, it became possible for the first time
to study intricate space-time interactions in a way that had been heretofore impossible (Mayzner, 1968). It was discovered that processing mechanisms in the visual system are so complex that no existing model can yet reliably elucidate the nature of specific subroutines. Theory building in this area is still in the inductive phase with predictive power relatively weak. However, as Mayzner noted, "even such a model can still serve a useful function in integrating present empirical findings and in suggesting new avenues of inquiry" (Mayzner, Tresselt, & Helfer, 1967, p. 9).

Kahneman (1968) continued the thrust of studying the spatio-temporal processes in the visual system as a possible way of exploring the transformations of information flow as it travels through the CNS. As Mayzner (1975a) noted, failures of a subject's visual output to match the objective input may reveal much about the inner workings of the system, such as how much time the CNS requires to accurately process a stimulus, given certain conditions. Kahneman (1968) described the use of visual masking paradigms to study specific space-time interactions:

visual masking...covers the class of situations in which... the effectiveness of a visual stimulus (the test stimulus, TS) is reduced by the presentation of another (masking stimulus, MS)...When MS follows TS, the situation is one of backward masking (p. 404).
Masking paradigms are powerful ways of studying the temporal characteristics of the letter recognition process.

Kahneman (1968) reported that several alternative interpretations have been advanced in efforts to understand the masking-by-"noise" phenomenon. As has been previously mentioned, Sperling's "interruption" hypothesis stated that presentation of MS interrupts or interferes with the processing of TS. How does the MS stop processing of the TS? Lindsley (1961) proposed that MS interrupts the consolidation of the percept of TS (that is, the neural impulses carrying encoded information from the masking stimulus "catch up" with the initial stimulus before the percept is fully formed). Averbach and Sperling (1960) suggested that the complete percept is degraded before its information can reach a more permanent store.

Kahneman (1968), in his review of the various models purporting to explicate masking phenomena, stated that all current conceptions of backward masking assume that "the visual response to a brief stimulus lasts much longer than does the instigating stimulus...(thus), responses to two successive stimuli may overlap in time" (p. 419). Kahneman (1968) observed that "Integration"
models, as opposed to " Interruption " paradigms, assume that TS and MS "are linearly (or non-linearly) summed and that the response to their presentation in sequence is the same as would be evoked by their joint presentation" (p. 420).

Mayzner and Greenberg (1971) discussed Mayzner and Tresselt's (1970) model which conceptualized the visual system as:

an information processing system...; as a given visual input passes through this system, various functions are performed...(which) require a finite amount of time to carry out...It is estimated that 100-130 msec of real-time input processing occurs...before it enters...'subjective visual experience' (SVE), where another 100 msec of processing occurs...Two or more inputs occurring in the same location in space (i.e., overprinted) should tend to interact and interfere with one another to the extent that they have occurred in the same 100 msec time frame, i.e., SVE processing time (Mayzner & Greenberg, 1971, p. 83).

Tresselt and Mayzner (1969) noted, however, that:
"SVE processing time cannot be treated as a single stable value, but rather represents a quantity that can vary as a function of the particular experimental paradigm employed to estimate its value" (p. 104).

The results of five investigations conducted by Mayzner and Greenberg (1971) pointed to the necessity of revising the model's assumption of simultaneity of visual experience, because it was found that "the on-off timing
of a two or N-input string critically affects the degree or amount of interference experienced by the subject in the SVE component of the model" (p. 83). It was concluded that neither the interruption nor integration paradigms could adequately interpret the results; rather the findings suggested that "input processing involves neither integration nor interruption...but rather differential application of coding subroutines in a totally continuous fashion" (p. 84). An adequate model must address the questions: "What subroutines are applied in analyzing these inputs, how much time does the execution of these subroutines require and...what interactions occur between different subroutines as a function of the time course of an input..." (p. 84).

In 1975a, Mayzner further explicated his model:

We believe...the degree of interference (is) in part a function of the geometric structure of the input and the geometric structure of the noise field (mask)...the visual system now has two processing tasks to handle, together, with a consequent degradation of both inputs if the first input has not been fully processed when the second input occurs (p. 52).

Visual Recognition

The basic question tackled by researchers in the area of pattern recognition is how can the human being recognize anything as a meaningful pattern? Letters of
the alphabet are often chosen as prototypical patterns. The notion that there are certain "critical" features about a letter which are used (in an encoded form) to distinguish it from another letter is held by most thinkers in the field. Turvey (1973) attempted to clarify what nervous system mechanisms are involved in pattern recognition and how they work. He employed various masking paradigms to investigate relations between target and mask. In essence, Turvey argued that peripheral and central nervous system processes overlap in time, thus are partly concurrent. However, correct recognition of a letter would be contingent on peripheral nets outputting data to the central decision process, data which would be used to reconstruct the whole figure and then make decisions about the nature of the object. Turvey (1973) stated that, on the basis of his findings, neither integration nor interruption hypotheses could accommodate the phenomena of masking: "there are many ways in which one stimulus may impair the perception of another" (p. 46). According to his concurrent/contingent model, TS followed by MS would trigger "a change in the decision state of Cn (central decision process) ... discovering what kind of object the mask is may require the services of decision nets beyond Cn which are presently engaged in discovering what kind of object the target is" (p. 47).
Mayzner (1975a) further extended his view that a useful paradigm would include:

1) a possible hierarchical ordering of processing subroutines of feature analysis..., based on geometric properties of the input and potential confusability patterns applied in a relatively fixed order by the visual system as each new input enters...this set of subroutines is probably highly similar across subjects and 2) the execution time for these processing subroutines can vary considerably, from a few milliseconds up to and quite well beyond 80 msec, across subjects (p. 52).

**Purpose**

Models previously discussed concerned themselves with several central issues:

1. What factors seem to modulate the operation of processing subroutines such that performance on various tasks is effectively modified?
2. What are the ultimate neurological limits to a human subject's capacity to improve the efficiency of his visual processing?
3. How can a paradigm account for the existence of marked individual differences in time requirements needed to accurately complete processing tasks, given the assumption of similarly ordered underlying structures across subjects?

This thesis examines the general question of
adaptability: How and in what manner does the visual system extract and interpret incoming sensory information? More specific hypotheses will be advanced at the end of the literature review section.

Felsten and Wasserman (1980) recently reviewed the visual masking literature, discussing new results and synthetic trends from psychophysical and psychobiological studies. The "interruption" versus "integration" interpretations of visual masking and the relative contributions of peripheral and central nervous system mechanisms to masking effects (Kahneman, 1968) were extensively re-examined in the light of current findings.

Supporters of the integrative position assume that the responses evoked by TS and MS interact in a common neural location, with a consequent degradation in the encoded representation "analogous to the effect produced by double exposure of photographic film" (p.332). Those who hypothesize about interruptive processes do not assume any direct interaction between responses, but rather propose that the visual system does not have enough time available for processing TS before MS claims attention. Felsten and Wasserman (1978) found that, although the initial response to TS may reach central levels before MS is presented, "there can still be a
receptor interaction between the later portions of the first response and the early parts of the second" (p. 340). Evidence from studies cited supported the idea that masking phenomena are mediated by neither purely peripheral nor solely central levels of processing, but "by successive stages of neural interaction" (p. 342).

Felsten and Wasserman (1980) concluded that the experimental evidence points strongly to the integrative nature of masking:

although the integration can produce an interruption of sensory signals. When the stimuli share the same receptors, masking occurs in the first place it possibly can and is mainly peripheral, mediated by receptor dynamics with central network interactions playing a smaller role. When the stimuli do not share the same receptors, central network effects come to the fore, with an as yet uncertain contribution from central integration (p. 351).
INTERSTIMULUS INTERVAL (ISI)

If there were no delays in the flux of experience, then consciousness itself would be a logical impossibility... the 'psychological present' is a definite temporal interval where events are temporally integrated—that is, brought together as a unitary experience (Blumenthal, 1977, p. 22).

Averbach and Sperling (1960) became interested in how a human processor "loses" key information from a visual presentation between time of exposure to the stimulus and reported experience. They suggested that subjects "hold" information in the form of a persistent visual image for a short time after the actual presentation has ceased. The authors wished to ascertain how quickly information could be "read out" from this visual store; thus, they used a backward masking paradigm in order to observe the temporal parameters involved in information extraction. How much time would be needed (in milliseconds) to accurately process the first stimulus before the masking stimulus appeared and added another processing task to the visual system?
Essentially, results of several experiments showed that as the time interval between the offset of TS and the onset of MS increased, there were progressively improving scores on various visual tasks. When the subjects had more time available to "read" or encode the stimulus, they were more accurate.

Similarly, Eriksen and Hoffman (1963) found greater form recognizability as interstimulus intervals (ISIs) increased, with an asymptote reached at 250 - 450 milliseconds. Eriksen and Steffy (1964), using a modified forced-choice task, found performance was worse at short ISIs with improving accuracy up to 100 milliseconds. Further evidence that performance was measurably better as ISIs increased was provided by the results of Eriksen and Lappin's (1964) study which used a form recognition task. When a three-field tachistoscope was used to present stimuli, Eriksen and Collins (1965) observed that the backward masking effect occurred when ISIs were less than 50 milliseconds. Thompson (1966), in a letter recognition task using a 100 millisecond light flash as mask, noted that as ISI values ascended, percent correct recognitions also increased.

Mayzner, Tresselt, Tabenkin, Didner, and Helfer (1969) began studying ISI effects using more
sophisticated procedural methods, including computerized presentation of stimuli on cathode-ray tube displays (Mayzner, 1968; Mayzner, Tresselt, & Helfer, 1967). They examined the impact of varying ISI values on recall of word strings using ISI values of 100 - 700 milliseconds. Katz, Schoenberg, and Mayzner (1970) investigated the impact of ISI values 60 - 300 milliseconds on recall of digit strings. Results from these investigations showed that as ISIs increased, percent recall also increased, up to 300 milliseconds. In order to systematically discover just how sensitive the visual system was to very minute changes in ISI values, Mayzner, Tresselt, Checkes, and Hoenig (1970) chose to work with ISI values of 20, 40, 60, 80, and 100 milliseconds. It was reported that as ISIs rose, mean percent recall scores also consistently improved. Perfect recall occurred at 300 milliseconds ISI. As Mayzner et al. (1970) noted, "results...suggest that ISI increments as small as 20 msec. may have profound effects on processing, storage, and retrieval performance" (p. 295).

Mayzner and Tresselt (1970) found that, when two sequential letters were displayed in the same location (overprinted), performance was better at longer ISIs, particularly with an ISI of 50 milliseconds. They interpreted these findings as signifying that longer
delays between two inputs provide "for more time between the excitatory fields associated with each input, and, therefore, less interaction between the successive excitatory fields should result with a concomitant increase in (correct) detections..." (p. 612). Tresselt, Mayzner, Schoenberg, and Waxman (1970) combined a blanking/overprinting paradigm and results seemed to suggest that:

the interacting excitatory fields of the two overprinted inputs, particularly at low ISI values,...most probably are coded together in the 'subjective visual experience' (SVE) of our model...since they are experienced together much of the time as a composite jumble of points...They most probably are also coded separately at least some of the time at a point prior to SVE...(p. 263)

Mayzner and Greenberg (1971) reported results from several studies. In one investigation, using a backward masking procedure, they found a "highly consistent and systematic increase in mean percent correct letter recognition scores as...off time (ISI) is increased for any given on time" (p. 80). ISIs were varied from 10 to 40 milliseconds ISI. Findings from Mayzner's (1972) study of the processing of alphabetic inputs led him to conclude: "That an increment as small as only a few milliseconds can produce such changes in performance suggests an exquisitely sensitive system of visual information processing" (p. 240).
Mayzner and Habinek (Note 1), in a study examining visual pattern recognition, found that increasing ISI values produced "massive improvements in recognition performances or processing rates" (p. 3). Schultz and Eriksen (1977) also noted that target identification performance improved with rising ISIs.

In brief, the results of all the aforementioned studies seem to support Rumelhart's (1977) assertion: "The longer one is allowed to process the stimulus the more information one will gather about it and the more accurate one will be in identifying it..." (p. 61).

Blumenthal (1977) certainly concurred when he stated:

the rate of cognitive performance in general (perception, thought, and memory) must be temporally limited in some manner...just as human sensory systems are 'tuned' to narrow ranges along certain energy spectra, so human cognitive activity...may be limited temporally to narrow ranges of event-durations and intermittencies (p. 24)

Practice Effects

Repetition is a variable of central importance in research on learning, and it is therefore surprising that it has not drawn much attention in perception...few models of perceptual behaviour have incorporated repetition effects (Haber, 1969, p. 227).

Results from several studies have shown that extended practice periods increased multiple comparison performance in visual search and scanning tasks (Neisser,
1963, 1967; Neisser, Novick, & Lazar, 1963). However, Sternberg (1967) found that there was no change in character recognition performance with only limited practice (two sessions). Haber (1969), on a word recognition task, observed that repetition alone, independent of any changes in the intensity of the stimulus, increased accuracy.

Nickerson (1966) found that prolonged practice decreased reaction time in a visual memory scanning task, such that subjects could more quickly identify whether one set of items contained commonalities with another. However, practice did not completely eliminate the fact that reaction time increased as the size of either set became larger. Burrows and Murdock (1969) investigated the impact of practice on a character recognition task. The experimenters required subjects to decide whether one set of targets was present in another set, which was presented later. Extended practice helped subjects to compare faster, but did not alter the basic nature of their search process. Kristofferson (1972a) reported results from subjects for 25 sessions on a visual search task. With increased practice, performance greatly improved; that is, subjects were able to visually scan and find the target progressively faster with time. However, even after extended practice, subjects "never
achieved as rapid scanning rates for 5 or 10 targets as for 1" (p. 327). Kristofferson (1972b) investigated whether character classification performance (a cognitive task involving memory search) was changed by extended practice. She found that response latencies decreased with practice; that is, subjects responded more quickly when indicating whether a single visually presented digit was a member of a previously designated set of digits.

Atkinson and Juola (1974) noted that information identification mechanisms may become more efficient, enabling swift decisions, as familiarity with the stimulus increases. Chabot, Miller, and Juola (1976) varied tasks such that each required a different level or "depth" of information processing. They found that, with repetition, subjects formed judgments more rapidly and accurately. However, even with repetition, decisions requiring deeper levels of processing required more time than shallow level tasks. Nelson (1977) reported results of three experiments which showed that repetition improved performance on a depth processing task, regardless of whether practice was massed or distributed. Fiorentini and Berardi (1981), using a visual discrimination task, found that correct responses progressively increased with repetition of trials up to 100 - 200 trials, and then leveled off.
Fisk and Schneider (1981) noted that results of perceptual vigilance studies had generally found that detection performance became worse the longer a subject was required to focus attention on and visually monitor the target. However, Schneider & Shiffrin (1977) observed that performance scores on many cognitive/perceptual tasks seemed to result from either primarily "automatic" or "control" forms of information processing. Automatic processes were characterized by the authors as rapid and requiring relatively little conscious effort by a subject, although extensive prior training was thought to be a prerequisite for their development. Optimal situations for this development occur when subjects focus on and consistently respond to each stimulus. Control processes require more time and conscious effort and are used when a subject is faced with new or constantly shifting information. Thus, Fisk and Schneider (1981) pointed out that the conflicting results of vigilance experiments may have been due to investigators not specifying whether automatic or control processes were involved in completing the tasks. Studies in which there were marked vigilance decrements with increasing practice may have been due to the use of tasks requiring control processing. Childs (1976) found no decrement in performance with practice in an automatic processing
task. Fisk and Schneider (1981) designed a vigilance task which could be performed using the automatic type of processing and found that subjects had much better performance with practice in the automatic versus control processing conditions. Results of Regan's (1981) experiments in letter naming were consistent with the notion that extensive practice is a necessary condition for automatic processing of the task to develop. Response times for naming well-known English letters were rapid, while latencies for naming unfamiliar Armenian letters were longer, although performance on the latter was greatly improved with practice.

Jacoby and Dallas (1981) hypothesized that recognition memory may improve as a function of simple repetition due to the organism's sensitivity to experience with the stimulus, producing in the subject a "relative perceptual fluency" or familiarity. Carroll and Kirsner (1982), using a lexical decision task, found that the retrieval mechanisms for lexical decision are susceptible to only a relative perceptual fluency form of memory...(that is) the feeling of familiarity resulting from prior presentation...operates on permanent components of the lexical system... (p. 68).
Maccoby and Jacklin (1974), in their review of the literature on sex differences, concluded that there were two cognitive differences which were "well-established": 1) female superiority on verbal tasks and 2) male dominance on mathematical and visuo-spatial tasks. Since that time, many investigators have found similar sex discrepancies in performance. For example, Sherman (1967) reported that males' performance exceeded females' on various spatial tasks including embedded figures, rod-and-frame test, mental rotation and map reading tasks, and mazes. Similarly, Thompson, Mann, and Harris (1981) found that males performed better on a spatial task (Piaget and Inhelder's water level). Birkett (1980) noted that performance on only the most complex of three visuo-spatial tasks (the Differential Aptitude Test of Space Relations, using three-dimensional items to test spatial manipulation) discriminated between male and female groups, with males' scores surpassing females'. Papineau (1981) reported that recall performance on a verbal paired-associate learning task was greater for females than males.

These performance differences have been attributed to presumed sex differences in brain hemispheric
functioning (McGlone, 1980). It has been proposed that the male's right hemisphere is more specialized for spatial processing than is the female's. For example, Dawson (1981) tested 40 right-handed subjects on a dichaptic (tactuospatial) processing task and found that males had a better performance with the left hand than did females. The author concluded that these results supported the hypothesis of greater male right hemisphere specialization. Bryden, in his 1979 review of possible sex differences in cerebral organization, observed that there are few notable patterns, other than that males may be more highly lateralized (i.e., more differentiated for task-specific functioning) than females.

Levy (1976) hypothesized that females' hemispheric processing in general was not as functionally specific as males'. He proposed that females' use of the right hemisphere for verbal processing interfered with its use in spatial problem solving. Berry, Hughes, and Jackson's (1980) findings lent some support to Levy's proposition. The authors stated that females' use of verbal aids in a simultaneous verbal-spatial task hindered their effectiveness due to inter-task interference, such that males outperformed females. However, Sherman (1978) concluded from her review of relevant studies that there is insufficient evidence to show that females are more
verbally bilateral than males.

Safer (1981) concluded from his study that "females have privileged access to left-hemisphere verbal codes for emotion" (p. 86). The author bases this conclusion on results from an investigation in which females were found to be more accurate than males in recognizing facial expressions of emotion when the stimulus picture was exposed to their right visual field (left hemisphere). Safer (1981) postulated that females are superior in storing emotional information using verbal codes. One implication of the findings is that females have words available to describe and classify their emotional experiences, while men may rely more on imaged memories of their own autonomic sensations, visual eliciting stimuli, tones of voice etc. (Cozby, 1973) and may have difficulty relating available words to internal feeling-states (right hemisphere). One interpretation of these results could be that males and females possess different neural structures or that each sex has a brain which innately "specializes" in facile processing of certain kinds of information, with opposite hemispheres dominant for each sex. Alternatively, however, it can be proposed that women's "privileged access to verbal codes for emotion (may) result from differential experience in expressing emotional feelings...learning can affect
hemispheric specialization" (Safer, 1981, p. 98).

It has been assumed by many investigators that sex differences in performance reflect actual underlying differences in brain or central nervous system organization. This assumption has been challenged by researchers who have generated alternative interpretations of the data. Bryden (1978) argued that subjects (as active processors) use idiosyncratic strategies for approaching experimental tasks and that procedures which have claimed to assess asymmetric brain function may have insufficiently accounted for other sources of variation. Kimura's (1966, 1967) structural interpretation of laterality effects states that one hemisphere is more specialized and efficient in processing certain kinds of information. However, Kinsbourne (1970, 1973, 1975) proposed that attentional factors can account for some lateralization results. Bryden (1978) noted that attentional bias, perceptual strategies, mental "set" and cognitive style may all affect and confound outcomes on tasks designed to test for laterality.

Sherman (1978) proposed that females and males differ in their problem-solving approaches, and not in their degree of lateralization, with females using verbal
strategies to solve spatial problems. A woman may approach a given task as a linguistic one for many reasons other than that of possessing a "specialized" left hemisphere. McGlone (1981) observed that males reported using specific cognitive strategies while working on spatial tasks such as "mental imaging" or "comparing alternative routes." Allen (1974) noted that women subjects have more often reported using either no particular strategy or a concrete approach, such as using a pencil to "map out" an area. McGlone (1981) found that, while solving a spatial task, females moved their heads and hands rotationally more than did men. While completing a verbal task, women made more vocalizations than did the men. Although both sexes were equally accurate on both tasks, males completed the spatial task more rapidly. Similarly, Freedman and Rovegno (1981) found that males obtained higher scores on the Vandenberg Mental Rotation Test than did females. Females counted blocks with their hands and used less visual imagery than males. Conceivably, males' exploratory behavior and subsequent greater familiarity with literal physical space may account for some of their ease in solving spatial problems. As McArthur, Crocker, and Folino (1981) noted, "Spatial perception requires the ability to represent one's body (or an object) in a variety of
orientations vis a vis a stimulus array" (p. 923). McArthur (1981) found that males performed better using proprioceptive rather than tactile cues on a spatial task. She hypothesized that this utilization of proprioceptive cues reflected "differential experience in the physical domain...boys receive greater stimulation of gross motor behaviour than do girls in the early years" (p. 929).

Although sex differences in task performance have often been demonstrated, Sherman's (1978) review noted that the magnitude of these "well established" gender differences was quite small. Hyde (1981) decided to perform a meta-analysis on Maccoby's (1974) data, using a "technique for analyzing a body of research by statistical analysis of the analyses of the individual studies" (p. 892) in order to evaluate and re-define the meaning implied in the phrase "well-established differences." Hyde found that the magnitude of differences in cognitive performance was statistically tiny and concluded:

gender is a poor predictor of one's performance on ability tests...also...a poor predictor of performance on jobs requiring these abilities...known differences are still too small to explain the observed occupational differences (for example, underrepresentation of females in certain fields such as engineering)...(p. 899).
Hyde's (1981) findings may partially illuminate the confusing and frequently contradictory results from many gender studies; as the author noted "If the true difference in population means for males and females is small, then one would expect that in repeated samplings, many would find no significant gender differences" (p. 900). Quasi-theoretical attempts to explain sex differences (such as laterality with varied samples) have generated vague and conflicting data perhaps due to the probability that the differences they are trying to explicate are very small. Hyde's (1981) findings combined with data which demonstrate the powerful impact of psychological/social/educational experience on both hemispheric specialization, self-concept, and achievement levels argue for cautious interpretations of any observed sex differences in the cognitive performance realm.

Males and females do differ in the proportion of circulatory sex hormones in their system, with adult males higher in androgen and females in estrogen levels (Stone, 1980). It is unclear just how the delicate hormonal substances interact with CNS mechanisms to regulate reproductive and other organismic activity, but some authors have attributed female superiority on certain tasks (such as psychomotor reminiscence) to the activating effects of estrogen, which may increase the
arousal level in the CNS (Broverman, Klaiber, Kobayashi, and Vogel, 1968). Wells and Payne (1979), for example, found that females reminisced significantly more at or near their estrogenic peak (ovulation) than at other menstrual phases. The authors proposed that high levels of estrogen (relative to the proportion of progesterone) increased intensity of responding in women. Since females' circulating levels of estrogen are consistently higher than male levels, studies showing sex differences on reminiscence and other perceptual tasks may be re-examined in the light of this hypothesis. It has been argued by Lamson-McBride and Payne (1981) that:

> estrogenic hormones may augment the actions of one or more neurotransmitters, such as epinephrine, norepinephrine, and serotonin, by inhibiting monoamine oxidase (MAO). This enhancement of central adrenergic activity might well account for an increased intensity of response activation, for...MAO inhibitors...can function as potent stimulants to produce an increased sense of well-being and heightened psychomotor activity (p. 99).

A review of studies investigating hormonal effects on task performance will follow.

The Influence of Sex Hormone Levels

We may now believe that in the intersitial tissues of the gonads, special chemical substances are produced, which, when taken up in the blood stream, charge definite parts of the central nervous system with sexual tension (Sigmund Freud, 1938, p. 610).
Changes in the activity of endogenous hormones (primarily estrogen and progesterone) associated with the normal menstrual cycle have been shown to be related to concomitant modulations in sensory/perceptual function, central nervous system arousal, and subjective mood. Altmann, Knowles, and Bull (1941) studied 55 menstrual cycles of female volunteers and found that, near time of ovulation, 67.5% of the women reported increased elation and 85.3% noted increased pleasurable activity relative to their feelings and activity levels at other cycle phases. In contrast, most of the women reported high degrees of depressive and tense feelings, along with increased nervous activity, during the pre-menstrual phase (just prior to actual menses flow). On the average, ovulation occurred on the 11.8th day of cycle" (p. 224). Apparently, the ovulatory phase of the menstrual cycle was associated with an increased sense of well-being among women investigated.

McCance, Luff, and Widdowson (1937) and Udry and Morris (1968) observed that women reported increased feelings of sexual arousal with more frequent coitus occurring at mid-cycle, along with fewer feelings of pain, fatigue and sadness. This finding does not contradict published reports of copulatory patterns in primates (Michael, 1968). Benedek (1960) found that
subjective feelings of anxiety and hostility decreased in the ovulatory segment of the menstrual cycle; she hypothesized, "sex hormones are facilitating agents which, by changing threshold values, allow specific nervous mechanisms of sexual behavior to be more readily stimulated" (p. 9). Similarly, Gottschalk, Kaplan, Gleser, and Winget (1962) demonstrated that measured inner directed hostility and anxiety scores dipped to their lowest at mid-cycle. "The 'narcissistic state' of the woman...signalizes the peak of sexual receptiveness about the time of ovulation. The enhanced libidinal state is felt as a satisfying state of one's own body" (Benedek, 1960, p. 12). Women in Ivey and Bardwick's (1968) study reported deeper feelings of contentment and capability or efficacy at ovulation.

In free-cycling women, estrogen levels reach a peak at or near the ovulatory stage, approximately on days 12-14 (Loraine & Bell, 1968; Lorraine, Bell, Harkness, Mears, & Jackson, 1963). Thus, cyclical changes in subjective emotional state may reflect underlying alterations in estrogen/progesterone secretion. Hamburg, Moos, and Yalom (1968) found that the subjects rated their sexual arousal as strongest near ovulation. Female subjects in another study rated themselves as lower on pain, anxiety, and aggression scales at ovulation while
they were higher on "pleasantness" and sexual arousal
(Moos, Kopell, Melges, Yalom, Lunde, Clayton, & Hamburg, 1969). Diamond, Diamond, and Mast (1972) cited findings which showed that women's olfactory and acoustic sensitivity were greatest during the ovulatory phase while pain sensitivity decreased during this same time period. Tobias (1972) noted that females were able to perceive binaural beats more frequently around time of ovulation. A pair of investigators (d'Orban & Dolton, 1980) studied the records of 50 females charged with violent crimes and found that there was a significant absence of offenses during the ovulatory phase.

Augur (1967) found that while free-cycling women's records showed significant variations in mood and autonomic symptoms, the ratings of oral contraceptive using women showed no such rhythmic fluctuations. However, Pill users did score lower overall on mood scales labeled "energetic" and "aggression" than did women not taking the Pill. The author also noted diminished parasympathetic activity among the Pill group. Diamond et al. (1972) found that, for normally cycling women, dark-adapted visual sensitivity (acuity) was greatest at ovulation while no such systematic variation was found in Pill users or men. In a like study, Tedford, Warren, and Flynn (1977) observed that free-cycling women
showed significant fluctuations in shock aversion threshold "from a maximum at ovulation to a minimum one week after the onset of menses" (p. 193). Female oral contraceptive users and males showed no such cyclic changes. It was the conclusion of Diamond et al. (1972) that:

> From the point of view of evolution, the emotional and sensory variations would be adaptive and likely to be perpetuated because an increased probability of coitus at the time of ovulation would result in an increased probability of conception" (p. 175).

Another hypothesis which attempted to explicate these changes in sensitivity was advanced by Kopell, Lunde, Clayton, and Moos (1969). Results of their study showed cyclical changes in two-flash threshold scores (a task which was defined by the authors as reflecting a general state of organismic arousal). They hypothesized that hormonal variations associated with the cycle regulated and modified central nervous system arousal states. Diamond et al. (1972) cited two supporting studies which found that women who had their ovaries removed showed an acute decrement in sensitivity to odor, but sensitivity was restored with estrogen treatment.

In support of the "arousal hypothesis", Broverman, Klaiber, Kobayushi, and Vogel (1968) attributed female superiority on specific overlearned cognitive tasks to
the known activating or energizing effects of estrogen on central nervous system arousal level since performance on these tasks was found to peak at ovulation when estrogen levels were highest (Broverman, Vogel, Klaiber, Majher, Shea, & Paul, 1981; Vogel, Broverman, & Klaiber, 1971). De Marchi and Tong (1972) found that, in a temporal discrimination task, threshold for fusion was highest premenstrually; that is, discrimination of two light flashes was poorest at that time. They concluded that menstrual phases can be conceptualized as changing the arousal cycle, with varying levels of activation (due to hormonal fluctuations) influencing performance such that a "curvilinear relationship (obtains) between arousal and perceptual discrimination" (p. 363). The authors interpreted the results cautiously in that they were reluctant to attribute the poor performance directly to hormonal changes (as did Kopell et al., 1969) since they found that subjects had also used more stringent response criteria premenstrually, perhaps to compensate for reported difficulties in focusing on these days.

Wong and Tong (1974), in a temporal discrimination task using signal detection procedures, compared a free-cycling with a Pill-using group of women and again found that oral contraceptive users did not show the cyclical performance changes shown by women off the Pill.
Further, Pill users were found to have lower overall discrimination sensitivity, particularly for days 10 - 15, or the time when they would have normally ovulated. Barris, Dawson, and Theiss (1978) tested free cycling women on a scotopic sensitivity task during the middle seven days of their menstrual cycle. They found a rise in sensitivity at ovulation.

Sher, Pionk, and Purcell (1981) tested highly trained subjects on a signal detection task (500 trials) at several different phases of the normal menstrual cycle. Highest dark-adapted visual sensitivity was found at ovulation, although this result did not hold for light-adapted states. The reasons for this discrepancy were unclear, but the authors believed that the findings limited the usefulness of the general arousal hypothesis (Kopell et al., 1969) and the evolutionary interpretation (Diamond et al., 1972) since neither predicted the occurrence of differences in sensitivity between dark and light-adapted conditions. However, the study conducted by Sher et al. (1981) may have contained some methodological flaws in that there were only four subjects and the light and dark-adapted sessions were conducted during separate menstrual cycles; thus, phase effects of one cycle may well have been unduly or unpredictably influenced by concurrent extraneous
external, historical, or inner psychological events. Testing over several cycles in each condition would correct for these possibilities, and provide more clarity about the processes involved.

**Individual Differences**

Mayzner, Tresselt, Tabenkin, Didner, and Helfer (1969) classified undergraduate subjects as "slow" or "fast" processors based on their performance on a word recognition task at short ISIs (less than 100 msec). The finding of wide individual differences in visual recognition performance in Mayzner and Greenberg's (1971) experiments led the authors to note that "the temporal resolving power of the visual system... (does) not yield a constant integration period of 10 to 20 msec" (p. 81). Large individual differences in processing rates between subjects were reported by Mayzner (1975b) on a letter/non-letter recognition task. Browning-Crinion, Dolmetsch, and Mayzner (1978) reported results from a word recognition study and again found enormous individual differences among their subjects. Although all subjects were presented with 220 words as stimuli, 10 subjects (of 50) reported seeing no words at all while the top ten subjects recognized from 143 to 185 words. Whatever processing occurs between presentation of the TS
and MS (with the mask immediately following the target stimulus) may differ greatly between individuals. If it is assumed that similar brain structures and processing stages are involved across subjects in the transmission, coding, and integration of stimuli, how can such wide individual differences in very basic perceptual processing be understood?

Attempts to group individuals according to some homogeneous classification system have shown that even within a categorized subgroup, large individual differences still occur. For example, Siegenthaler and Knellinger (1981) noted that research investigating central nervous system functioning is difficult due to individual differences among subjects tested. In trying to assess results of CNS damage through the use of a dichotic listening task, the authors found that brain-injured subjects, as had been expected, performed more poorly as a group than did normals. However, nearly one-third of the subjects in each homogeneously classified group performed quite differently from their respective subgroup fellows.

Clearly, performance on a specific cognitive task may be influenced by an individual's genetic makeup, intellectual capacity, presence of brain injury, degree
of psychopathology, temperamental and other stable personality traits, and situational or transient variations in emotional or physiological "states."

**Influence of Transient "State" Factors**

Several "situational" variables have been associated with changes in perceptual and cognitive task performance. These factors are "task motivation", diurnal rhythmic variations in efficiency, and "state" mood. Differences in individual "states" may account for differential performance. Individuals may differ in their degree of "task motivation". It is presumed that motivated subjects focus their attention on the task and make optimal use of processing resources. For example, motivational manipulations have produced differential performance on cognitive tasks with adolescent schizophrenic inpatients (Wallace, 1981), grade school students with psychoeducational problems (Adelman & Chaney, 1982), normal children (Bandura & Schunk, 1981), and female undergraduates (Strang, 1981).

Several investigators have noted that physiological functions and measures of performance may vary over the course of the day (Conroy & Miles, 1970; Palmer, 1976). Craig, Wilkinson, and Colquhoun (1981) found that correct auditory vigilance responses were lowest in the morning
with better performance occurring later in the day. It has been proposed that such diurnal variation may reflect fluctuating levels of arousal (Craig et al., 1981) and that individuals differ as to when they feel most alert, focussed and emotionally stable. Kerkhof (1982) found that detection efficiency on an auditory threshold task was significantly influenced by time of day for evening-type subjects only, with optimal performance latest in the day. The authors hypothesized that these changes probably reflected shifts in response criteria rather than alterations in signal detectability.

"Emotional experience is an essential aspect of the process of cognition and must be considered in any adequate description of it" (Blumenthal, 1977, p. 101). Clinical studies have suggested that emotional mood states may have a powerful influence on cognitive functioning. Leight and Ellis (1981) studied the effects of induced "state" depression on a memory task and found that the induced mood hampered letter sequence recall and chunking performance. The authors proposed that:

cognitive interference associated with depression may reduce processing capacity...(depressive mood may be associated with) inefficient use of effortful processes such as organization, imagery, mneumonic, or elaborative devices and rehearsal (p. 252).
Strategies, Styles, and Traits

Differing perceptual strategies and cognitive styles have been associated with alterations in perceptual/cognitive task performance. According to Blumenthal (1977) the process of biological evolution has developed a central nervous system which operates in ways that ensure order and regularity so that humans' experience of the environment is stable and so that organismic integrity is maintained. Individuals may thus exhibit differing perceptual criteria or strategies when approaching a perceptual or cognitive task. For example, Bowen, Sekuler, Owsley, and Markell (1981) investigated the phenomenon of perceptual brightness enhancement. This is a "perceptual phenomenon in which a pulse of light of approximately 50 - 150 msec appears brighter than longer or shorter pulses (of equal luminance)" (p. 587). Bowen et al. classified observers into three types according to whether they perceived temporal brightness enhancement under two conditions. The authors concluded that "distinct classes of observers use different perceptual criteria in judging the brightness of isolated pulses of light" (p. 592).

Several studies have reported that subjects may differentially encode serial patterns as a function of
both stimulus features and individual strategic operations (Greeno & Simon, 1974; Jones & Zamostny, 1975; Restle, 1976). Posner and McLeod (1982) define strategies as "dynamic processes that perform specific operations...elementary mental operations may be assembled into sequences and combinations that represent the strategy developed for a particular task" (p. 480). Smith and Baron (1981) noted that strategies used may not necessarily relate to intellectual capacities. For example, the authors studied adult subjects with various levels of tested intelligence on multi-dimensional classification tasks. They found "individual differences in the tendency to use similarity criteria in free classification...(this) tendency...was not correlated with intelligence" (p. 1132). Thus preferred cognitive strategies, whether efficient or not, may spring from sources other than cognitive ability.

Blumenthal (1977) noted that attentional focussing can differ from typically narrow to more global integrations of experience. For example, Huang (1981) classified undergraduates as either "broad" or "narrow" categorizers on a design classification task. On a later memory for design task, these two groups seemed to use different information processing strategies such that broad categorizers recalled features which had been
similar to each other or had shared common characteristics, while the "narrow" group recalled features which had differed slightly from each other. Reis and Bird (1982) tested undergraduate subjects (with either broad or narrow attentional styles) on a cue-processing task. Broad attenders were superior in the processing of peripheral cues.

Suedfeld (1971) reviewed current research concerned with investigating how and whether visual input is initially encoded. Many concepts have been advanced in attempts to explain how individuals "block" or "filter" certain information from entering subjective visual experience. Examples of such concepts are Freudian defense mechanisms of avoidance and denial, and the notion of perceptual defense. Suedfeld (1971) noted that the transformation of visual input may be influenced by a person's ability to discriminate, differentiate, and integrate information components, and by how richly or systematically he can organize the elements.

As Erdelyi (1974) observed, "the perception of external stimuli is not free of the shackles of internal events: attitudes, values, expectancies, needs, and psychodynamic defenses all impinge upon perception" (p. 1). Whether or not one agrees that internal events are
"shackles", a consideration of an individual's characteristic approach to many cognitive tasks would seem important in interpreting experimental results.

Different individual strategies for the analysis of stimuli may be reflections of general underlying traits or stable personality organizations. The quantity, flexibility, integration, and complexity of strategies used are probably manifestations of unique personality styles. For example, Cooper (1976) labelled two processing strategies in adults as holistic and featural and Zelnicker and Jeffrey (1976) reported that impulsivity (quick responding on complex tasks) is associated with global or holistic processing in children.

Emotional disturbance has been shown to be associated with perceptual deficit, in some cases severe deficit. Since a frequent side effect of Pill use is mental depression, a brief review of studies is presented here illustrating the effect of depression on perceptual task performance. It has been reported that depressives perform more slowly than other psychopathological groups on motor speed tasks (Payne & Hewlett, 1960), and that depressives exhibit visual and spatial perceptual disturbances on a number of tasks (Wapner, Werner, &
Krus, 1957). It has been hypothesized that depressives are slow due to distraction by sad thoughts or worries (cognitive interference), impairment in their ability to shift a mental set, or differential use of response criteria (Friedman, 1964).

Two studies reported that depressives required longer exposure times than did controls before recognizing pictures presented on a tachistoscope. Friedman (1964) reported that psychotic depressives had significantly longer recognition times than normals for a common object. Whether these differences are due to some defective perceptual mechanism, inattention, fatigue, lack of motivation, or slowness in responding is not clear.

Posner and McLeod (1982) discussed a model first proposed by Humphreys, Revelle, Simon, and Gilliland (1980) in which personality traits...interact with situational mediators...to inhibit or excite activational states...which in turn act either to improve or inhibit the functioning of information processing constructs such as attention and short-term memory (p. 505).
Hypotheses

1. Studies cited in the literature review using forced-choice, form, word, digit, and letter recognition tasks found that length of ISI significantly affected performance. In this study, it is hypothesized that, when ISIs are varied from short (10 msec) to long (50 msec), all subjects would obtain significantly different letter recognition scores at each ISI, with higher scores as ISI increases.

2. The visual system has been conceptualized as an information processing system with a given processing capacity. Investigations previously cited demonstrated that performance improved with prolonged practice on cognitive tasks as varied as visual search and lexical decision making. Recognition of familiar alphabetic letters would presumably tap automatic rather than control processes and it is hypothesized that, in this study, processing subroutines should begin to operate more efficiently, producing improved performance, as a result of repeated practice (over 18
sessions). This trend toward improvement is expected to continue over repeated testing, with a practice effect occurring for each level of ISI, except perhaps for the 50 msec ISI, for which an approach to asymptote is probable. Even with prolonged practice, it is predicted that performance at the most briefest ISIs should not reach or exceed performance at longer intervals.

3. The variety of findings reported in the literature review noted that females have been shown to excel in verbal tasks and males in visuo-spatial tasks. Since the task involves recognition of a letter stimulus (verbal) rather than manipulation of an object in space (spatial), it is expected that females in this study should perform better than males, although this difference is not expected to be statistically significant.

4. a. Many studies cited in the literature review support the notion that performance on a variety of sensory/perceptual tasks is highest at ovulation for free cycling women. Therefore,
it is expected that free cycling women (No Pill group) in this study should show a change in performance with repeated testing on a letter recognition task across their menstrual cycle phases; that is, they are expected to achieve peak performance near time of ovulation.

b. Investigations previously cited noted that oral contraceptive users do not show the characteristic cyclical changes in performance associated with their menstrual cycle phases. Since oral contraceptive use substantially alters circulating levels of sex hormones, it is hypothesized that oral contraceptive using women (Pill group) in this investigation should show no significant fluctuations in recognition performance as a function of their cycle phase.

c. Augur (1967) has noted that Pill users in her sample showed less parasympathetic activity than free cyclers. Wong and Tong (1974) found that Pill users had lower overall discrimination sensitivity than free cycling women, particularly on Days 10-15, or during the time when Pill users would ordinarily ovulate. Thus, it is expected that Pill users
in this study will show a depressed performance relative to free cyclers and that performance at the time of normal ovulation might be worse for Pill users than for free cyclers.

5. Large individual differences in visual recognition scores and in many other cognitive task scores have been consistently found, although they have not been thoroughly explicated. It is expected that significant and stable individual differences in performances will be demonstrated by subjects within each group in this study.

Transient or situational "state" factors have been shown to affect performance differentially for distinct individuals. Thus, possible situational correlates of differential performance such as mood, task motivation, fatigue level, and diurnal rhythm are expected in this study to impact on subjects' performance such that those who were highly motivated, experiencing positive moods, and who were well-rested, and performing at their personally optimal time of day are expected to perform better than poorly motivated, fatigued
persons who experienced negative moods, and were tested at less than optimal times.

Clinical studies have indicated that depression is a frequent side effect of oral contraceptive use, thus it is expected that Pill users should show a more consistently negative mood across sessions.
CHAPTER III

METHOD

Subjects

Subjects were ten female and five male volunteers, giving informed consent, between the ages of 23 and 34. Subjects were divided into three groups: 1) women who were currently using oral contraceptives (combination estrogen/progesterone pills for an average of 5 years (n=5)), 2) women who were not currently using the pill (n=5), and 3) men.

Materials

Each woman kept an accurate daily chart of her menstrual cycle, and began the record on the first session of this study, noting the time when she started her last period as "Day 1" of her cycle and counting forward until she reached the day of session. Each woman also recorded her morning body temperature, using a thermometer orally. All subjects completed a brief "daily interview" form, noting his/her own subjective mood (rated as "negative" (1), "neutral" (2) or "positive" (3)).
(3)) and actual number of hours of previous night's sleep. At the conclusion of the study, subjects rated their own enthusiasm or motivation for participating in the study, rated on an increasing scale from (1) to (5), with (5) being "highly motivated", and classified themselves into diurnal biorhythmic categories ("morning", "afternoon", or "evening" person). These situational factors of mood, fatigue level, motivation and diurnal rhythms were rated and coded across sessions by two independent judges for later use in correlating with performance scores for each group. Subjects also recorded spontaneous associations to several words related to pregnancy and the menstrual cycle; the stimulus words were "menstruation", "Pill", and "pregnancy".

**Procedure**

For each of 18 days (sessions), subjects sat in a darkened room and viewed stimuli presented on a CRT (VR14 display, PDP8E computer). Upon signal from the subject, one of 25 letters of the alphabet was presented for 10 msec and followed, after a variable interstimulus interval (ISI) of 10, 15, 20, or 50 msec, by a spatially overlapping square masking stimulus, 500 msec in duration. The subject's task was to correctly recognize
and record the letters. Each of the 18 sessions consisted of 100 random alphabetic presentations, with 25 letters (no Q) per ISI. Sessions were held Mondays, Wednesdays and Fridays at regularly scheduled times, and were about ten minutes in duration per subject. The independent variables were: ISI (10, 15, 20 and 50 msec), Practice (effect of repeated testing over 18 sessions), Gender (male versus female), Hormone Group (Pill, No Pill, and Males) and Phases of Cycle (score at ovulation (Day 12, in cycle Phase IV) versus scores at non-ovulatory cycle Phases (I through VII).
CHAPTER IV

RESULTS

To study the effects of ISI, practice and Pill use on recognition performance, a repeated measurement quasi-experimental design was used. The dependent measure was "number of letters correct."

A complex ANOVA with repeated measures was computed with (3 x 18 * 3 x 5 or Groups: (Pill, No Pill, Males), Sessions, ISI level (10, 15, 20 msec) and Subjects (n=5)) as the variables of interest, with repeated measures on the "Sessions" and "ISI" variables. Results revealed a significant main effect for ISI \( F(2, 24) = 229.78, p < .000001 \). As predicted, all subjects performed more efficiently at longer ISIs and more poorly at shorter ISIs. There were significant differences in recognition scores at each ISI. The differences between ISI 20 and ISI 15 were significant, \( t(13) = 17.85, p < .003 \). The differences between ISI 20 and ISI 10 were significant, \( t(13) = 29.02, p < .001 \). The differences between ISI
15 and ISI 10 were significant, \( t(13) = 26.48, p < .001 \). The mean for ISI 20 \((n=15)\) was 271.7 \((S.D. = 13.1)\). The mean for ISI 15 \((n=15)\) was 189.8 \((S.D. = 19.4)\). The mean for ISI 10 \((n=15)\) was 100.5 \((S.D. = 23.2)\).

**Practice (Sessions)**

There was also a significant main effect for practice or sessions, \( F(17,204) = 21.87, p < .000001 \) and a significant session x ISI interaction effect \( F(34,408) = 1.838, p < .003 \). The range of mean performance scores with practice was follows: the mean performance score for all subjects \((n=15)\) at Session 1 was 38.8 \((S.D. = 17.5)\), while the mean at Session 17 was 66.2 \((S.D. = 16.3)\). The mean performance score averaged across sessions was 58.8 \((S.D. = 16.7)\). As expected, all subjects' performance improved linearly and at approximately equal rates for each ISI (see Figures 1 and 2). Lines were fit to the data in Figure 2 and ISIs 10, 15, 20 were found to have similar slopes, while ISI 50 had a different slope, indicating an increasing linear trend (with possible eventual convergence of the lines at asymptote). Regression equations were computed for ISI levels \((10, 15, 20 \text{ msec})\). For the 10 msec ISIs, \( R = .372, p < .00001 \), and the regression equation
FIGURE 1: Mean number of correct recognitions as a function of sessions and groups.
FIGURE 2: Mean number of correct recognitions as a function of sessions and ISI.
is \( Y = .463 + 1.668 \). For the 15 msec ISIs, \( (R! = .433, p < .00001) \), and the regression equation is \( Y = .626X + 5.427 \). For the 20 msec ISIs, \( (R = .5178, p < .000001) \), and the regression equation is \( Y = .660X + 9.95 \).

**Gender, Group and Phase of Cycle**

Mean performance scores were not significantly different for males and females \( (t (13) = .47, p < .64) \). The mean for males was 950 (S.D. = 284), while the mean for females was 1026 (S.D. = 295). Results of a complex 3 x 7 x 3 x 5 ANOVA (Group; menstrual cycle phase: Day 1 – 3 = Level I, Day 4 – 6 = Level II, Day 7 – 9 = Level III, Day 10 – 12 = Level IV, Day 13 – 15 = Level V, Day 16 – 18 = Level VI, Day 19 – 21 = Level VII; ISI; and subject) showed no significant differences associated with groups (Pill, No Pill, and Males), \( (F (2,12) = .2518, p < .781) \), or for menstrual cycle phase, \( (F (6,72) = 1.922 , p < .08) \). However, as Figure 3 illustrates, there were some interesting and suggestive trends. As hypothesized, free-cycling women (No Pill) did markedly peak near time of ovulation (Day 12 on Figure 3, menstrual phase level IV) while Pill users showed an acute decrement during the same ovulatory phase. Males showed no discernible patterned changes across sessions. A visual inspection of Figure 1 shows that the No Pill
FIGURE 3: Performance as a function of menstrual cycle phase and groups.

NOTE: * indicates that missing data were interpolated and included.
group scored slightly higher overall (from Day 7 onward) than either the Pill or Male groups. The mean for males was 950 (S.D. = 284). The mean for the No Pill group was 1064.4 (S.D. = 340.9) and the mean for the Pill group was 987.6 (S.D. = 276), although this difference was not significant, \(t(8) = -0.39, p < .70\).

**Individual Differences**

A visual inspection of Figure 4 demonstrates the very large individual differences in recognition scores among subjects in the Pill group, as hypothesized. For example, subject #17 never reached as accurate performance level as subject #14. Out of a possible perfect recognition score of 100, subject #17's performance scores ranged from 21 letters correct to 62 with practice, while subject #14's ranged from 52 to 91. When scores were averaged across sessions, the standard deviation for the Pill group was 16.24 (mean = 58.0). For the No Pill group, the standard deviation was 20.05 (mean = 62.6) and for the Males, the standard deviations was 16.7 (mean = 55.8). Results from the other two groups showed similar ranges of individual differences as those illustrated in Figure 4.
FIGURE 4: Number correct as a function of sessions for females using the pill.
Situational Influences

Correlations were computed for state measures of daily mood (1 = "negative", 2 = "neutral", 3 = "positive"), hours of sleep (1 - 8), final ratings of enthusiasm (motivation—self-rated on an increasing scale of 1 to 5), and diurnal rhythmic category ("night", "afternoon", or "morning" person) with number correct (performance score) and with each other, for each group (Pill, No Pill, and Males), for gender (male, female) and for all subjects (n = 15). Although two correlations were significant for the No Pill group, between mood and hours of sleep, (r = + .80, p < .05) and sleep and performance score, (r = + .96, p < .005), these positive correlations could be expected to occur by chance given the large number of correlations computed and a sample size as small as 5 subjects per group. Multiple regressions were computed and revealed that, for the group at large (n=15), mood explained the most variance in scores: (multiple R = .301, RSQ change = .090, and simple R = .301). For pill users and males, motivation level accounted for most of the variance in scores: for the Pill group, (multiple R = .494, RSQ change = .24, and simple R = .494) and for the males, multiple R = .665, RSQ change = .442, and simple R = .665). For the No Pill group, hours of sleep and mood accounted for the most
variance in scores: for the sleep variable, (multiple $R = .96$, $R^2$ change $= .924$, and simple $R = .96$) and for the mood variable, (multiple $R = .997$, $R^2$ change $= .0701$, and simple $R = .61$).
Practice

This study examined the impact of several variables thought to be associated with changes in letter recognition performance, (e.g., practice, ISI level, gender, sex hormone activity, and "state" situational correlates). Subjects (n = 15) were divided into three groups (Pill, No Pill, and Males) and recognition performance was measured over 18 sessions, at four ISI levels (10, 15, 20, 50 msec) per session.

As expected, with repeated practice, performance for all subjects improved linearly and at approximately equal rates for each ISI (except 50 ISI). These findings are consistent with results from previously cited studies which found that, within limits, prolonged practice increases performance scores. Practice effects can be explained in several ways. It is probable that subjects' increasing familiarity with the experimental procedure, task demands, and stimulus features allowed them to
respond more efficiently as time passed. Recognition of an overlearned alphabetic letter probably required little conscious effort, enabling rapid "automatic" processing to occur. Clearly, performance was still increasing after 17 sessions (with a slight "end of experiment" drop on the 18th session). Human visual information processing rates may have ultimate fixed limits which are not yet known. Additional investigations could be conducted which would progressively increase the number of sessions and decrease ISIs to determine how far basic processing capacity can be extended. Perhaps there is a way of "teaching" the system to process more efficiently other than through simple repetition.

The human visual system seems to have greater capacity than previously suspected in that, with practice, some subjects were able to recognize letters with an extremely brief ISI intervening between target and mask (10 msec). How did subjects begin to perceive letters where previously they had seen only a mask? It appears that processing subroutines began to adapt to the environmental demand represented by experimental instructions to recognize as many letters as possible. In general, increased efficiency with practice may be "built in" genetically as an "evolved capacity of (a) living system to cope with relentless flux and change"
(Blumenthal, 1977, p. 21). The repeated impingement of stimuli seemed to "fine-tune" the analyzers such that less time was required for subroutines to operate, although the manner or nature of the analytic process probably did not change. Perhaps once the letter reached SVE (subjective visual experience), it could be "read out" as a response more quickly. Essentially, the recognition task itself may have involved several stages of processing such as encoding, searching memory, and responding. With practice, these stages perhaps become a smoothly functioning integrated unit or activated "associative pathway" (Regan, 1981). An organized network could work faster than separate analytic components working in a discrete and independent manner. It is unclear from results whether encoding and buffer processes were affected more than central attentional integration processes. These results suggest that any viable model of human visual information processing must elucidate which subroutines are modified with practice and how their functioning is modulated.

Since it is difficult to specify exactly how experience modifies brain physiology, an examination of analog models of neurophysiological structures can be useful in clarifying what may be occurring at neural levels to the target and mask with practice. For example,
Farley and Clark (1961) produced a "neuron model" to study activity in networks of neuron-like elements caused by one input closely followed by another. They studied patterns of activity and found that "(spatial) activity from a given stimulus input when excited in combination with another may be entirely different from that resulting when it is excited alone" (p. 244). In discussing this model, Good (1961) noted that:

If element \( i \) has just contributed to the firing of element \( j \), then the synaptic joint is primed with a degree of primality, which starts at a constant positive value and then tends to zero exponentially. The primality is temporarily added to \( s_{ij} \), thus facilitating local reverberation (p.249).

Thus, with practice the subject may increase the strength of primed synapses and increase efficiency.

Hartmanis (1961) noted that:

in a large number of systems which can learn (or organize themselves) to perform a task, the learning is achieved by a step wise refinement...the system first learns to perform a rough approximation of the desired task and then repeatedly learns to refine its abilities until it can perform the task exactly (p. 327).

Minsky and Selfridge (1961), discussing learning in random nets, assumed that in a pattern recognition process, "correct" responses are reinforced and "incorrect" responses slowly extinguished such that "the net as a whole will organize itself so as to tend to make only right responses, even when they are very complicated
and abstruse" (p. 335). Minsky and Selfridge continued:

If each of the inputs and outputs represent, say, a single active cell, then the problem is one of establishing good conduction paths between contemporaneously excited pairs. It is easy enough to invent neural nets which do this; connections between each pair \( S_i R \) of cells might improve their conductivity on each occurrence of the proper sequence of activity at their terminals (p. 336).

Systematic "nets" might thus begin to operate more efficiently with practice. Results from this study suggest that the responsiveness of the underlying neural mechanisms can be adapted to have a different sensitivity to input.

Since capacity for visual pattern recognition has shown to be very malleable for all subjects, it can be inferred that underlying central nervous system mechanisms are held in common and that the visual system is very complex and highly organized. Adaptation may occur at any or all neural stages of processing; that is, processes within the retina itself may change as well as processes at more advanced central stages. It is not currently clear precisely how psychological and physiological concepts of processing interrelate. It appears that the system "learned" to make better use of inherent capacities in response to environmental demands. However, this inherent capacity is limited. As Lindsley (1961) noted in discussing flicker-fusion phenomena:
all stages in the visual system, except the cortex (of a cat) give individual, discrete responses (often both on and off responses) to each flash of light even when the repetition rate is over one hundred per second...The cortex...constitutes a limiting link and is apparently responsible for the failure of the human perceptual judgment to differentiate the individual flashes and hence...fusion (is perceived) instead of flickers (p. 367).

Development of mechanisms for visual recognition seems to be a combination of innate capacity and acquired experience.

**ISI**

As hypothesized, all subjects obtained significantly different recognition scores at each ISI, with better performance as ISI values were increased from 10 to 50 msec. Even repeated practice could not overcome basic processing limits; that is, performance at the shorter ISIs never improved sufficiently to reach or surpass performance at longer intervals. These results are consistent with findings from current research studies which have reported that the accuracy of pattern recognizability increased with longer ISIs. Longer delays may provide the central nervous system with more time to process and extract information about each input, resulting in less interaction and degradation of both inputs' clarity.
Clearly, the visual system was highly sensitive to ISI increments of as small as 5 msec. The precision and regularity of the visual system's operations were illuminated by the finding that there were very orderly and systematic increments in performance according to ISI levels. These results demonstrate that, although the visual system's operations can be modulated to some extent, biological limits seem to exist such that processing subroutines require relatively more time to analyze features of a letter input if the ISI is very brief before onset of the mask. The fact that subjects obtained perfect recognition scores at 50 msec with 18 sessions of practice suggests that 50 msec may be an adequate amount of time for processing subroutines to analyze the letter and mask as two separate configurations. It is unclear whether performance at the shorter ISIs would continue to increase to asymptote given more session of practice.

The continuous operations of processing subroutines can be improved in efficiency, within unknown limits, with practice. The results suggest that any useful model must accomodate such "plasticity" of the visual system, and discover the ultimate temporal limits regulating the execution of processing subroutines and explicate how subroutine interactions change as a function of time
variations.

Sex Differences—Menstrual Phase/Oral Contraceptive Effects

Although there was no significant difference in performance between males and females, or among the three groups of males, free-cyclers, and pill users, it was observed, at least in terms of mean differences, that the females (both Pill and No Pill groups) performed slightly better overall than the males. Given the nature of the task (letter recognition) and the presumed verbal task superiority of females, these findings are consistent with results from previously cited studies.

Again in terms of the direction of means it was observed that free cycling women performed slightly better overall than Pill-using women and men, although the magnitude of the differences was small. Again these findings are in line with previous research which reported generally lowered parasympathetic activity and discrimination sensitivity performance for Pill users. Pill users were also found in this study to be more fatigued and experienced more negative moods than free cyclers, such that these transient states may have produced the mild deficit in performance. It is possible that there were pre-existing personality differences
between Pill and non-Pill users which may have mediated cognitive performance. For example, Pill users, in contrast to free cyclers, reported typically fewer hours of sleep per night and reported feeling optimally alert in the evening. These factors may reflect larger lifestyle or personality differences between the two groups. Although most of the correlations between the "state" variables of mood, fatigue, motivation, and diurnal rhythm were not significant, they were all in the predicted direction. Overall, free cycling women had the highest mood, the most hours of sleep, and best performance score. Pill users had the lowest consistent mood, fewest hours of sleep, and lower performance scores than free cyclers. Overall, the subjects were a highly motivated group; however, it appeared that subjects were motivated by their judgment that research in this area is "valuable." They were not particularly task motivated (i.e., were not intensely interested in viewing 100 letters a day). Thus, effects of state motivation were not really measured.

Clinically reported side effects of the Pill may have contributed to poorer performance by users. Pill users may have been a slightly more depressed group than free cyclers, since depression is a frequently cited side effect of oral contraceptive use. Rose and Braidman
(1973) found that women using the Pill had altered tryptophan metabolism. Tryptophan is an amino acid necessary to the synthesis of a neurohormone (5-hydroxytryptamine) sometimes found to be lower than normal in depressives. The finding that free cyclers markedly peaked and Pill users acutely deteriorated during the same menstrual phase (ovulation) points to the strong possibility of a drug effect. There is abundant research literature which has demonstrated that free cycling women peak on many tasks near ovulation (vis a vis their performance at other phases). Diamond, Diamond, and Mast (1972) offered the evolutionary interpretation that all sensory and perceptual modalities which mediate sexual arousal would operate at their maximum efficiency near time of ovulation so that the probability of coitus occurring when the female was fertile would be higher. Presumably, the species would thereby be ensured of an adequate rate of reproduction. The "general arousal" hypothesis advanced by Kopell, Lunde, Clayton, and Moos (1969) attributed superior performance by females to the activating effects of estrogen on central nervous system arousal. Superior performance would be expected to occur when estrogen levels were highest at ovulation. The similarity of menstrual phase findings across different sensory
modalities (hearing, touch, vision) suggest that central nervous system processes are importantly affected by hormonal shifts.

The finding of a marked decrease in performance for Pill users at the time they would normally ovulate was not wholly expected, nor has it been explained in the literature. This decrement may be related to the fact that oral contraceptives work by preventing ovulation (release of the egg) through the complicated and multiple impacts of added synthetic sex hormones on normally balanced endogenous hormonal activity. It is conceivable that the woman's body, which is biologically programmed to ovulate each month, may need to make strenuous and potentially disruptive internal adjustments when ovulation is stopped by the potent drug. This process of adjustment probably has ramifications felt throughout the woman's entire physiological and psychological system, including her visual system, which may be expected to operate at less than maximum efficiency.

It is not known what occurs neurally with Pill use, but is possible that the "conductivity" of synapses are modified by the synthetic hormones' effect in the system, leading to reduced capacity on certain tasks. Clearly, it would be essential to replicate these findings
consistently across many samples before more definitive generalizations about the Pill's impact on cognition can be made. Further, more refined measures (such as actual periodic hormone assays) could be used to determine exact levels of hormones and to pinpoint ovulation time. It would be important to study (if possible) women before Pill use, during and after discontinuation, in order to assess true Pill effects.

**Individual Differences**

As expected, stable individual differences in visual recognition scores were observed within each group. Even with prolonged practice, subjects who performed poorly on the task never "caught up" to the accuracy levels of optimally performing subjects. This result is consistent with the findings of large individual differences in other studies on varied cognitive tasks. The main effects for practice and ISI for all subjects support the assumption that the order and nature of processing subroutines are similar across subjects, but it appears that some individuals require more time to process than others. It is unclear what factors might hamper or enhance rapid responsiveness, but "state" or trait variables may account for some of the individual variance. For example, it would be important
to know how subjects differed in strategies used to perform the task, particularly what strategies were used by efficient processors. The possibility of differences in "cognitive style" or personality traits affecting performance cannot be ruled out since "each organism brings to any new experience something of its past... the total past experience of the central nervous system enters into the effect of a beam of light..." (Lindsley, 1961, p. 364).

It might be fruitful to study the impact of well-defined normal personality styles on visual recognition scores. For example, it could be argued that subjects classified as having "obsessive compulsive" features could be characterized as having had life-long "practice" with this type of task, which requires fine and focused attention to emotionless detail and in which the ability to globally view and synthesize the contextual surround is not particularly needed. Another group (histronic) might have difficulty in sustaining concentration, particularly since the stimuli are not emotionally symbolic or colorful. Performance would probably be less "automatic" for this group, since they would be apt to become distracted and preoccupied with other feelings and thoughts while completing the task. Clearly, each group may have learned to focus their
attention in ways that would maximize their psychological survival in their earliest environment. Perhaps these two groups use very different information processing strategies as adults in approaching the same task.

One implication of these findings of individual differences within groups is that it is difficult to use models based on averaged group scores to predict performance of an individual on an information processing task. To the extent that individual difference factors are controlled, within-group error variance can be reduced and, thus, increase the sensitivity and psychological "interpretability" of research studies. Melton (1967) proposed that:

the sooner our experiments and our theory...consider the differences between individuals...the sooner we will have theories...that have some substantial probability of reflecting the fundamental characteristics of these (component) processes (pp. 249-250).

For example, the time "constant" for visual processing of a stimulus may vary so widely among individuals that it may be necessary to speak of a normal range, within which each subject has his or her own "constant."
Clinical Associations

Subjects in each group (Pill, No Pill, and Males) free associated to three stimulus words: "menstruation", "Pill", and "pregnancy". Interesting clinically observed differences were found between the groups. For women in both Pill and No Pill groups, associations to "menstruation" were highly personal, intense, and affect-laden, with the most frequent response being "blood," followed by "pain" and "ugh." In contrast, men associated to this same word in a descriptive and affectively neutral manner, e.g., "ovulatory cycle," "puberty," and "natural monthly period."

Associations to "Pill" by women were almost uniformly concerned with "safety" (from pregnancy) and "danger" (from unwanted and possibly serious side effects). The same word was associated to by males in an impersonal and unrelated way ("women," "baby," "chemical contraceptive") except when they responded with words implying freedom from responsibility for sexual acts.

Pill users differed from non-Pill users in their associations to pregnancy, although both groups of women focussed on the negative consequences of unwanted or accidental pregnancies. The difference was in the degree of urgency expressed. For example, some of the Pill
users' associations were "awful" and "not yet" while free-cyclers were slightly more positive ("babies," "child," "nice, but not now").

Women's associations to these stimuli were more visceral, personal, and expressive than men's. It would be interesting to replicate the study with a large sample and examine frequency distributions and means for the groups. Implications of this small sample of partially conscious attitudes for shared responsibility for birth control are interesting.

Conclusions

In general, the operation of visual processing subroutines may be importantly modified by such variables as prolonged practice, temporal variations between target and mask, hormonal activity, and state/trait factors underlying individual differences. It would seem that time (both "real" and psychological time) is a critical dimension for the human information processing system. It would be interesting to see if higher level psychological processes needed to solve complex cognitive problems are as affected by the variables examined here as are visual recognition processes. In future investigations, it seems important that a woman's position in her menstrual cycle phase be noted, since present results have suggested
possible functional associations between hormone level and performance. Reducing within-group variance through a consideration of individual differences would also be an important factor in the design of future experiments in this area.

Inferences which can be drawn from results of this study are limited in generalizability for several reasons: 1) the sample size for each group was relatively small, n=5; 2) since there were only 18 sessions of practice, it is very unclear whether performance at shorter ISIs would ever converge and how many practice sessions produce asymptote; 3) the masking paradigm itself has in-built limitations since only two inputs out of an unknown number of time/space variations were studied. Also, conditions in the laboratory with this small segment of behavior do not test external validity.

Only further research can provide more knowledge about this complicated set of variables. However, given the "rough" measures used to pinpoint ovulation and given that statistical techniques were used which would have been biased in the direction of losing power, it is interesting to note the presence of an effect at ovulation.
SUMMARY

Current models of visual recognition have concerned themselves with several issues: 1) What factors seem to modulate the operation of processing subroutines (feature analyzers) such that performance on various tasks (including visual recognition) is effectively modified? 2) What are the ultimate neurological limits to a human subject's capacity to improve the efficiency of his/her visual processing? 3) How can a paradigm account for the existence of marked individual differences in time requirements needed to accurately complete processing tasks given the assumption of similarly ordered underlying structures across subjects?

This thesis examined the general question of adaptability: How and in what manner does the visual system extract and interpret incoming sensory information? It was hypothesized that, even with repeated practice, when ISIs are varied from short (10 msec) to long (50 msec), all subjects would obtain significantly different letter recognition scores at each ISI with higher scores as ISI was increased. Even with repeated practice, it was predicted that performance at the briefest ISIs would not reach or exceed performance at longer intervals. It was expected that performance would
improve for all subjects with repeated practice over 18 sessions. This trend toward improvement was expected to continue over repeated testing with a practice effect occurring at each level of ISI. Women were expected to show a superiority in performance over males on the task. Free-cycling women (No Pill) were expected to peak in performance near time of ovulation and perform better overall than Pill users. It was hypothesized that large individual differences within groups would be observed. Transient "state" variables were also examined as possible correlates of individually different performance. Clinical associations to stimulus words were also noted.

Subjects were 10 female and 5 male volunteers, between the ages of 23 and 34. Subjects were divided into three groups: 1) oral contraceptive-using women, 2) free cycling women, and 3) men. For each of 18 days (sessions), subjects were presented 100 letters of the alphabet on a CRT. Upon signal from the subject, one of 25 letters was presented for 10 msec and followed, after a variable interstimulus interval (ISI) of 10, 15, 20, or 50 msec, by a spatially overlapping square mask, 500 msec in duration. The subject's task was to correctly recognize and record the letter. Complex ANOVAs with repeated measures and correlations were computed.
Results showed main effects for practice and ISI, and a significant session x ISI effect, supporting the hypotheses previously advanced. There were no significant differences between the sexes, or between the three groups; however, free cyclers peaked near time of ovulation, while Pill users showed acute deterioration at this same cycle phase. Results were discussed in terms of possible mechanisms underlying the obtained practice, ISI, and hormonal effects, and implications for a viable model of human information processing were considered.
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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

Dec 5, 1982
Date

Mark Mayzner
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