AN EVALUATION OF MOTOR-BASED PRECONSCIOUS DETECTION IN A NUMERICAL TARGET SEARCH TASK

by

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ABSTRACT

AN EVALUATION OF MOTOR-BASED PRECONSCIOUS DETECTION IN A NUMERICAL TARGET SEARCH TASK

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Traditional information processing theories allow little room for unconscious mental activity. However, a large and growing body of research has been performed in the area of information processing without awareness. Research investigating target detection tasks reveals that perception of targets in a high-load task is a multi-stage, or feature integration process. A multi-stage process indicates that some processing may occur before conscious awareness.

Research directed at motor indicants of preconscious processing indicates subjects may indeed process information in a visual target search task prior to consciously discovering the target. Experiments which have looked at rythmic motor responses, such as key tapping, during visual search tasks have discovered subtle differences in the motor response between target-present and target-absent conditions.

The underlying mechanism for how preconscious processing can interfere with a motor response may be found in the theory of motor programming. Essentially, the execution of one motor program can be hindered by the partial execution of a second motor program under conditions of uncertainty as in a target search task.

The present research examined the use of a key tapping response while subjects searched for numerical targets in a high-load visual target search task. None of the direct measures of on-times and off-times showed a significant difference between target-present and target-absent conditions. However, the distribution of differences of rank-ordered measures of on-times and of off-times showed significant asymmetry between target-present and target-absent conditions. Possible explanations for this result are given within the context of motor programming theory. Weaknesses of the current study and suggestions for future research are discussed.

INTRODUCTION

Psychologist's understanding of information processing has taken enormous strides in the last half century. Much of the work has been directed at investigations of perception, attention and processing of ambient stimului. Classic information processing models include an arrangement of structures for sensing, processing and storing information. Conventionally, stimuli that are above our level of awareness (threshold) are perceived, stored and incorporated into our mental schemata of the world. This classic view holds that stimuli which are below our perceptual threshold, or limen, escape our sensory receptors and pass by our conscious mind unnoticed and to no effect. But are these stimuli that are below our perceptual limen of no effect? Recent views of information processing theory suggest a different answer to this question. Psychologists have long reported the puzzling occurrence of the processing of apparently subliminal stimuli. The present research explores the application of a motor programming model of cognitive and visual information processing to a target search task using motor variations as the indicators of subliminal target detection.

Background

Classic information processing theory describes mental structures and processes whereby environmental stimuli are sensed, perceived, stored and acted upon. This model leaves little room for unconcious mental activity. Information that is sensed, but not perceived has little affect upon the individual (Wickens, 1984). More recent models, however, attribute a more meaningful role to unperceived, or unconscious, information. Models such as Anderson's ACT (adaptive control of thought) (1983) and PDP (parallel distributed processing) imply that the cognitive unconscious plays an important role in mental processing (Kihlstrom, 1987). Researchers have come to understand that an object need not be fully represented in consciousness before information about it can influence perception, thought, and action (Kihlstrom, 1987).

A large, growing body of research has been performed over the years in the area of information processing without awareness. Perky (1910) demonstrated, in fact, that subjects may process supraliminal stimuli without realizing the stimuli are real. She instructed subjects to conjure up a mental image of a particular object. Perky surreptitously displayed a dim, barely visible image of the object on a screen. Except for three of the subjects who discovered the nature of the deception through an experimenter's error, none of Perky's subjects realized they were viewing actual images, but instead thought they were imagining them. Subjects received visual stimulation above their normal limen (actual limen were determined after the experiment), but were unaware of it.

Miller (1939), in his classic review, summarized several early investigations of subliminal perception which concluded conscious behavior is influenced by stimuli which are below the threshold of conscious awareness. Miller's own research, one of the earliest well-controlled investigations into the area of subliminal perception, investigated the question of whether subjects could demonstrate visual perception without being aware of the visual stimuli, and whether the limen of awareness was equivalent or not to the limen of discrimination.

Miller told his subjects he was investigating clairvoyance and instructed them to stare into a mirror, mounted on the wall. Unknown to the subjects, the mirror was a one-way glass and Miller projected geometric shapes at low intensities onto the mirror from the rear. Subjects were instructed to stare into the mirror and guess which one of five geometrical shapes he, seated behind a partition, drew from a deck of cards, one at a time. Subjects were unaware of any actual visible image. After each subject was tested, they were informed about the nature of the experiment and the perceptual limen for each geometrical shape was carefully determined for each subject. After the first experiment, it was repeated with subjects who were knowledgeable about the setup and nature of the experiment, but still reported being unable to perceive any image whatsoever. Results from both experiments, 6500 tials, showed the subjects' "guessing" to be much better than chance and indicated the intensity threshold for discrimination to be below the threshold for awareness. Miller concluded that subjects made behavioral responses to subliminal stimuli of which they were unaware.

Davis (1950) found subliminal aural stimuli to elicit muscular tension responses in subjects previously instructed to execute a movement in response to audible stimuli. Davis used both supraliminal and subliminal stimuli in his experiment. Subjects were unaware of the subliminal nature of some of the stimulus items; even in post-experimental debriefings, subjects reported no knowledge of any subliminal stimuli. Yet small muscle tension responses were noted in response to the subliminal stimuli, while supraliminal stimuli elicited the instructed movements. The responses of Davis' subjects to the subliminal stimuli were along the same response dimension as the instructed response. It seems plausible these responses were mediated by cognitive processes at some level.

A comprehensive review of subliminal perception was done by Dixon (1971; 1981), reviewing research of both proponents and dissenters of the subliminal perception theory. He concluded subjects can subconsciously discern stimuli of which they are consciously unaware.

Matthew Erdelyi (1974), in his review of cognitive processing, concluded perception is not a singular event that either occurs or fails to occur. He stated certain stimuli might reach unconscious levels of registration and identification, but never reach conscious perception. Information about these stimuli might be briefly held in some fleeting buffer and be rejected from further processing and hence, from conscious perception. He favored a multi-stage perception concept of information processing.

Silverman (1976) tachistoscopically presented libidinal and aggressive stimuli to subjects at 4-msec exposures. Subjects could not distinguish between these stimuli and neutral (control) stimuli, yet the experimental stimuli significantly affected mental attitudes from pre-exposure baselines. It was concluded some processing was taking place at the subconscious level without the subjects' awareness.

Zajonc (1980) further demonstrated cognitive processing can take place without conscious awareness. In this study, subjects preferred targets to which they had previously been subliminally exposed, although they did not recognize them as such.

Seamon, Brody and Kauff (1983) also found that processing stimuli for preference can occur without awareness. They presented ten stimuli (geometric shapes) to subjects for 2-msec durations. Afterwards, in a test sequence, these stimuli were paired, one-at-a-time, with comparable geometric shapes (controls) and subjects were instructed to choose the stimulus they had seen previously. After ten trials, the test sequence was repeated and subjects were asked to make preference choices for each pair. (The order of judgements was reversed for half the subjects.) Subjects chose the experimental stimuli significantly more often in the preference choice than in the recognition choice. These findings seem to reveal that affective processing (preference) is separate from cognitive recognition and indicate subconscious processing was taking place.

Niedenthal (1990) found subliminal affective information can influence identification of supraliminal stimuli. She paired slides of novel cartoon characters with subliminal presentations of faces expressing joy or disgust. Later, in a speeded discrimination task, subjects identified previously seen cartoon characters faster if those stimuli had been paired with affect-consistent faces.

Jacoby and Whitehouse (1989) found subliminal stimuli can give subjects the illusion of memory. They presented subjects a lengthy list of words for study. In a later recognition test, subjects' falsely identified test words as being in the previous list more frequently when the test words were preceded by a subliminal context word that matched the test word than when the preceding context word was supraliminal.

In Schneider and Shiffrin's (1977) investigation of information processing of search tasks, they defined automatic processing as the activation of a sequence of memory nodes independent of the subject's control or attention. In contrast, they said controlled processing is the activation of a temporary sequence of nodes requiring the control and attention of the subject. Automatic processing is learned following the earlier use of controlled processing to link the same memory nodes in sequence. According to their model, when consistent mapping exists between stimuli and responses, automatic target detection develops with extensive practice. Eventually targets exhibit the characteristics of attracting attention and initiating responses regardless of other memory loads.

However, King, Stanley and Burrows (1984) reported automatic processing may not be operative in high-load tasks. They found that threshold targets (such as embedded numbers/letters within a large matrix of numbers/letters) place a high demand on attentional capacity and require controlled processing. These researchers used target slides of camouflaged human figures and found that reaction times increased with task load for affirmative responses and suggested that a considerable number of cognitive operations may be required in a threshold target detection task. They concluded that feature integration processing was probably involved in detection of threshold targets.

This is supported by the results of Nodine, Carmody and Kundel's threshold target search task (1978). These researchers monitored subjects' eye movements as they searched a stimulus field for the target. They reported the reason subjects failed to detect the target was not inadequate sampling of the target areas. On the contrary, out of 35 targets that went undetected, 31 were sampled. Nodine, Carmody and Kundel therefore concluded that eye fixation on the target does not necessarily guarantee target detection. In fact, they discovered a target fixation time of approximately 1 second yielded only an 86% probability of detection. Their results also support a feature integration processing model of target detection. A feature integration model is used here to refer to a multi-stage model of information processing, similar to the formulation of Treisman and Gelade (1980). In such a model, fast or parallel feature extraction processes may take place early and without awareness, and only later the slower or serial processes of classification, integration, and semantic interpretation enter into awareness. A multi-stage model of perception emphasizes some processing may take place well before conscious awareness.

Related Research

A feature integration or multi-stage perception concept of information processing seems to be supported by research reported by Bower and Spravka (1983). They used a randomized letter matrix and conventional telegraph key to investigate whether preconscious processing can be detected in motor responses to a secondary task. Bower and Spravka theorized preconscious processing might be detected by modulations in the motor response to a high-noise target search task. They instructed subjects to tap a telegraph key at an even rate while searching a randomized letter matrix for a target. Subjects were to tap continuously during the search, stopping only if they located the target.

Even though the target was never found (verbally reported), subjects showed some tendency to decrease tapping rate during presentations of matrices containing the target. Greatest decreases in the subjects' overall tapping rate occurred during later portions of trials in which the matrix contained the target. The experimenters attributed the results to conflicting motor programs involved in producing the motor response. Since subjects were instructed to stop tapping upon detecting the target, the motor program responsible for execution of the stopping response was believed partially activated by the preconscious extraction of target information. However, this preconscious processing was not strong enough to actually prevent performance of the conscious continuous tapping motor program. Thus, it was theorized that a small magnitude, partial conformance with experimental instructions to stop tapping may have occurred in later portions of presentations of matrices containing the target because the partial target detection response had more time to recruit the program for the "stop tapping" response.

A multi-stage perception concept of information processing is also supported by Bower and Jones (1984). They found motor indicants of preconscious perception of visual stimuli in a target search task. Bower and Jones presented matrices of letters to subjects while the subjects were continuously tapping a dual-position telegraph key which allowed horizontal key movements. Subjects were instructed to maintain a constant tapping rate, while alternating between left and right contact positions. The procedures utilized two targets: half of the matrices presented contained target A and the other half contained target B. The experimenters presented the matrices in alternating sequence. Subjects were instructed to stop tapping and hold the key in the right position if they detected one target (A) and to stop tapping and hold the key in the left position if they detected the other target (B). The subjects were to continue tapping at an even rate if they detected neither target in a matrix. It was hypothesized that if subjects were preconsciously processing the target, then the presence of a target would be accompanied by an increase in the closure time of its associated key position.

None of the subjects in their experiment ever reported finding a target and the results reveal responses did not show a significant difference in mean closure (or contact) time between the two targets. However, the researchers developed a measure to detect differences in response pattern, depending on which matrix, A or B, was being presented at the time the tap occurred. Key taps for each subject were classified into four categories: 1) correct right key; 2) correct left key; 3) incorrect right key; and 4) incorrect left key. Key contact times (on-times) for each category were then rank ordered and grouped into five regions of equal density. The on-times for each region were then summed and the absolute differences between each sum were calculated. These were referred to as the first-order differences. Second-order differences were obtained by calculating the absolute differences between each of the first-order differences. For correct and incorrect key times, the second-order differences were converted into percentages of the sum of all the differences. The middle percentage was found to be significantly smaller for the set derived from correct key on-times than the set derived from incorrect key on-times. Bower and Jones concluded that subjects were processing the target at a preconscious level -- unknowingly, but yet revealed by the subjects' motor response.

Bower and Ferere (1984) used a similar experimental procedure to investigate preconscious processing of stimuli, except Bower and Ferere also included investigation of the differences between use of dominant and non-dominant hand. The researchers presented subjects matrices of non-letter keyboard characters (@,#,$,%,*). The target was a diamond shaped pattern of four asterisks that was contained in only half of the presented matrices. Two matrices which contained identical nontarget symbols were presented alternately to the subjects. One matrix contained the target while the other did not. All the subjects were right-handed, but half of them were instructed to tap a telegraph key with their left hand, and half were instructed to tap the key with their right hand. Subjects were instructed to search the CRT-presented matrices while maintaining an even tapping rate on the telegraph key unless they detected the target, whereupon they were to close and hold the telegraph key down.

Again, results showed several response measures were significantly different during presentations of the target matrix compared to presentations of the nontarget matrix, using a response measure similar to Bower and Jones. No differences in response measures were found between subjects tapping with their right hand and subjects tapping with their left hand. Bower and Ferere postulated these differences in response measures could represent the partial (or preconscious) activation of the motor program to stop tapping when the target was present.

The keytapping studies cited above measured the key contact times in an attempt to detect preconscious processing of the target. Response variation as measured by standard deviations of key contact times apparently either did not carry information related to target processing or the effect was unobserved. In the three studies cited, it appears there were subtle, systematic, non-linear differences between individual taps, however, the mean key on-time and rate did not reflect those differences across target versus non-target conditions, which was, of course, consistent with experimental instructions to maintain a constant tapping rate. The changes in patterns detected by the differencing technique were assumed to be different from those detected by comparison of standard deviations. Though this differencing technique was apparently sensitive in indicating information related to preconscious or subthreshold detection of target stimuli, it is not a standard technique in this field of research.

For this reason, Bower and Greenidge (1985) explored preconscious detection responses using a modified recording and analysis technique in hopes of detecting evidence for preconscious target processing in standard response measures. They attempted to simplify the relationship between the experimental instructions and the motor response. They added a speech response as a second secondary task to the first secondary task (key tapping) in an effort to assess separate channels as indicators of preconscious target detection. The researchers instructed subjects to search a matrix of letters for a target consisting of a four-letter nonsense word while simultaneously speaking the letters of the target and tapping a telegraph key with each letter spoken. Subjects were instructed to push and hold the key down and to stop speaking immediately if they located the target.

Bower and Greenidge hypothesized the performance of the secondary tasks prior to conscious detection of the target would reflect the instructed response more when the target was present compared to when the target was not present. Specifically, it was expected the inter-response time of the speech response (used as a measure of speaking rate) would be different when the target was present versus when the target was absent. They also hypothesized key contact time (on-time) would be longer when the target was present versus when the target was absent. The synchronicity of the speech task and tapping task was also analyzed. Preprocessing of the target was theorized to interfere with the synchrony of performance of the two motor tasks. The two tasks were expected to be less synchronous when the target was present compared to when it was absent from the matrix.

The results showed that although no subjects reported finding the target, the percent of key contact time (on-time) was greatest for trials in which the target was present in the matrix. In addition, the speech reponses were significantly slower, and more variable, and less in synchrony with the key tapping responses when the target was present compared to trials in which the target was not present in the search matrix.

When a subthreshold stimulus is presented to a subject performing a simple, repetitive motor task, any changes in subsequent motor performance might be used to reveal interference effects related to the stimulus processing. The next section examines the possible nature of stimulus-related interference.

Motor Programming

The underlying mechanism for how preconscious perception can interfere with a motor response may be linked to a body of research in motor programming. A motor program is defined as a representation of the redundant or structural properties of a skill (Keele & Summers, 1976). It specifies the identities, order, and relative timing of elements of a motor task. As such, a motor program is applicable to relatively simple, but possibly very difficult motor tasks. Motor programs are produced by practice in a motor skill (Lashley, 1951; Pew, 1966; Lenneberg, 1967; Shaffer, 1976). Motor programs include arguments that allow the generation of vastly different motor patterns (Pew and Rosenbaum, 1988). These arguments themselves can call up other programs as subroutines. Key tapping, using a limited muscle group and simple action, exemplifies a behavior that is ideal for the formation of a motor program. The repetitive motion used in key tapping is a motion nearly universally well-learned by most adolescents and adults in modern culture, from tasks such as dialing a touch tone phone to tapping a pencil. This simple response can generally be performed with little conscious attention except to initiate and stop the tapping response. The stopping of an action contingent upon a second event, typically a stimulus event, as in a simple reaction time task, should theoretically be adaptable to the development of a motor program. The less the stimulus uncertainty, the easier the formation of the motor program.

Bower and Spravka (1983) described a "conflicting motor programs" hypothesis whereby the motor program of tapping a telegraph key during search for the target was affected by a second, contingent motor program to stop tapping upon detecting a second stimulus event, a prescribed visual target. When the subject found the target, nested in noise characters, they were to stop tapping (initiate the "stop tapping" motor program) immediately. Bower and Spravka assumed the interference of two well-installed motor programs would be a very sensitive mechanism for the indication of partial or preconscious information processing.

This hypothesis was based on the theory that motor sequencing requires coordinated switch of neural "codes" underlying one motor action with that supporting the second motor action. Cortical activity certainly precedes muscular activity. This is clear from research involved with recording readiness potentials (Kornhuber, 1974; Coles, 1989) in which voltage potentials can be recorded over widespread regions of the scalp. These potentials develop as early as 700 milliseconds preceding a motor response. These potentials evidently arise from association areas in the parietal, temporal, and motor cortex.

The development of a readiness potential to stop one motor program in order to execute a second motor program is the mechanism that may be active in the conflicting motor programs hypothesis. The building readiness potential of the second motor program would be expected to effect the breakup or blocking of neural codes underlying the first motor program. The effectiveness of the conflicting motor programs is thought to be such that almost any conflicting neural code build-up due to low-level target processing would, to some degree trigger the breakup of the ongoing task codes representing the motor program currently being executed.

Further, Bower and Spravka theorized this modulation of neural codes is itself automatized by its frequent repetition in everyday sequencing of motor actions. Hence, even with very low-level code support for the presence of the target there would still be a propensity to interfere with the ongoing motor program.

This conflicting motor programs model was utilized in the design of further investigations mentioned earlier using this technique to detect the preconscious or subliminal processing of a visual target nested in a large set of visual distractors, i.e. target detection in very low signal-to-noise ratio sets (Bower and Jones, 1984; Bower and Ferere, 1984; Bower and Greenidge, 1985).

Subliminal Processing Models

Various models of subliminal or preconscious processing are tenable:

a. Subliminal stimuli may be related at the neuron level to low-level graded potentials which are not of sufficient magnitude to markedly alter action potential rates of neurons (See Shepherd, 1979). This postulation could describe neural events at both the sensory input stage and the motor output stage, as well as the mediating stages of information processing of low-level stimuli. Much of the research in the area of subliminal perception is consistent with predictions of the weak effects model of information processing regarding weak neural response to associated weak stimuli. R. C. Davis' research, described earlier, would fall in this category. This formulation would also describe a large number of studies which explore subjects's responses to very low-magnitude, below threshold stimuli.

b. Processing of visually subliminal stimuli may involve a spatial coding relationship involved with a second cortical visual system. In addition to the main optical neural pathway (retino-geniculo-striate visual system) a projection of optical neural fibers previous to the lateral geniculate nuclei connects to the superior colliculi in the midbrain, subsequently to the pulvinar region of the thalamus, and then to the association areas of the cortex (Schneider, 1969). The processing of visual information in the retino-midbrain system is believed to provide the explanation for "blindsight" -- the ability of individuals with optic nerve/lobe dyssfunction to identify objects within areas of their visual filelds in which they have no conscious sight.

This kind of blindsight was reported by Weiskrantz et al. (1974) in a patient which had lost a major part of their right visual cortex. In spite of the homonymous hemianopia occurring, the patient could correctly identify within the "blinded" area the location of a light flash and discriminnate better than chance between horizontal and vertical line segments as well as between the letters "X" and "O". In this type of phenomena, neuroelectric signals perhaps are reaching sufficient magnitudes but located in spatial regions of brain not related to conscious visual perception.

c) Subliminal processing may come into play with supraliminal stimuli that are nonattended for some reason.

Stimuli may be well within normal range for conscious experience, and there may be no anatomical dysfunction, but still, the subject does not attend, consciously, to the above-threshold stimulation. The research discussed above (Bower & Spravka, 1983; Bower & Ferere, 1984; Bower & Jones, 1984; and Bower & Greenidge, 1985) all relate to this formulation of subliminal perceptual processing.

A wider area of research explores this formulation, but it is principally concerned with theoretical issues in attention, perception, and the development of automatic information processing, and does not utilize motor response analysis as the information channel to preconscious processing.

Present Research

The present research is most closely related to the third model above. It explored the conflicting motor programs formulation as an indicator of subliminal or preconscious target detection. The approach of the current research was similar to that of Bower and Spravka with principal differences consisting of: (a) the evaluation of numerical targets instead of alphabetical characters for both the target and noise characters, (b) the incorporation of a between-subjects design, and (c) the use of a digital waveform analyzer to record real-time patterns of the subjects' responses. The continuous recording method permitted the separate measurement of average onsets and offsets individually for the first, second, and third key taps performed during each target search.

It was believed important to explore the technique within the context of a between-subjects experimental design. Half of the subjects were never presented the target while the other half were presented the target on every trial. In spite of the control problem of the between-groups design, and its insensitivity given a limited number of subjects, coupled with the low intensity of the expected effect, it was deemed important to assess the sensitivity and reliability of the detection method within the context of repeated target presentations. Previous motor studies did not evaluate the dependent measure of motor variability in the case of repeated target-present versus repeated target-absent stimulus presentations.

The experimental question addressed is whether, within a very demanding target detection task, preconscious processing of numerical targets embedded in a large matrix of noise digits can be detected through variations in motor performance of a secondary task that conflicts with the response normally used to report the successful detection of the target. If subjects are instructed to execute a given response upon finding the target, will subjects reliably exhibit a different response (prior to consciously locating the target) when the target is present than when the target is absent?

METHOD

Subjects

Thirty-six undergraduate volunteers from the Department of Psychology, University of Dayton reporting normal visual accuity were selected as subjects for the present research. They each received one unit of research credit towards the fulfillment of research requirements of their introductory psychology course.

Apparatus

The experiment utilized a 13-inch (diagonal) monochrome video display terminal (VDT) to present stimuli to the subjects. An IMSAI VDP/80 microcomputer was programmed to display frames of stimulus information. In addition, an IBM microcomputer was used to control a Signamax Waveform Digitizer (Coulbourn Instruments) which recorded the on-off waveforms produced by a common telegraph key. All recording was programmed from the IBM using Signamax software to store the on-off waveshapes during the trials of target search.

Measurements

Key closures and releases were recorded and digitized by the Signamax Digitizer into intervals of .036 sec. If two events occurred within the same intersample interval, for example, they were assigned to the same latency value.

Stimulus Materials

Four stimulus matrices were used in the experiment. Each matrix consisted of 21 rows of numerals, each numeral 6 mm high by 3 mm wide. (Refer to Figures 1 through 4.) The overall dimensions of the matrices were 15 cm high by 20 cm wide when presented on the VDT. Two of the matrices were designated as signal matrices, or frames, and each contained one occurrence of a unique sequence of four digits (the target), always in the same position, for which the subjects were instructed to search. The other two matrices were designated noise matrices, or frames, and contained four different (noise) digits in place of the four-digit targets in the signal matrices. The two signal matrices were each constructed using random selection of digits (0-9), and the four-digit target was determined by the four digits centered in the fourth row from the bottom of the matrix, ensuring this four-digit pattern did not occur anywhere else in the matrix. Each signal matrix was then used to define a corresponding noise matrix by randomly selecting four noise digits to take the place of the target. Each signal matrix was therefore matched to a noise matrix, to which it was identical except for the presence of the target. The four stimulus matrices thereby consisted of two matched matrix pairs, each matrix pair made up of a signal matrix and a corresponding noise matrix.

```
2 7 2 4 6 9 8 0 4 6 0 1 9 7 2 7 4 7 6 1 8 3 1 0 2 7 5 3 8 1 0
 5 2 4 7 2 6 0 2 4 9 8 9 3 0 5 3 0 2 4 5 0 3 2 5 2 3 2 4 6 8
7 3 8 0 5 4 5 4 6 1 8 3 2 7 3 2 3 2 7 5 0 3 5 4 7 5 3 5 1 7 4
 1 7 4 6 8 1 7 4 6 9 5 4 7 2 5 2 4 5 3 9 5 3 9 6 9 4 8 2 5 3
9 8 1 9 5 3 0 1 6 9 7 3 9 5 3 2 6 1 8 1 9 8 0 5 3 8 2 3 0 5 1
 7 5 0 2 7 4 7 2 6 8 9 8 9 5 4 8 2 6 7 5 4 7 2 5 3 0 4 9 5 3
0 1 9 6 7 2 5 1 9 3 2 6 7 6 8 1 6 7 1 7 4 9 6 1 8 9 7 4 9 8 9
 5 2 6 0 1 9 6 7 2 6 7 3 0 2 7 3 4 9 7 6 7 5 1 0 3 2 5 3 1 9
8 3 2 7 6 9 4 5 1 0 5 1 6 7 3 2 6 9 5 3 9 5 1 0 2 5 2 7 4 5 2
 7 6 9 6 0 2 6 0 4 8 2 3 1 6 8 9 6 0 1 6 9 7 6 1 8 3 2 3 4 9
5 0 4 7 3 9 4 5 2 3 0 2 7 4 8 1 6 7 3 2 3 8 2 4 8 2 5 1 6 9 8
 6 7 4 7 3 0 4 7 2 4 6 0 2 5 3 2 3 7 4 7 3 0 1 0 8 1 8 2 3 7
3 0 5 1 9 8 2 4 5 4 2 4 9 7 6 1 0 5 0 3 8 9 5 1 0 2 3 2 5 2 6
 0 3 0 2 3 9 5 3 8 9 6 7 2 4 9 6 8 0 5 3 1 8 9 4 7 3 1 6 7 6
2 7 6 0 3 1 0 3 9 7 4 9 5 1 0 3 0 5 2 4 7 6 0 2 4 9 4 8 0 3 2
 3 0 7 3 8 3 9 6 9 4 8 2 4 6 7 4 6 0 2 7 4 9 5 1 6 8 3 8 1 9
4 5 3 0 9 6 9 5 3 1 6 8 0 2 7 3 9 6 1 9 4 8 1 9 7 6 9 5 0 5 4
 6 9 7 3 8 0 3 0 1 8 0 4 8 9 7 2 4 8 0 4 6 9 7 4 9 7 5 0 1 9
7 6 7 5 1 7 2 6 9 6 7 5 0 5 2 7 6 8 3 2 6 1 9 8 1 7 2 6 0 5 4
 5 4 1 2 9 7 9 6 7 0 9 2 3 8 9 4 8 0 7 1 8 5 3 1 3 9 7 3 0 7
0 2 1 3 1 5 2 4 9 2 6 0 3 4 5 3 7 5 0 6 4 1 8 7 5 0 3 5 9 2 1
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FIGURE 1: Matrix I, Target-Present (Underlined)

2 7 2 4 6 9 8 0 4 6 0 1 9 7 2 7 4 7 6 1 8 3 1 0 2 7 5 3 8 1 0
5 2 4 7 2 6 0 2 4 9 8 9 3 0 5 3 0 2 4 5 0 3 2 5 2 3 2 4 6 8
7 3 8 0 5 4 5 4 6 1 8 3 2 7 3 2 3 2 7 5 0 3 5 4 7 5 3 5 1 7 4
1 7 4 6 8 1 7 4 6 9 5 4 7 2 5 2 4 5 3 9 5 3 9 6 9 4 8 2 5 3
9 8 1 9 5 3 0 1 6 9 7 3 9 5 3 2 6 1 8 1 9 8 0 5 3 8 2 3 0 5 1
7 5 0 2 7 4 7 2 6 8 9 8 9 5 4 8 2 6 7 5 4 7 2 5 3 0 4 9 5 3
0 1 9 6 7 2 5 1 9 3 2 6 7 6 8 1 6 7 1 7 4 9 6 1 8 9 7 4 9 8 9
5 2 6 0 1 9 6 7 2 6 7 3 0 2 7 3 4 9 7 6 7 5 1 0 3 2 5 3 1 9
8 3 2 7 6 9 4 5 1 0 5 1 6 7 3 2 6 9 5 3 9 5 1 0 2 5 2 7 4 5 2
7 6 9 6 0 2 6 0 4 8 2 3 1 6 8 9 6 0 1 6 9 7 6 1 8 3 2 3 4 9
5 0 4 7 3 9 4 5 2 3 0 2 7 4 8 1 6 7 3 2 3 8 2 4 8 2 5 1 6 9 8
6 7 4 7 3 0 4 7 2 4 6 0 2 5 3 2 3 7 4 7 3 0 1 0 8 1 8 2 3 7
3 0 5 1 9 8 2 4 5 4 2 4 9 7 6 1 0 5 0 3 8 9 5 1 0 2 3 2 5 2 6
0 3 0 2 3 9 5 3 8 9 6 7 2 4 9 6 8 0 5 3 1 8 9 4 7 3 1 6 7 6
2 7 6 0 3 1 0 3 9 7 4 9 5 1 0 3 0 5 2 4 7 6 0 2 4 9 4 8 0 3 2
3 0 7 3 8 3 9 6 9 4 8 2 4 6 7 4 6 0 2 7 4 9 5 1 6 8 3 8 1 9
4 5 3 0 9 6 9 5 3 1 6 8 0 2 7 3 9 6 1 9 4 8 1 9 7 6 9 5 0 5 4
6 9 7 3 8 0 3 0 1 8 0 4 8 6 0 5 1 8 0 4 6 9 7 4 9 7 5 0 1 9
7 6 7 5 1 7 2 6 9 6 7 5 0 5 2 7 6 8 3 2 6 1 9 8 1 7 2 6 0 5 4
5 4 1 2 9 7 9 6 7 0 9 2 3 8 9 4 8 0 7 1 8 5 3 1 3 9 7 3 0 7
0 2 1 3 1 5 2 4 9 2 6 0 3 4 5 3 7 5 0 6 4 1 8 7 5 0 3 5 9 2 1

FIGURE 2: Matrix I, Target-Absent
(Noise Digits Underlined)

```
0 5 6 9 5 0 1 7 2 8 0 9 2 6 2 9 7 5 5 8 1 3 4 4 7 8 6 8 4 6 2
 3 2 7 3 5 9 8 4 1 9 7 8 5 2 7 1 9 1 4 9 8 3 5 8 2 1 8 3 7 0
2 9 1 1 5 7 4 8 4 7 7 8 3 2 4 0 4 1 5 1 2 4 8 4 2 4 8 1 6 3 8
 6 5 6 1 9 7 0 9 4 1 3 0 6 4 4 6 8 9 2 8 2 1 0 8 3 8 7 9 8 6
1 9 5 3 2 1 5 7 6 3 5 1 0 3 2 9 8 2 4 4 3 8 2 4 1 8 5 5 8 4 9
 4 5 8 2 3 2 3 0 2 2 1 7 3 4 5 2 4 6 0 1 1 4 0 6 2 3 2 6 0 6
7 9 5 3 5 1 3 6 4 6 5 1 8 7 9 7 9 4 6 6 8 3 7 2 1 2 0 5 6 8 4
 2 5 8 7 9 8 1 2 0 6 3 6 5 0 6 7 1 4 8 7 4 3 1 5 2 5 8 7 1 5
8 6 0 7 1 9 8 9 4 2 9 1 0 2 2 1 6 1 8 6 2 9 3 0 8 3 9 2 5 2 3
 2 4 8 9 3 5 8 9 2 7 4 1 6 5 3 7 2 3 7 8 3 5 3 4 6 9 1 0 6 9
4 7 4 9 6 2 0 9 5 3 9 4 0 7 2 5 3 4 5 7 8 9 4 7 8 6 4 0 5 1 2
 6 0 3 6 8 3 5 9 5 0 2 7 9 1 8 0 3 7 0 8 3 1 6 8 2 9 3 5 6 1
0 2 7 1 2 0 8 5 6 8 4 0 4 3 6 1 9 6 4 9 5 6 4 8 0 1 4 7 9 8 6
 9 1 8 6 1 4 3 0 2 4 7 3 1 3 3 9 8 5 2 6 0 4 0 2 6 1 2 5 3 0
1 2 6 1 5 1 0 8 2 7 6 5 9 8 3 2 1 3 1 9 6 7 9 4 7 2 3 7 5 2 8
 5 7 1 4 3 4 2 7 5 3 2 4 6 7 1 9 6 8 9 7 4 7 9 6 8 9 4 3 1 7
3 4 5 8 9 2 0 4 6 9 0 1 6 2 4 7 8 0 5 6 2 7 6 8 5 3 0 1 9 8 3
 7 4 1 5 0 4 1 2 9 7 3 9 2 8 2 6 4 9 0 7 1 4 4 2 7 1 5 9 3 6
9 0 4 9 1 3 2 7 5 9 3 2 9 1 5 3 8 9 3 0 6 7 1 8 3 9 6 0 5 1 4
 8 2 7 6 3 7 8 3 9 6 4 7 0 6 8 3 5 1 2 3 0 9 8 9 5 1 4 1 3 5
2 1 0 4 8 9 4 5 6 3 5 3 4 2 1 9 9 2 7 8 4 5 3 4 8 2 6 5 9 7 8
```

FIGURE 3: Matrix II, Target-Present (Underlined)

0 5 6 9 5 0 1 7 2 8 0 9 2 6 2 9 7 5 5 8 1 3 4 4 7 8 6 8 4 6 2
3 2 7 3 5 9 8 4 1 9 7 8 5 2 7 1 9 1 4 9 8 3 5 8 2 1 8 3 7 0
2 9 1 1 5 7 4 8 4 7 7 8 3 2 4 0 4 1 5 1 2 4 8 4 2 4 8 1 6 3 8
6 5 6 1 9 7 0 9 4 1 3 0 6 4 4 6 8 9 2 8 2 1 0 8 3 8 7 9 8 6
1 9 5 3 2 1 5 7 6 3 5 1 0 3 2 9 8 2 4 4 3 8 2 4 1 8 5 5 8 4 9
4 5 8 2 3 2 3 0 2 2 1 7 3 4 5 2 4 6 0 1 1 4 0 6 2 3 2 6 0 6
7 9 5 3 5 1 3 6 4 6 5 1 8 7 9 7 9 4 6 6 8 3 7 2 1 2 0 5 6 8 4
2 5 8 7 9 8 1 2 0 6 3 6 5 0 6 7 1 4 8 7 4 3 1 5 2 5 8 7 1 5
8 6 0 7 1 9 8 9 4 2 9 1 0 2 2 1 6 1 8 6 2 9 3 0 8 3 9 2 5 2 3
2 4 8 9 3 5 8 9 2 7 4 1 6 5 3 7 2 3 7 8 3 5 3 4 6 9 1 0 6 9
4 7 4 9 6 2 0 9 5 3 9 4 0 7 2 5 3 4 5 7 8 9 4 7 8 6 4 0 5 1 2
6 0 3 6 8 3 5 9 5 0 2 7 9 1 8 0 3 7 0 8 3 1 6 8 2 9 3 5 6 1
0 2 7 1 2 0 8 5 6 8 4 0 4 3 6 1 9 6 4 9 5 6 4 8 0 1 4 7 9 8 6
9 1 8 6 1 4 3 0 2 4 7 3 1 3 3 9 8 5 2 6 0 4 0 2 6 1 2 5 3 0
1 2 6 1 5 1 0 8 2 7 6 5 9 8 3 2 1 3 1 9 6 7 9 4 7 2 3 7 5 2 8
5 7 1 4 3 4 2 7 5 3 2 4 6 7 1 9 6 8 9 7 4 7 9 6 8 9 4 3 1 7
3 4 5 8 9 2 0 4 6 9 0 1 6 2 4 7 8 0 5 6 2 7 6 8 5 3 0 1 9 8 3
7 4 1 5 0 4 1 2 9 7 3 9 2 3 0 2 7 9 0 7 1 4 4 2 7 1 5 9 3 6
9 0 4 9 1 3 2 7 5 9 3 2 9 1 5 3 8 9 3 0 6 7 1 8 3 9 6 0 5 1 4
8 2 7 6 3 7 8 3 9 6 4 7 0 6 8 3 5 1 2 3 0 9 8 9 5 1 4 1 3 5
2 1 0 4 8 9 4 5 6 3 5 3 4 2 1 9 9 2 7 8 4 5 3 4 8 2 6 5 9 7 8

FIGURE 4: Matrix II, Target-Absent
(Noise Digits Underlined)

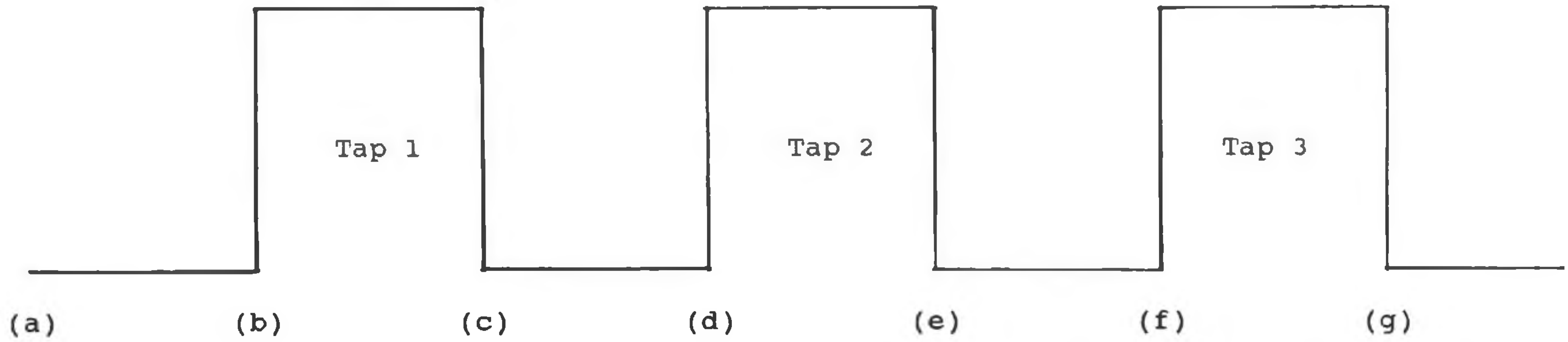
Procedure

Subjects were instructed to search a matrix of digits on the VDT screen for a four-digit target, while simultaneously tapping a telegraph key. (See Appendix A: Instructions to Subjects.) They were told target digits would be positioned in a sequence horizontally. Subjects were randomly assigned to four experimental groups without regard to gender: target present, matrix I; target present, matrix II; target absent, matrix I; target absent, matrix II. Subjects in the target present groups always saw a signal matrix (each subject always saw the same one). Subjects in the target absent groups always saw a noise matrix (each subject always saw the same one). Subjects in the matrix I groups were instructed to search for the digits 9,7,2,4, and subjects in the matrix II groups were instructed to search for the digits 8,2,6,4.

All subjects were instructed to tap four equal-length and evenly-spaced taps on the telegraph key during each stimulus frame presentation. Additionally, they were instructed to immediately push and hold down the telegraph key, and notify the experimenter, if they found the target.

Subjects were seated at a table with the VDT and telegraph key positioned in front of them. They viewed the VDT screen at a 65 cm viewing distance and used their preferred hand to operate the telegraph key. Prior to the start of the experiment, subjects were allowed to practice tapping the telegraph key using a metronome set to the required rate. Each presentation of a stimulus frame lasted 3.0 seconds, and comprised one trial. During each trial, subjects made four separate key closures and releases (or taps) on the telegraph key. The offset, or release, of the first tap was used for timing purposes to trigger the computer and was referred to as the timing offset. The remaining three taps were analyzed and were referred to as taps 1, 2, and 3. (See Figure 5.) The VDT screen was blanked for 4.0 seconds between trials.

Pilot data indicated subjects began to detect the target after more than ten trials. Additionally, data storage limitations of the waveform digitizer required too gross of measurement when the number of trials was much greater than ten. Therefore, to guard against recognition of the target and to use as fine grain measurement of the tap response as was necessary, every subject was presented just ten trials.



(a) Timing Offset
(b) Leading Edge or Onset of Tap 1
(c) Offset (Release) of Tap 1
(d) Leading Edge or Onset of Tap 2
(e) Offset of Tap 2
(f) Leading Edge or Onset of Tap 3
(g) Offset of Tap 3

FIGURE 5: Example Trial Structure

Design

Three independent variables were included in the design: (a) signal (target presence) vs. noise (target absence) in the stimulus search frames, (b) matrix I vs. matrix II (two signal frames and two corresponding noise frames), and (c) tap number 1 vs. tap number 2 vs. tap number 3 (analogous to successive tests in a memory recall task). Both (a) and (b) were between-subject variables, while (c) was a within-subject variable.

Seven dependent variables were related to the design: (a) mean on-times of key closures, (b) mean off-times, (c) mean on-time percentages of the tapping response (on-time as a percentage of total trial duration), (d) mean intertap intervals, (e) mean leading-edge latencies, (f) standard deviations of leading-edge latencies, and (g) distribution asymmetry of the on-times and the off-times of the key-tapping responses.

RESULTS

Mean On-Times. Mean on-times were the mean durations of the key closures. Mean on-times of key closures were evaluated by means of a three-factor mixed design analysis of variance (ANOVA), with repeated measures on one factor. The variables were signal, matrix, and tap number (first, second, third) in a 2 x 2 x 3 factorial, with repeated measures on tap. Durations of key closures were not significantly different in magnitude and may be insensitive to low-level signal processing. The results revealed no significant main effects or interactions. (See Table 1 in Appendix C.) This is consistent with findings of earlier studies by Bower and Ferere (1984) and Bower and Jones (1984).

Mean Off-Times. Mean off-times of the tapping response were the mean durations of the key-open periods between taps (key closures). Mean off-times were evaluated by means of a three-factor mixed design ANOVA (2 x 2 x 3). The variables were signal, matrix, and tap, with repeated measures on tap. Durations of key-open time periods were not significantly different in magnitude and may likewise be insensitive to low-level signal processing. The results revealed no significant main effects or interactions. (See Table 2 in Appendix C.) This result is also consistent with findings of earlier studies of motor indicants of preconscious processing (Bower and Ferere, 1984; Bower and Jones, 1984).

Mean On-Time Percentages. In order to differentiate possible differences in the relative patterns of tapping responses, mean on-time percentages were figured by summing the three on-times per trial and dividing the sum by the total trial duration (on-time as a percentage of total trial duration). Mean on-time percentages were evaluated by means of a three-factor mixed design ANOVA (2 x 2 x 3). The variables were signal, matrix, and tap, with repeated measures on tap. On-time proportions of total trial duration were not different between signal and noise conditions. The results revealed no significant main effects or interactions. (See Table 3 in Appendix C.)

Mean Intertap Intervals. Mean intertap intervals were computed by measuring the mean intervals between tap leading edges (or key closure onsets). Mean intertap intervals were evaluated by means of a three-factor mixed design ANOVA (2 x 2 x 2). The variables were signal, matrix, and intertap interval (ITI), with repeated measures on ITI. The results revealed no significant main effects or interactions. (See Table 4 in Appendix C.) Consistent with previous findings of related research on intertap interval in preconscious target detection, intertap interval does not appear to be sensitive to target discrimination, if subliminal target detection occurred.

Mean Leading-Edge Latencies. Mean leading-edge latencies were the mean latencies, measured from the timing offset, of the key three closure onsets. Mean leading-edge latencies were evaluated by means of a three-factor mixed design ANOVA (2 x 2 x 3). The variables were signal, matrix, and tap, with repeated measures on tap. Tap had a significant effect [F(2,64) = 1433.25, p < .0001]. The significance of tap is to be expected due to the nature of the task. No other main effects or interactions were significant. (See Table 5 in Appendix C.)

Standard Deviations of Leading-Edge Latencies. Standard deviations of leading-edge latencies were evaluated by means of a three-factor mixed design ANOVA (2 x 2 x 3). The variables were signal, matrix, and tap, with repeated measures on tap. Variability of position of the leading edge of each tap increased as a function of tap sequence. This is probably inherent to the task since the beginning of each trial was synchronized to the offset of an initial tap (timing offset) and any acceleration/deceleration in subjects' tapping rate would tend to progressively increase variability with tap. Since this variability did not interact with signal, no further analysis was conducted. Tap had a significant effect [F(2,64) = 49.45, p < .0001]. No other main effects or interactions were significant. (See Table 6 in Appendix C.)

Distribution Asymmetry. Asymmetry of the distribution of on-times and off-times was evaluated by a differencing technique similar to Bower and Ferere (1984). In the present technique, second-order differences between rank-ordered on-times and off-times were separately determined. For each subject, the on-times (key contact durations) and off-times for each of the three taps were determined. Since variability in duration of key closure vs. key open positions was of interest, not temporal order, the mean on-times for each tap were rank ordered and the mean off-times for each tap were rank ordered. Absolute differences between these three mean on-times (off-times) resulted in first-order difference scores. Second-order difference scores were then computed for on-times vs. off-times and target-present vs. target-absent conditions. Perfect regularity in the tapping response would produce symmetry in the distribution of on-times and off-times and the second-order differences would go to zero.

Asymmetry of the distribution was evaluated by means of a two factor mixed design ANOVA (2 x 2). The variables were signal (target-present vs. target absent) and response type (on-time vs. off-time) with repeated measures on response type. The effects of signal [$F(1,34) = 4.83$, $p < .05$] and response type [$F(1,34) = 5.74$, $p < .05$] were significant. The interaction was not significant. (See Table 7 in Appendix C.) The greater degree of symmetry (smaller second-order means) in the target-present condition, suggests a smoother, more regular response generation pattern than that found in the target-absent condition. The distribution asymmetry measure as a function of signal and response type is shown in Figure 6.

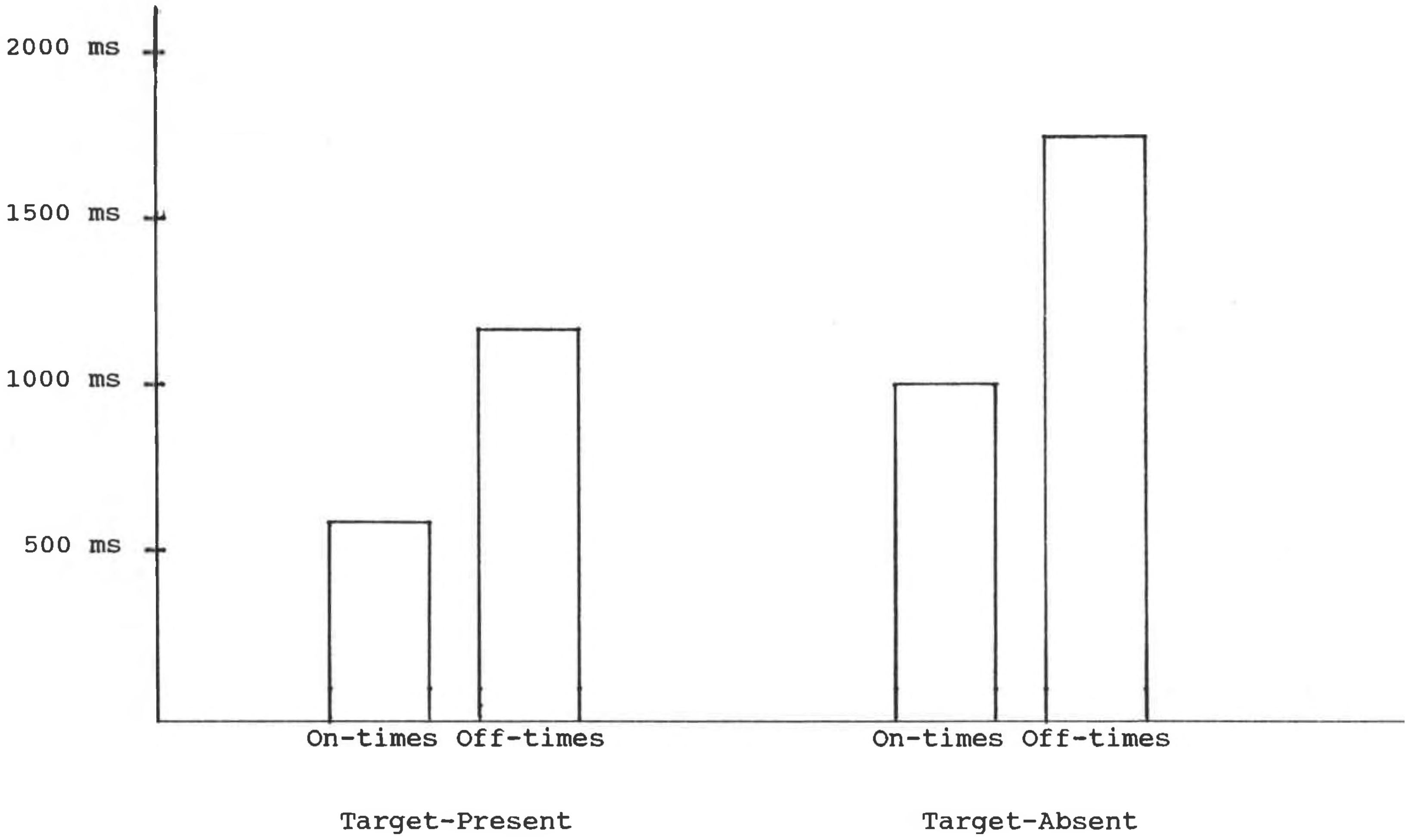


FIGURE 6: Second-Order Difference Scores

Because of pure random assignment of subjects to experimental groups without regard to gender, the target-present and the target-absent conditions contained an unequal number of males and females. Although there was no theoretical reason to expect gender might interact with the distribution asymmetry measure, it seemed prudent to examine the distribution asymmetry data by gender. To investigate the possiblility that gender of the subject was a source of response asymmetry, two t-tests were performed, comparing for each sex separately, the summed second-order difference scores between target-present and target-absent conditions.

The first t-test was performed on the females' data. The mean second-order difference for the target-present condition was 0.791 s and the mean second order difference for the target-absent condition was 1.567 s. (See Figure 7.) Response asymmetry was significantly less in the target-present condition than in the target-absent condition [$t(1,22) = 3.6056$, $p<.05$]. A second t-test was performed on the males' data, comparing the target-present condition with the target-absent condition. Mean asymmetry was found in the same relative direction as in the females' data, but was not significantly different.

The finding of a significant difference between target-present and target-absent conditions for females and an effect in the same direction for males seems to offer evidence that the overall effect observed in the F-score for the distribution asymmetry measure is due to the target-

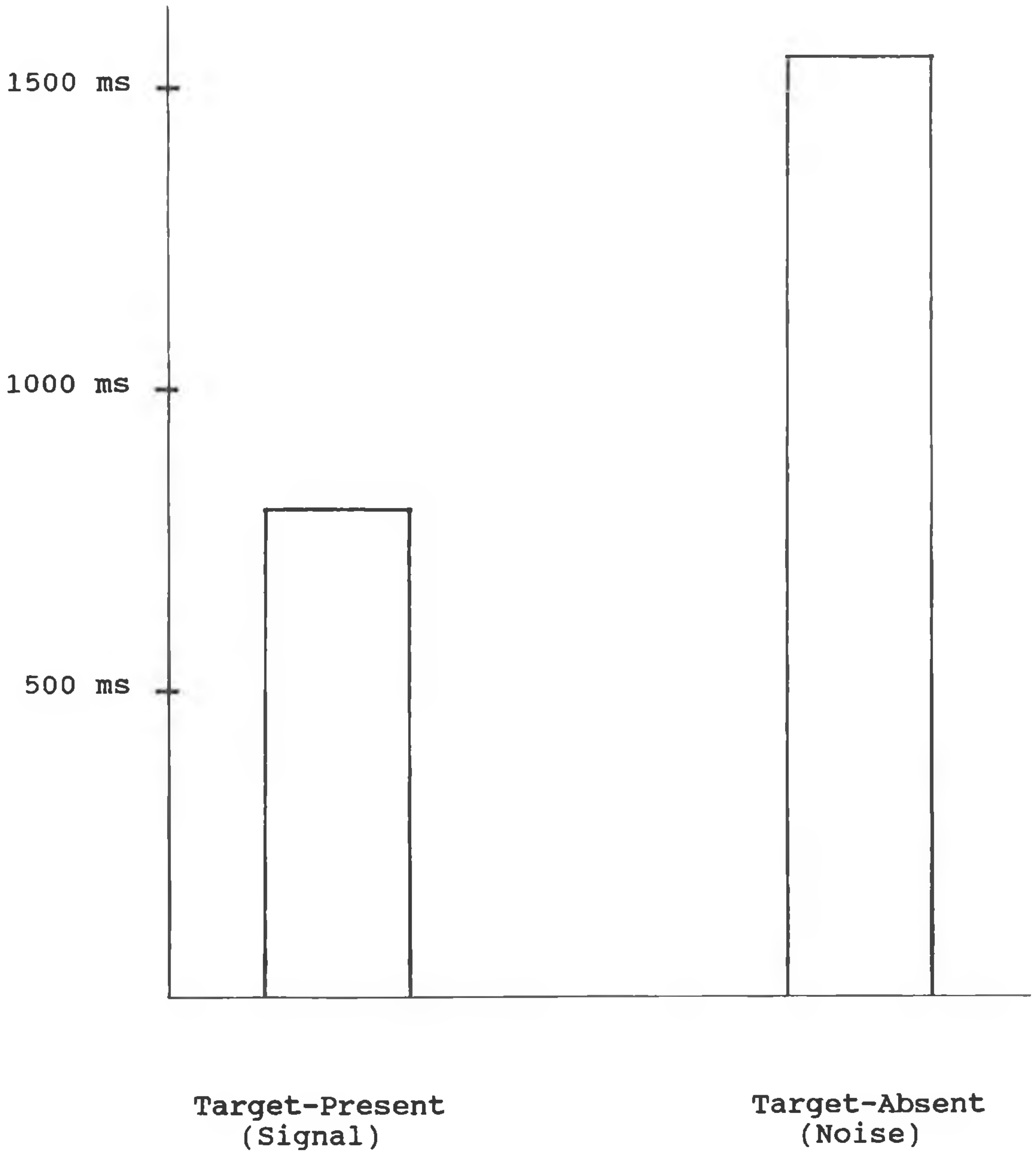


FIGURE 7: T-Test Scores, Female, Signal vs. Noise

present vs. target-absent effect, and not simply a result of the assignment imbalance of gender to signal conditions. The distribution asymmetry measure may, however, be more sensitive to preconscious processing in females as opposed to males. Such speculation would require additional research in order to be evaluated.

DISCUSSION

The lack of significant results among the measures directly related to on-times, off-times, latencies, intertap intervals and the variabilty of these measures is consistent with results reported by earlier studies using a key tapping motor response paradigm (Bower and Jones, 1984; Bower and Spravka, 1983; and Bower and Ferere, 1984). Clearly, the present research did not demonstrate easily-interpretable evidence for subconscious detection of numerical targets. However, the significant difference found between 2nd order, absolute differences of on-times and off-times in the target-present and target-absent conditions does argue that some signal-related differences may have manifested themselves in subjects' motor responses. This phenomena merits further exploration.

The rank ordering of the on-times and off-times in the differencing analysis destroyed the temporal order of tap position or number. This was done because interest was in the broader issue of variability in duration of key closure. Temporal order was not the focus of the analysis. The distribution asymmetry statistic treats each tap equally without regard to sequential position. The focus of this analysis was the duration of the longest tap, not where it occurred in the sequence.

The differential response distributions as defined by the differencing analysis used in the present research reinforces the findings of Bower and Ferere (1984). However, any comparison must be of a general nature only, since the measures were not the same in each study. There does at least appear to be a sensitivity of the distribution asymmetry measure to complex differential tapping responses associated with motor-related information processing. In the current study, the measure revealed a greater symmetry in the on-time and off-time distributions of the target-present condition than that found in the distributions of the target-absent condition.

This greater degree of symmetry may reflect an observed tendency toward increased regularity in a simple repetitive motor task when distracted by an event external to the motor task (Boder, 1935; Posner, 1969; Rose, 1973). As discussed in Rose (1973), Boder found some subjects performed a tapping task with more regularity when performed with a secondary task than when the tapping task was performed alone. Research in this area indicates that when the primary task is simple and well practiced (as with a key tapping task), a simple secondary task can improve regularity of the primary task. As reviewed in Rose (1973), Posner (1969) attributed this effect to an automated movement that is performed better if attention is directed away from it.

The greater degree of symmetry could be caused by the "distraction" of the target during target search and the partially fulfilled processing of information related to target presence in the visual system. In effect, the subject's information processing system perhaps was performing as if a supraliminal attention task was being performed when the target was present. Even though the target was not discovered, the attention process was occupied sufficiently (diverted from the tapping task) to allow the tapping task response with less variability. This variability is differentiated from that indexed by traditional measures of standard deviation. Regularity of the distribution of key tapping responses probably reflects a higher order regularity than that usually described by the standard deviation. Further investigation is needed to explore the most basic structure of motor responses associated with subconscious target detection.

Suggestions for Future Research

The present study enhanced the data collection of real-time tapping responses using the waveform digitizer and a microcomputer. It allowed the assessment of a fine-grain, real-time data collection technique. The between-subjects variability may not have permitted the detection of any differences that might have occurred in direct measures of on-times, off-times, latencies and intertap intervals. Though the current study allowed real-time data collection, the digitizer used in the study was taxed at the data rates that were collected in this simple design. The smallest intersample interval that could be used was .036 sec. This may have limited the sensitivity of the present study to detect real differences in the tapping response. There is a need for the use of higher capacity memory and processing digitization equipment.

Perhaps the greatest need in research investigations in this field of study is the adaptation of higher order data collection techniques such as spectral analysis. Any consistent detection of an alteration in variability caused by subtle motor dynamics will require very fine-grain data collection techniques. Based on previous research (conflicting motor programs theory) and the current findings, it appears subsequent studies should markedly increase the sensitivity of measures and methods in order to usefully reveal the underlying structure of motor responses related to target-present vs. target-absent conditions. Perhaps the telegraph key should be replaced by a contiuous motion transducer such as a spring-loaded rheostat. A continuous measure of a repeated oscillating motion would provide a rich data base for Fourier analysis. Additionally, specialized spectral techniques should be explored in order to optimize the depiction of underlying order in the motor reponse. Recommended is the use of instrumentation and techniques which would permit a very large number trials per subject. A greater capacity analysis system would permit a more exhaustive number of comparisons within and between trials.

At this stage of research, it is still not certain the motor measurements are consistently revealing any particular indicator of target detection. Results do, however, suggest further research in order to determine if a consistent and valid indicator can be isolated. Inasmuch as the present research did not find standard response measures, such as tapping rate and tapping rate variabilities, useful in the analysis of target detection, it has made even more important the need for measurement systems more likely resonant to complex response order.

APPENDICES

APPENDIX A: INSTRUCTIONS TO SUBJECTS

This experiment deals with searching for a target number which may or may not be present while tapping a telegraph key. In this experiment you are asked to search a matrix of numbers (digits) on a video display terminal (VDT) screen for a specific "target" consisting of four digits positioned horizontally (on the same line) and in sequence (right next to each other). Only one "target" will appear in a particular matrix.

While you are searching for the number sequence, press down (tap) a telegraph key in 4 evenly spaced intervals. I'll show you how fast you have to tap -- please maintain the same constant rate throughout the experiment. Use your preferred hand to operate the telegraph key.

The matrix of digits will be presented for three seconds and then the screen will go blank for a short time, and then a matrix will appear again on the screen. This will be repeated for a number of times. When the screen comes on each time, search for the target sequence while tapping the telegraph key.

(AT THIS POINT, I DEMONSTRATED A SHORT TAPPING SEQUENCE AND EACH SUBJECT WAS ALLOWED TO PRACTICE TAPPING WITHOUT VIEWING ANYTHING ON THE VDT.)

During the experiment, if you find the target number immediately push the telegraph key down and hold it down and notify me.

Any questions? The target number you will be searching for is 9,7,2,4*. Let's begin.

* Half of the subjects were instructed to search for 8,2,6,4.

APPENDIX B: DEBRIEFING REPORT

General Area of Psychology:

Human Information Processing -- Human Factors

Statement of the Problem:

Can individuals identify information they are not aware of and can this processing be detected in subtle motor programs? When we search a visual display seeking a particular target item, the visual information concerning the target enters the brain some time before we "find" the item. If we are instructed to perform a certain action when we find the target, will the instructed response occur in some partial form before we consciously locate the target item?

Specific Hypothesis Being Tested:

Subjects instructed to tap a telegraph key while searching for a target and to hold the key down if they find the target, will have more key closure time and shorter intertap intervals in their tapping response when the target is present compared to when the target is absent.

Variables. Independent: Presence or absence of the target.
Dependent: Tapping response profile.

Control Procedures:

Matched visual displays are identical except for the presence or absence of the target. Subjects are randomly assigned to presentation groups. Half of the subjects receive only signal matrices and the other half receive only noise matrices. Two different signal matrices are tested.

General implications:

Given that preconscious processing is valid and reliable, then systems could be designed which would sense response patterns during search so that the system could indicate the presence of the sought after item before the operator is aware of target presence.

References for Further Research:

(see References)

APPENDIX C: EXPERIMENTAL DATA

TABLE 1: F-Scores of Mean On-Times

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	3.64	1,32	NS
Matrix (M)	1.54	1,32	NS
S x M	0.16	1,32	NS
Tap (T)	2.22	2,64	NS
S x T	0.75	2,64	NS
M x T	0.31	2,64	NS
S x M x T	1.30	2,64	NS

TABLE 2: F-Scores of Mean Off-Times

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	0.23	1,32	NS
Matrix (M)	1.26	1,32	NS
S x M	0.01	1,32	NS
Tap (T)	2.66	2,64	NS
S x T	0.09	2,64	NS
M x T	0.59	2,64	NS
S x M x T	0.04	2,64	NS

TABLE 3: F-Scores of Mean On-Time Percentages

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	1.44	1,32	NS
Matrix (M)	0.06	1,32	NS
S x M	0.02	1,32	NS
Tap (T)	2.88	2,64	NS
S x T	0.51	2,64	NS
M x T	0.37	2,64	NS
S x M x T	1.24	2,64	NS

TABLE 4: F-Scores of Mean Intertap Intervals

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	0.11	1,32	NS
Matrix (M)	3.46	1,32	NS
S x M	0.04	1,32	NS
Intertap Interval (ITI)	1.10	1,32	NS
S x ITI	1.32	1,32	NS
M x ITI	2.37	1,32	NS
S x M x ITI	0.00	1,32	NS

TABLE 5: F-Scores of Mean Leading Edge Latencies

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	0.00	1,32	NS
Matrix (M)	2.44	1,32	NS
S x M	0.03	1,32	NS
Tap (T)	1433.25	2,64	p<.0001
S x T	0.16	2,64	NS
M x T	0.74	2,64	NS
S x M x T	0.08	2,64	NS

TABLE 6: F-Scores of Standard Deviations of Leading Edge Latencies

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	0.97	1,32	NS
Matrix (M)	0.71	1,32	NS
S x M	0.16	1,32	NS
Tap (T)	49.45	2,64	p<.0001
S x T	0.06	2,64	NS
M x T	0.77	2,64	NS
S x M x T	0.28	2,64	NS

TABLE 7: F-Scores of the Distribution Asymmetry Measure

Variable	F-Score	Degrees of Freedom	Significance
Signal (S)	4.83	1,34	p<.05
Response Type (R) (On-Time vs. Off-Time)	5.74	1,34	p<.05
S x R	0.21	1,34	NS

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