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CONSCIOUS PROCESSES IN AUTOMATIC VISUAL AND AUDITORY SEARCH

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CONSCIOUS PROCESSES IN AUTOMATIC

VISUAL AND AUDITORY SEARCH

A THESIS

APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

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Abstract

A series of experiments investigated automatic processing in visual and auditory search tasks using masking techniques. Processing load in terms of the number of possible targets in the test period was varied under conditions in which test stimuli mask onset asynchrony (test SOA) was systematically reduced in duration. In Experiment 1, subjects received 17-18 hours of search task practice requiring speeded judgments of target presence or absence, using a consistent mapping procedure with categorical differences between targets and distractors. Accuracy and RT performance after extensive practice generally satisfied the capacity criterion for automatic detection of flat curve slopes across processing load levels in both the visual and auditory tasks. Experiments 2A and 2B compared automatic target detection to detection of the presence or absence of any test stimuli and ability to identify the test stimuli by verbal report at test SOAs between 50 and 1 ms. Stimulus detection was more accurate than automatic target detection at shorter test SOAs. Report performance and target detection performance did not differ. All of the tasks were performed accurately at shorter test SOAs with auditory stimuli. In Experiment 3, a multiple same target positive trial condition was compared to the highly practiced single target positive trial condition at reduced test SOAs. Accuracy was better in the multiple same target condition, indicating activation additivity in automatic target detection. Results of these experiments suggest that automatic target detection in search tasks is a conscious process and that it requires cognitive resources in addition to those required for stimulus detection.

Conscious Processes in Automatic Visual and Auditory Search

Two-process theories of cognition represent one of the most popular contemporary approaches to the development of a functional architecture of mental processes. The central feature of these theories is a delineation of two modes of information processing: automatic and controlled or effortful processing. Automatic processing is typically described as capacity unlimited, wholistic, nonattentional, unintentional, and unconscious; controlled processing is described as highly capacity limited, serial, attentional, intentional, and conscious (e.g., Posner, 1978, 1982; Shiffrin & Schneider, 1977; Potter, 1976).

This distinction has served as a primary basis for theoretical definitions of attention and consciousness in contemporary cognitive theory. However, empirical demonstrations have not unequivocally supported a clear delineation of these two theoretical modes of processing (e.g., Allport, 1980; Boyer, 1984). In addition, there are important questions as to which mental acts fall into which category, as well as to the appropriate operational criteria to use in making the categorization for a particular mental act.

In summarizing the literature on automatic processing, Boyer (1984) outlined three general operational criteria used to identify an automatic process: capacity, intentionality, and reportability. The capacity criterion concerns whether or not a cognitive process is subject to processing load effects, as in the visual search findings of flat performance curve slopes across load levels; or does not interfere with other ongoing mental activity as in dual task paradigms. The intentionality criterion concerns whether instructional cues aid performance and whether specific cognitive processes can be avoided or stopped. Automatic processes purportedly are unavoidable and do not benefit from conscious attentional control such as occurs in the utilization of cues. The reportability criterion is usually defined in terms of the ability of a subject to provide verbal reports of the content of cognitive processing. Inability to provide reports of tasks performed accurately implies that the processing is unconscious.

Marcel (1983) has demonstrated the utility of masking techniques for the investigation of unconscious processes, and has suggested that possible examples of unconscious processing should be tested using masking techniques that prevent conscious awareness or availability for verbal report. Automatic detection of targets in search tasks has been tested extensively using the capacity and intentionality criteria (e.g., Schneider & Shiffrin, 1977). Although there is some ambiguity as to the degree to which automatic search tasks satisfy these two criteria (e.g., Boyer, 1984; Shiffrin, Dumais & Schneider, 1981), the reportability criterion for automaticity has received little attention in the case of automatic search performance. The experiments reported in this paper investigated automatic target detection in search tasks with respect to the reportability criterion, using masking techniques similar to those reported by Marcel (1983).

Attempts to identify conscious and unconscious processes in two-process theories have a long history in experimental psychology. Wundt (1912) proposed a two-process theory that distinguished the processes of apperception and apprehension. Apperception referred to clearly perceived, focal attentive processes in conscious awareness; and apprehension referred to vaguely perceived, inattentive processes in the periphery of conscious awareness. For

Wundt, automatic processes were learned habitual reflexes that developed with repetitive practice. Development of automaticity involved a process of "retrogradation" (Wundt, 1907, p. 213), during which all mental elements experienced in an initial conscious task faded out with practice until the habitual act was performed as a physiological reflex with no conscious mental components. The criterion Wundt (1907) proposed for most clearly demonstrating automaticity was that a choice reaction time task should be performed as rapidly as a simple reaction time task, indicating no intervening stages of mental activity. This criterion probably has not been met by any of the recent automatic processing research.

Titchener (1908, p. 220) emphasized the generality of Wundt's two-process theory in "the law of the two levels," but he seemed to differ with Wundt by considering automatic processing to be a conscious process. According to Titchener (1906, 1924), conscious choice tasks may degenerate with habitual practice to an acquired automatic reflex with no affective components such as feelings of effort; but the conscious sensations associated with the task continue to be experienced in the margin of consciousness.

James (1890) similarly held that automatic processing takes place in the <u>conscious fringes</u> or region of <u>conscious inattention</u> outside of focal attention, and that the accompanying conscious sensations allowed for simple direction and monitoring of task performance. James (1890) agreed with a statement by Judd (1907, p. 207) that, "Too often the psychology of habit has been guilty of the statement that habituation leads to unconsciousness. This is not the case. When we deal skillfully with any situation, we have an attitude of attention wholly different from the attitude of indefinite excitement which comes from unpracticed performance."

In a more recent two-process theory that contrasts with James' and Titchener's views of automaticity, Neisser (1967) delineated conscious focal attention and unconscious preattentive processes. According to this theory, prolonged practice may lead to the development of preattentive recognition analyzers that can, for example, automatically signal the presence of a target stimulus without focal attention or conscious awareness. Neisser (1967) commented that a considerable portion of daily activities such as walking, driving, other guided movements, tracking of visual stimuli, and directing the attentional mechanism in general, are under the control of unconscious preattentive processes. However, most recently Neisser (1976) has expressed major concerns about models of cognitive processes that attempt to localize consciousness to a discrete mechanism in a series of functional stages of processing, as his earlier model implied.

Posner (1978, 1982) has argued strongly for a two-process theory that associates consciousness specifically with a central attentional mechanism and that emphasizes unconscious automatic processes. He identified conscious attention with a limited capacity central processing system that is not utilized in many complex, learned mental operations. Posner and Warren (1971, p. 34) stated that "use of this system becomes the central definition of a 'conscious process' and its non-use defines what is meant by 'automatic'." Further, Posner (1978, p. 180) has noted that a common difficulty throughout the psychological literature is the failure to understand that "conscious awareness is a discrete event that plays a specific role within the stream of information processing."

Posner (1978) proposed that an automatic process is indicated if the process occurs without intention, without generating conscious awareness, and without interfering with other ongoing mental processes. For the most part, Posner attributes automaticity only to activation of sensory encoding functions such as graphemic, phonemic, and semantic analyzers. Decision processes such as response selection are considered conscious attentional processes that require the limited capacity central processing mechanism.

Allport (1977) and Marcel (1978, 1983) have obtained results in support of the notion that sensory encoding processes operate without conscious awareness. In a priming study by Allport (1977), semantically related and unrelated words were presented parafoveally along with foveally presented words at very brief exposure durations and were followed immediately by a pattern mask. Although subjects were unable to detect the presence of the masked words, less interference occurred to a subsequent lexical decision probe when the parafoveally presented words were semantically related to the probe compared to when they were unrelated.

Marcel (1978) presented subjects with a single target word or a blank field, followed by a pattern mask and then two probe words. Surprising results were obtained for a group of passive subjects who did not try to apply any intentional strategies. As target word mask onset asynchrony (SOA) was reduced, chance accuracy for the passive subjects occurred first on judgments of the presence or absence of a target word, then on graphic relatedness of the target word to the probe words, and finally on semantic judgments of the target word and probe words. These results suggested that pattern masking prevents conscious awareness or reportability of the target words while allowing perceptual analyses to continue, including access to the semantic lexicon.

In a related priming study, Marcel (1978) required lexical decisions to the first and third of three successive letter strings. The second letter string was an ambiguous word with two primary meanings, one of which is typically experienced according to the context (e.g., palm). The first and second letter strings were either semantically related or unrelated, and the second letter string was unmasked, pattern masked or energy masked. According to Marcel (1978), energy masks prevent peripheral processing, which also precludes central conscious processing. However, pattern masks prevent conscious central processing without disrupting peripheral processing (Turvey, 1973; Marcel, 1978, 1983). In the pattern mask condition, the second letter string was presented at an SOA that was 5 ms below the level at which the subject could no longer make letter string presence or absence judgments above chance, determined preexperimentally for each individual subject. Marcel (1978) noted that no subject was able to report the second word either in the pattern mask or energy mask conditions, which he used as the criterion for unconscious processing.

When the second letter string was energy masked, a priming effect on the third word was obtained only when the first word was a semantic associate of it; the second word had no effect. In the unmasked condition, the target priming effect occurred when the first word was related to the same meaning of the second ambiguous word as was the third word, suggesting that prior context selectively affects lexical responses to the third word when conscious awareness of the words is not precluded. In the pattern mask condition, however, reliable priming of the third word was obtained for both meanings of the ambiguous word regardless of prior context, suggesting that the second word accessed both of its lexical entries even when conscious awareness of it was precluded by the pattern mask.

Finally, in another priming study, Marcel (1983) repeated, from 1-20 times, target words that were unreported by the subject due to pattern masking. Subjects were instructed before each trial to make either a lexical decision or a detection judgment on the pattern masked word. Marcel (1983) reported that reaction times for the lexical decision showed facilitation with repeated exposures, but ability to identify the word did not change with repetition. Marcel concluded that conscious and unconscious processes appear to be qualitatively different. Either the perceptual representation is criterially available to awareness or not; it does not appear to be based on the strength of the representation or amount of activation. He further speculated that awareness may not be a threshold phenomenon susceptible to additive accumulations of perceptual information, but rather appears to depend on the availability of a particular type of representation in the cognitive processing system.

These studies support the conclusion that semantic processing of visually presented words can occur whether or not subjects are able to provide a verbal report about the processing or about the eliciting stimuli. Posner's criterion that conscious awareness should not be required in an automatic process seems to be met in the case of automatic activation of semantic encoding processes, if inability to report is a sufficient indicant that a process is unconscious.

Shiffrin and Schneider (1977) also advanced a two-process theory in which automatic processing is an important construct. Automatic processing in their theory is described as "a learned sequence of elements in long-term memory that is initiated by appropriate inputs and proceeds. . .without subject control and without necessarily demanding attention" (Schneider & Shiffrin, 1977, p. 1).

Shiffrin and Schneider (1977, p. 160) proposed two types of automatic processing. "Informational" automatic processes are similar to Posner's use of the term; these automatic processes do not involve overt actions and do not interfere with other processing functions. "Actional" automatic processes can direct internal processes such as automatically attracting an attentional mechanism to a particular stimulus input, and also can direct overt responses without participation of the attentional mechanism at all. They suggested that this type of automaticity is demonstrated by visual search tasks in which a rapid response is required. Conscious awareness in their theory is a subprocess in the central attentional mechanism, so automatic processes that bypass this mechanism would be phenomenally unconscious. Shiffrin and Schneider (1977) explained that the elements in automatic processes are usually hidden from conscious perception.

Shiffrin and Schneider's theory of automatic target detection is based largely on research extending the Sternberg (1966) high speed visual memory search paradigm. This paradigm requires subjects to compare a set of stimuli held in memory with a test display and to indicate whether or not any of the test set stimuli match any stimuli in the memory set. The primary variable manipulated in the task is processing load, defined as the number of stimuli in the memory and test sets in an experimental trial. An important design factor in visual search tasks is the relationship between responses and targets or distractors. In the fixed set (Sternberg, 1966) or consistent mapping (Schneider & Shiffrin, 1977) condition, memory set stimuli which serve as targets in the test display are always associated with positive responses and never serve as distractors. With practice the subject is able to learn which stimuli always signal matches and which signal mismatches. Stimuli change roles across trials in varied mapping, sometimes serving as memory targets and sometimes as distractors, such that practice does not bring reduction of uncertainty across trials as to the role of a particular stimulus. Consistent mapping of stimuli to a particular category of response is considered essential for automatic processing to develop.

Shiffrin and Schneider stated that at the outset of practice a controlled mode of processing is required, in which test set items and memory set items are compared serially and which results in slower and less accurate performance as processing load increases. With extensive practice under consistent mapping conditions, an automatic mode of processing develops in which items are compared in parallel and which results in a flattening of performance curve slopes compared across increased levels of processing load. Flat slopes across increased memory and test set sizes have been used as an operational indicant of automatic processing in search tasks. This pattern of results implies no effects of increased processing load indicative of a relatively capacity free mode of processing (e.g., Neisser, 1964; Sternberg, 1969; Shiffrin & Schneider, 1977; Logan, 1978).

Schneider and Shiffrin (1977) reported experiments that investigated changes in visual memory search performance as a function of shorter exposure durations of the test display. In the same series of experiments, they also conducted a whole report study using visual search stimuli. These studies bear directly on the experiments reported in this paper. The first of their experiments tested accuracy performance in detecting consonant memory targets among digit distractors in a multiple frame task. Subjects searched a sequence of 20 frames or test displays with up to 4 stimuli on each frame for 1 or 4 consonants held in memory. Extensive practice was given under consistent and varied mapping conditions. In the consistent mapping condition, exposure durations of the test frame sequence were 120, 80 and 40 ms per frame. Overall error rates averaged about 25-35%, and seemed to increase 5-10% across processing load levels, at the 40 ms frame time. Schneider and Shiffrin (1977) attributed the loss in performance with shorter frame times to perceptual deficits.

Their whole report study was a single frame design in which subjects reported all stimuli in a test display. A test display size of 4 items was used, either 4 consonants or 4 digits. Frame times were 40, 80, 120 and 160 ms. Schneider and Shiffrin (1977) reported that all 4 consonants were named in correct reading order on 84% of the trials, and all 4 digits were named correctly on 92% of the trials, at the 80 ms test SOA. However, at the 40 ms frame time, whole reports were correct on 51% of the trials for consonants and 64% for digits. They also noted that performance decrements were due primarily to inability to report the last two reading order positions (lower positions). These results will later be compared to the results obtained in the experiments reported in this paper.

In addition to the issue of whether or not automatic target detection is a conscious process, the experiments reported in this paper also examined the generalizability of findings in visual memory search paradigms. Although inferences about central processing operations and automatic processes have been made on the basis of extensive research in search tasks using visual stimuli, the few reported results of auditory memory search tasks have been mixed. Poltrock, Lansman, and Hunt (1982) reported a version of the search task using auditory stimuli. Subjects listened for 1 or 3 target letters during successive test periods in which 2 letters were presented dichotically. Their results showed that subjects made fewer errors and responded faster in the consistent mapping condition compared to the varied mapping condition. Also, the effect of processing load (1 versus 3 memory items) decreased with practice only in the consistent mapping condition. Poltrock, et al., concluded that automatic target detection was developing after approximately 2500 trials of practice because the performance curve slope across processing load levels was flatter than at the beginning of practice.

Boyer and Charleston (1984) developed an auditory memory search task using simultaneously presented pure tones as stimuli that was a rather precise analogue to the single frame visual memory search tasks reported by Schneider and Shiffrin (1977, exp. 2). However, they did not obtain statistically flat performance curve slopes across processing load levels after 5000 trials of practice under consistent mapping conditions. Neither the Poltrock, et al. study, which employed spoken letters as stimuli, nor the Boyer and Charleston study, which employed pure tones as stimuli, utilized a categorical difference between targets and distractors. Schneider and Shiffrin (1977) reported that a categorical difference, such as letters for targets and digits for distractors, facilitated the development of automatic target detection in the visual memory search task.

Subjects received extensive practice in the present experiments using visual and auditory search tasks under conditions of consistent mapping and categorical differences between targets and distractors. In the visual tasks, targets were letters and distractors were numbers. In the auditory tasks, targets were pure tones of low pitch and distractors were pure tones of relatively higher pitch.

In Experiment 1, subjects received extensive practice in either visual or auditory memory search tasks (Target Detection) at various processing load levels to develop automatic target detection according to the flat performance curve slopes criterion. Subjects performed the same tasks in Experiment 2A, under conditions in which the test stimuli mask onset asynchrony (test SOA) was systematically reduced until target detection accuracy approached chance performance. In Experiment 2B, subjects were shown the same stimuli as in Experiments 1 and 2A at reduced test SOAs but were instructed to provide verbal reports for each trial (a) to indicate whether or not any stimuli had appeared in the test period (Stimulus Detection); and (b) if yes, to identify any of the stimuli (Stimulus Report). In Experiment 3, visual task subjects were presented multiple same targets in the test period of positive trials interspersed with the highly practiced single target condition to test for activation additivity in automatic target detection at reduced test SOAs.

If extensive practice in the search task develops an unconscious automatic mode of processing, it would be expected that target detection would still be performed at test SOAs in which verbal reports could no longer be given. Based on the theoretical positions of James (1890) and Titchener (1907), however, this result would not be expected.

Following the position that automatic detection is a conscious process, it was hypothesized that the test SOA at which target detection dropped to chance levels would not change with practice, and especially that stimulus detection could be performed accurately at test SOAs in which target detection could not be performed. In addition, it was hypothesized that presentation of the same target simultaneously in multiple test positions would improve target detection performance, indicating target activation additivity in automatic search. With respect to a comparison of the two modalities, no major differences in the pattern of results were expected; however, performance levels in the auditory task were expected to reflect greater difficulty compared to the visual task.

General Method

Design

Visual and auditory memory search tasks were used in a within subjects design. The following descriptions apply to both visual and auditory tasks unless otherwise stated.

An experimental trial consisted of (a) a 250 ms memory period in which 1, 2 or 4 memory stimuli appeared simultaneously; (b) a mask for 750 ms; (c) a test period of 250 ms in which 1, 2 or 4 test stimuli appeared simultaneously; and (d) a white noise mask for approximately 1.75 s. The ITI in which no stimuli were presented was 2 s in duration.

The independent variables were memory set and test set sizes, and positive or negative trials. Memory set size (*M*) and test set size (*T*) were varied at the following 5 levels: *M*=1, *T*=1, 2, 4; *M*=2, 4, *T*=1. Half of the trials were positive and half were negative within subblocks of 8 trials. On positive trials, one of the stimuli appearing in the memory period also appeared in the test period as a target match. On negative trials, only distractors appeared in the test period. Subjects indicated whether or not each trial contained a match.

A consistent mapping (Schneider & Shiffrin, 1977) procedure was used, in which memory stimuli never appeared as distractors. In the visual task, memory stimuli were letters and distractors were digits. In the auditory task, memory stimuli were low pure tones and distractors were relatively higher pure tones.

Three blocks of 64 trials per block were used for each of the five levels of *M* and *T*. Memory stimuli were block randomized to appear equally often within blocks of trials. Distractors were chosen at random without replacement for each trial. On positive trials, targets were block randomized to appear equally often in each of the test period positions within blocks.

Trial blocks were 5.5 minutes long and were separated by brief rest periods. Sessions lasted 1 hour and were usually given on consecutive weekdays.

Visual Stimuli

Letters, digits, random dot masks and pattern masks printed in black were used as visual stimuli. Memory stimuli were the upper case letters A, E, H and M. Distractors were the digits 0, 2, 3, 5 and 9. Letters and digits were in 12-pitch Prestige typeface, reduced 60% onto transparencies and slidemounted. An upper case letter or digit measured .5 cm wide x .7 cm high on the projection screen, subtending approximately .43 x .61 deg of visual angle. The test period stimulus field contained 4 positions in a square configuration with a focal dot in the center. The field measured 2 cm square and subtended less than 2 deg of visual angle, well within the foveal field of vision for the subject.

For T=1 or 2, random dot masks consisting of 10 dots, randomly placed in an area slightly larger than the letters or digits, filled all positions not occupied by either a target letter or a distractor. In the memory period, letters appeared on a single line in the center of the projected stimulus field. Pattern masks were constructed using letters and letter fragments from the same typeface, distributed at all angles over a 3.5 cm square area at approximately 40% density. The pattern masks subtended 3 deg of visual angle.

Luminance levels at the screen surface were measured using a GE 214 light meter with 10-15% accuracy variability. Memory and test displays measured approximately 70-75 lm. Pattern masks measured approximately 45 lm, less than memory and test period displays because of higher density of black print. The ambient luminance level without the projected slide displays was approximately 7 lm.

Auditory Stimuli

Auditory stimuli consisted of pure tones and white noise presented at relatively equal subjective loudness as reported by the subjects. Sound pressure of the auditory stimuli was measured using a Quest 215 sound level meter from a position approximately where the center of the subject's head was placed. Pure tones measured approximately 63 dB, within 5 dB of normative data (Fletcher & Munson, 1933) using the same equiloudness contour, thus confirming the subject's reports that the tones were equally loud. The white noise mask measured approximately 50 dB. Memory items were the tones 210 Hz, 260 Hz, 310 Hz and 360 Hz. Distractors were the higher frequency tones 590 Hz, 690 Hz, 830 Hz, 990 Hz and 1175 Hz. These frequencies were selected from the flattest region of an equiloudness contour reported by Norman and Lindsay (1977).

Tones were presented from four separate speakers positioned in a rectangular configuration. Tone position was block randomized with target tones appearing equally often from each position within blocks. White noise masks were presented from all four speakers.

Apparatus

The subject was seated in a comfortable chair inside a 1.11 m x 1.11 m x 2 m sound attenuation chamber, facing a small projection screen and 4 speakers. Two momentary push buttons were mounted 2.25 cm apart on the front end of the right armrest of the chair, and a gooseneck microphone stand and microphone were mounted on the back of the armrest. Visual task subjects gave manual responses and auditory task subjects gave vocal responses.

Visual stimuli were front projected, using a Gerbrands G-1177 3-field projection tachistoscope with timer, onto a white 5.5 cm square projection screen mounted over a small window cut into the chamber wall approximately

.65 m from the subject at eye level. According to specifications, the tachistoscope shutters had a rise time of 2 ms and a fall time of 2 ms or less. A Gerbrands G-1159 tachistoscope logic interface and a Gerbrands 300 6-T 6-channel digital millisecond timer activated a Lafayette 54030 digital stop clock. Manual responses made by the subject were measured with the stop clock and a Gerbrands G-1360 reaction time apparatus.

Auditory stimuli were generated and recorded onto separate channels of a Teac A-3440 simul-sync 4-channel tape recorder using a Lafayette 15010 tone generator, a B & K E-3108 sine/square wave generator, a Lafayette 1432 (15013) white noise simulator and two stereo cassette tape decks. The sequence and duration of taped stimuli were controlled using the 6-channel timer and logic interface.

Auditory stimuli were presented using the 4-channel tape recorder, two stereo amplifiers and four 20 cm speakers. The speaker cabinets were mounted in a .6 m high x .7 m wide rectangular configuration onto the inner wall of the chamber facing the subject and surrounding the projection screen. The subject sat approximately .5 m from the vertical plane of the speakers.

The auditory signal occurring at the onset of each trial triggered a sound-actuated relay connected to a Gerbrands G-1271 digital millisecond clock/counter. Vocal responses of the subject, given into a Shure 5755 omnidirectional microphone in front of the subject's lips, activated a Gerbrands G-1341 voice-operated relay that stopped the clock/counter.

Procedure

Subjects were instructed to indicate the presence or absence of any memory set stimuli in the test period on each trial. Visual task subjects pressed the rightmost button with the right hand middle finger to indicate a positive trial and pressed the other button with the right hand index finger to indicate a negative trial. Vocal responses of yes for positive trials and no for negative trials were required in the auditory task. Subjects were encouraged to respond accurately and quickly throughout the experiments. All subjects were tested individually. Prior to the first session subjects received 8 trials of practice. In addition, the first 2 trials of each sequence of trials given during the experiments were considered practice and were not included in the data analyses.

Subjects

Four male and four female undergraduates at the University of Oklahoma participated in the experiments for course credit. Two of each gender were given the visual task and the other four were given the auditory task. Visual task subjects reported normal vision and right-handedness. Auditory task subjects were pretested using a standard hearing test and scored within the normal range (20 dB HTL or below at all test frequencies). Subjects had preexperimental experience with reaction time tasks, but were naive to the purpose of the experiments.

Experiment 1

The purpose of Experiment 1 was to establish automatic detection of the presence or absence of target stimuli in visual and auditory memory search tasks according to the capacity effects criterion of flat performance curve slopes across levels of processing load (Neisser, 1964; Sternberg, 1966, 1969; Schneider & Shiffrin, 1977). The literature on visual memory search tasks indicates that automatic processing develops with extensive practice under fixed set conditions in which stimuli are consistently mapped to responses, and is facilitated by the use of a categorical difference between targets and distractors (e.g., Schneider & Shiffrin, 1977). Subjects were given extensive practice under these conditions to maximize the likelihood of developing automatic processing. A modality search task in which processing load is varied only in the test period, and a memory search task in which load varied only in the memory period, were used in Experiment 1.

Method

Visual subjects received 18 one-hour sessions in the visual memory search task and auditory subjects received 17 one-hour sessions in the auditory memory search task. During each session the subject received six blocks of trials. Blocks 1-5 in a session were the five levels of M and T; Block 6 was the same M and T level as Block 1. The three different versions at each M and T level were presented repeatedly, without replacement, across sessions. Each subject received at least 6500 trials of practice in his or her assigned task. Verbal feedback of "incorrect" or "wrong" was given for incorrect responses.

Results and Discussion

To evaluate the effect of extensive practice, MRT scores and percent errors at each set size (M and T values) for Sessions 1 and 18 were analyzed using repeated measures analyses of variance. (See Appendix A for ANOVA summary tables.) Scores from Block 1 and Block 6, which were at the same set sizes in each session, were averaged. In addition, RT scores exceeding four standard deviations of the noninclusive mean for a block were excluded from the analyses. RT scores for correct responses only were included in the analyses.

Visual Memory Search

MRT scores and percent errors are plotted as a function of Positive/Negative trials, Set Size, and Sessions 1 and 18 in Figure 1 for the averaged scores of the four visual memory search subjects (see Figure 1). Visual search and memory search scores are both presented. Data for the $M=1$, $T=1$ condition is presented twice, once for each task, for easier comparison across set sizes in the tasks. MRT scores are quite fast and show considerable improvement after practice, but there appears to be little change in error rates with practice.

Insert Figure 1 about here.

A 2x5x2 ANOVA of MRT scores for Positive/Negative trials, Set Size, and Session confirmed a significant difference between Sessions 1 and Session 18, $F(1,3)=16.59$, $p<.05$; subjects responded faster in Session 18. The Positive/Negative trials factor was also significant, $F(1,3)=9.90$, $p<.05$, confirming the typical finding in visual memory search of faster responses to positive trials (e.g., Schneider & Shiffrin, 1977). The Set Size factor was not significant, and there were no significant interactions.

The comparison of primary interest in Experiment 1 is the effect of set sizes after extensive practice. A 5x1 ANOVA of MRT scores comparing set sizes in Session 18 only was not significant $F(4,12)=1.44$. This result indicates no processing load effects across the set sizes tested after extensive practice in the visual memory search task, which fits the capacity criterion of flat curve slopes across processing load levels for inferring that an automatic mode of processing developed in the search task.

A 5x1 ANOVA of MRT scores from Session 1 was also conducted to compare the effect of set sizes at the beginning of practice. The Set Size Factor for Session 1 also was not significant, $F(4,12)= .34$. This interesting result indicating no effects of processing load at the beginning of practice will be discussed in the General Discussion.

Percent errors were also analyzed to evaluate practice effects. A 2x5x2 ANOVA of percent errors for Positive/Negative trials, Set Size, and Session resulted in a significant difference only between positive and negative trials, $\underline{F}(1,3)=21.13$, $\underline{p}<.05$. Mean percent error for negative trials was 2.68% compared to a mean percent error for positive trials of 5.65%. Also, percent errors for Session 18 were not significantly different than for Session 1, $\underline{F}(1,3)= .22$. The Set Size factor was not significant, and there were no significant interactions.

A 5x1 ANOVA comparing set sizes for Session 18 only resulted in a significant set size factor, $\underline{F}(4,12)=4.47$, $\underline{p}<.05$, which indicates an effect of processing load on accuracy performance. Overall accuracy was high, however, with percent errors varying only between 1% and 5.5% across set sizes.

A 5x1 ANOVA of percent errors across set sizes in Session 1 was also conducted to test for load effects at the beginning of practice. Interestingly, the Set Size factor in this analysis was not significant, $\underline{F}(4,12)= .91$. Both MRT and accuracy performance in Session 1 produced flat curve slopes across set sizes, indicating no effects of processing load. Although these results may be affected by high variability, especially at the beginning of practice, it suggests that a flat performance curve slope across load levels may not be a sufficient criterion for demonstrating the theoretical notion of automaticity. This issue will be considered further in the General Discussion.

Auditory Memory Search

Figure 2 is a graph of auditory memory search MRT scores and percent errors as a function of Positive/Negative trials, Set Size and Session using the averaged scores of the four auditory subjects in Experiment 1 (see Figure 2). As in the visual task, response time appears to improve, and accuracy does not appear to change, after extensive practice.

Insert Figure 2 about here.

Analyses similar to those used in the visual task were conducted on MRT and error rate scores for auditory memory search performance. A 2x5x2 ANOVA of MRT scores for Positive/Negative trials, Set Size and Session resulted in a significant difference only for the Set Size factor, $\underline{F}(4,12)=3.27$, $\underline{p}<.05$. The difference between Session 1 and Session 18 was in the right direction but was not significant, $\underline{F}(1,3)=5.69$; three of the subjects improved considerably, but one of the subjects showed no improvement. Significance at the .05 level was not obtained for the Positive/Negative trials factor, nor for any of the interactions. Figure 2 shows that there was a reversal of response times for Positive/Negative trials between auditory search and memory search (see Figure 2). In the memory search task, negative responses were faster than positive responses. Data on percent errors do not suggest that this change can be explained as a speed/accuracy tradeoff effect. There are no other data in the search literature with which this result can be compared. Strategies appear to change with the different types of auditory tasks. When one tone is compared to a set of tones briefly held in memory, it seems reasonable that the tone is slightly easier to identify as a mismatch than as a match. A consistent finding of this effect would indicate modality specificity in the memory search task.

A 5x1 ANOVA of MRT scores across set sizes for Session 18 only was not significant at the .05 level of significance, $\underline{F}(4,12)=2.66$. This result in the auditory memory search task after extensive practice meets the flat performance curve slope criterion for automatic processing.

However, a 5x1 ANOVA of MRT scores across set sizes for Session 1 only was also not significant, $F(4,12)=1.96$, under conditions of no previous practice in which automatic processing would not be expected to develop. Subject variability at the beginning of practice may partially account for this result. Figure 2 shows considerable differences in averaged MRT scores across set sizes in Session 1 for the auditory task subjects.

For accuracy performance, a 2x5x2 ANOVA of percent errors for Positive/Negative trials, Set Size, and Session resulted in a significant difference only for the Set Size factor, $F(4,12)=14.01$, $p<.001$. The difference between Session 1 and Session 18 was not significant, $F(1,3)=2.89$, indicating that subjects were as accurate at the beginning of practice as after extensive practice. The Positive/Negative factor and all the interactions were not significant.

A 5x1 ANOVA of Session 18 percent errors for Set Size was conducted to evaluate the effects of load after practice. The Set Size factor for this analysis was not significant, $F(4,12)=2.05$, which fits the capacity criterion for automatic processing. In addition, Session 1 error rates were analyzed to evaluate the effects of processing load at the beginning of practice. A 5x1 ANOVA of these scores comparing set sizes was significant, $F(4,12)=7.77$, $p<.01$, indicating processing load effects. Figure 2 shows that percent errors increased with increases in the memory load at the beginning of practice (see Figure 2).

Except for the differences in percent errors after practice in visual memory search performance, the findings from Experiment 1 support the conclusion that a purported automatic mode of processing developed in both the visual and auditory memory search tasks after 17-18 hours of practice. Subjects developed the ability to detect the presence or absence of target stimuli with little or no effect of the number of stimuli to be searched. These results provided the basis for examining other parameters of automatic search performance in Experiments 2-3.

Experiment 2A

The purpose of Experiment 2A was to examine changes in automatic target detection in visual and auditory search as a function of practice, under conditions in which the test stimuli mask onset asynchrony (test SOA) was systematically reduced. Using the same trial format and stimuli used in Experiment 1, the same subjects were presented blocks of trials at $\underline{M}=1$, $\underline{T}=1,2$, and 4, beginning with a test SOA of 50 ms, and then at shorter test SOAs until accuracy performance dropped to the chance level. A 250 ms test period was used during Experiment 1.

For visual subjects, one session of the search task at reduced test SOAs was given at the start of practice in Experiment 1, and one session was given after completion of Experiment 1. For auditory subjects, equipment difficulties prevented giving reduced test SOAs in the auditory task at the beginning of Experiment 1. Data for reduced test SOA performance in the auditory task were collected only after the completion of Experiment 1. In place of receiving the auditory task reduced test SOAs at the beginning of practice, auditory subjects were given one session of the visual search task at reduced test SOAs, to compare with performance by the visual subjects on the same visual task.

Based on pilot research, it was expected that accuracy performance at all set sizes would deteriorate to chance levels at about the 20 ms test SOA in the visual task. Further, it was expected that the test SOA at which performance dropped to chance levels would not change after extensive search task practice, supporting the notion that perceptual thresholds for target detection do not change with the development of a purported automatic mode of processing.

Method

All parameters in Experiment 2A, including the subjects, were the same as in Experiment 1, except for the following details.

Apparatus and Masking Stimuli

In the visual search task, the primary difference with Experiment 1 was the presentation of reduced test SOAs. Test SOAs were controlled using the Gerbrands 3-field tachistoscope and tachistoscope logic. Test stimuli were immediately followed by the pattern mask. Duration of a trial was shortened slightly, according to the reduced duration of the test SOA.

In order to control test SOAs in the auditory task, a fifth speaker was required from which the white noise mask was presented immediately following the test stimuli. The test tone signals sent from the 4-channel tape recorder to the speakers were temporarily disconnected using a contact closure controlled by the tachistoscope logic, which also activated a white noise mask generated by the white noise simulator. The white noise mask following the test period was approximately 65 dB as measured by the Quest sound level meter. As in the visual task, duration of an auditory trial was slightly shortened according to the test SOA.

Design and Procedure

Only the visual and auditory search stimuli at $\underline{M}=1$ and $\underline{T}=1,2,$ and 4 were used. The critical manipulation in Experiment 2A was variation of test stimuli mask onset asynchrony (test SOA). In the visual task, test SOAs of 50 ms, 30 ms, 20 ms and 10 ms were used for the first reduced test SOA session. In the second reduced test SOA session, a test SOA of 5 ms was also used. In the auditory task, test SOAs of 30 ms, 20 ms, 10 ms, 5 ms and 1 ms were used.

Two versions of each of the three set size blocks of 64 trials were presented, in the sequence of two blocks at T=1, then two blocks at T=2, and finally two blocks at T=4. The test SOAs were presented at each set size.

The first session of Experiment 2A was conducted the day after the beginning session of Experiment 1. For continuity with Experiment 1, this session will be called Session 2. In this session, both visual and auditory subjects received the visual search tasks at reduced test SOAs. The last session of Experiment 2A, which will be called Session 19, was conducted after the completion of Experiment 1. In this session, auditory subjects received the auditory search task at reduced test SOAs.

Subjects were instructed to respond passively, without trying to apply any particular strategies, and to guess if necessary. No feedback was given regarding correct or incorrect responses.

Results and Discussion

Repeated measures analyses of variance were applied to percent errors and MRT data in the same manner as in Experiment 1, with the addition of the test SOA variable. Percent errors was the dependent variable of interest. Scores were calculated using the combined average of positive and negative trials. The same procedure as in Experiment 1 was used to exclude extreme RT scores.

Visual Search

The first analysis of visual search performance at reduced test SOAs compared visual task subjects with subjects designated auditory task subjects in visual search at the beginning of practice in Experiment 1 (Session 2). A 4x3x2 ANOVA of percent errors for Test SOA, Set Size, and Group resulted in a significant difference only for the Test SOA factor, $\underline{F}(3,3)=86.82$, $\underline{p}<.001$. The Group factor was not significant, $\underline{F}(1,6)=1.81$; the Set Size factor also was not significant, $F(2,2)= .85$; and there were no significant interactions. Visual search performance at reduced test SOAs for subjects assigned to the visual task was not different than performance of subjects assigned to the auditory task. In addition, a 4x3x2 ANOVA of MRT scores for Test SOA, Set Size, and Group yielded no significant differences at the .05 level of significance. The visual and auditory subjects responded approximately equally fast on the visual search task. Also, there were no differences in response time as a function of test SOA, which suggests that subjects did not use strategies across test SOAs that differentially affected response time.

The issues of primary interest in the visual task for Experiment 2A are comparisons of accuracy performance at different SOAs, and a comparison of accuracy performance at the beginning of practice and after extensive practice, for the visual subjects. A 4x3x2 ANOVA of percent errors for Test SOA, Set Size, and Session resulted in a significant difference only for the Test SOA factor, $\underline{F}(3,9)=40.64$, $\underline{p}<.001$. Session 2 and Session 19 percent errors did not differ, $\underline{F}(1,3)= .06$. The Set Size factor was not significant, $\underline{F}(2,6)=2.55$, nor were any of the interactions. A 4x3x2 ANOVA of MRT scores with the same factors resulted in a significant difference only for Session factor, $\underline{F}(1,3)=10.56$, $\underline{p}<.05$; Session 19 responses were faster. No other factors or interactions were significant.

Figure 3 shows percent correct scores for Session 19 plotted as a function of Test SOA in the visual search task (see Figure 3, solid circles). Percent correct at the 50 ms test SOA averaged 85%. This average performance is considerably lower than the 97% average for this task in Experiment 1 with a 250 ms test

SOA. Performance at shorter test SOAs dropped rapidly, leveling off near the chance levels at 20, 10 and 5 ms.

Insert Figure 3 about here.

For Session 19 only, a 4x3 ANOVA of percent errors for Test SOA and Set Size yielded a significant result only for the Test SOA factor, $\underline{F}(3,9)=19.23$, $\underline{p}<.001$. The Set Size factor was not significant, $\underline{F}(2,6)=2.76$; nor was the interaction at the .05 level of significance, $\underline{F}(6,18)=2.39$. In addition, a 4x3 ANOVA was conducted on MRT scores for Test SOA and Set Size. All ccmparisons in this analysis were not significant at the .05 level of significance.

The conclusions supported by the results of the visual search task at reduced test SOAs in Experiment 2A are that accuracy performance significantly changes as test SOA changes, and that accuracy performance at reduced test SOAs does not improve with the development of automaticity in the visual search tasks.

Auditory Search

Included in Figure 4 are average percent correct scores plotted as a function of Test SOA for the auditory search task in Experiment 2A (see Figure 4). Performance shows no deterioration at test SOAs of 50, 30 and 10 ms. Percent errors at these test exposure durations averaged 5%, relatively comparable to the 2% average across set sizes and subjects for the same task in Experiment 1 at a 250 ms test SOA. At the 5 ms test SOA subjects averaged 9% errors, and were still relatively accurate with an average of 19% errors at a test SOA of only 1 ms. These results are not surprising in view of the general auditory literature which attests to the high sensitivity of auditory processes.

Insert Figure 4 about here.

A 5x3 ANOVA for Test SOA and Set Size was conducted on percent errors for Session 19 of the auditory search task. The only significant difference in this analysis was the Test SOA factor, $F(4,12)=9.95$, $p<.005$. The Set Size factor was not significant, $F(2,6)=3.10$; and the interaction also was not significant. The same analysis conducted on MRT scores resulted in significant differences for the Test SOA factor, $F(4,12)=4.93$, $p<.05$, and for the Set Size factor, $F(2,6)=15.13$, $p<.01$. RT was slower at shorter SOAs and at increased test set sizes. The interaction, however, was not significant, $F(8,24)= .98$.

These results for both percent errors and MRT follow a pattern similar to the visual search task results for performance after extensive practice. However, auditory task accuracy is higher at shorter test SOAs than visual task accuracy. Whereas accuracy approached the chance level of 50% errors at the test SOA of 20 ms in the visual task, it averaged 80% at the test SOA of 1 ms in the auditory task. At this test SOA, subjects heard only a brief click; but the pitch variations of the click,.produced by the low and high tones in positive and negative trials, were frequently discriminable.

Experiment 2B

In Experiment 2B, the same subjects from the previous experiments were given stimulus detection and report tasks at reduced test SOAs using the same stimuli and trial format as in Experiment 2A. Subjects were asked to make judgments of the presence or absence of <u>any</u> stimulus in the test period, and to provide a report of the test stimuli when a positive response was given. Data from these tasks were compared to the data from the target detection search tasks at reduced test SOAs of Experiment 2A.

It was expected that accuracy performance for detection of the presence or absence of any stimulus in the test period would remain significantly above the chance level at shorter test SOAs than target detection performance in Experiment 2A. This finding would support the notion that automatic target detection in a search task requires cognitive processes in addition to those required for simple stimulus presence or absence detection. It was also expected that subjects would be able to name accurately test stimuli at test SOAs in which they cannot perform the target detection task accurately. This finding would suggest clear differences between automatic identification of a test stimulus—such as a letter, digit, high or low tone—and automatic target detection.

Method

Experiment 2B was the same as Experiment 2A, except for the replacement of the target detection tasks with the stimulus detection and report tasks and for other details explained below.

Design and Procedure

Subjects were asked to provide verbal reports for each trial (a) to indicate whether or not any stimuli appeared in the test period; and (b) if yes, to identify any of the test stimuli. Visual subjects named the letters or digits. Auditory subjects reported whether the test stimuli were all high tones or contained a low tone.

The same trial blocks were used as in Experiment 2A, but in 50% of the trials the test period was blank. Blank trials were interspersed among regular trials using a block randomization procedure with equal blank and nonblank trials in subblocks of 16 trials. In the visual task, a blank slide was presented. Blank trials in the auditory task were brief silent periods with no auditory signals. Test SOAs of 50, 30, 20, and 10 ms were used in the visual task. Only the test SOAs of 5 and 1 ms were used in the auditory task.

Subjects were able to provide verbal responses to both questions within the regular interval between the test period and the beginning of the next trial. Experiment 2B was conducted in a single one-hour session the day following the completion of Experiment 2A (Session 20). Subjects were encouraged to respond accurately. If a response to the stimulus detection task was positive on a particular trial but the test stimuli could not be named, the subject was instructed to report, "I don't know."

Results and Discussion

Repeated measures analyses of variance were applied to the combined average percent errors of positive, negative and blank trials at each test SOA and Set Size condition.

Visual Stimulus Detection

Figure 3 presents percent correct scores for the stimulus detection task (Session 20) along with the target detection task (Session 19) percent correct scores, plotted as a function of Test SOA in the visual task (see Figure 3). Stimulus detection scores are consistently higher than target detection scores, but drop rapidly toward chance performance of 50% correct at the 10 ms test SOA. A 4x3x2 ANOVA of percent errors for Test SOA (50, 30, 20 and 10 ms), Set Size, and Task resulted in several significant differences. The Task factor, comparing target detection and stimulus detection, was significant, $F(1,3)=20.38$, $p<.05$. The Test SOA factor was significant, $F(3,9)=29.48$, $p<.001$; and the Test SOA x Task interaction was also significant, $F(3,9)=9.50$, $p<.005$. Accuracy scores converged toward the chance level of 50% errors at the 10 ms test SOA. The Set Size factor was not significant, nor were any other interactions, at the .05 level of significance.

Tests of significance were also performed comparing percent errors to the chance level of performance in both tasks and at each test SOA. A 4x3x2 ANOVA of percent errors for Test SOA, Set Size, and Session 19 (the target detection task) versus chance (50% error rate) was conducted. Significant differences resulted for Test SOA, $F(3,6)=28.20$, $p<.001$; for the difference of Session 19 scores and chance, $F(1,2)=84.35$, $p<.001$; and for the Test SOA x Session 19 versus chance interaction, $F(3,6)=28.20$, $p<.001$. The Set Size factor was not significant, $F(2,9)=1.16$, and no other interactions were significant. 3x2 ANOVAs for Set Size and Session 19 versus chance scores were conducted for each Test SOA condition. For the 50 ms test SOA in Session 19, performance was significantly different from chance, $F(1,3)=128.29$, $p<.005$; Set Size was also significant, $F(2,6)=5.89$, $p<.05$; and the interaction was significant, $F(2,6)=5.89$, p .05. For the 30 ms test SOA, only the difference between Session 19 and chance was significant, $F(1,3)=14.41$, $p<.05$. However, Session 19 performance did not differ from chance at the 20 ms test SOA, $F(1,3)=3.16$, nor at the 10 ms test SOA, $F(1,3)=.91$. The Set Size factors and interactions in both of these analyses were not significant.

The equivalent 4x3x2 ANOVA comparing Session 20 stimulus detection to chance resulted in the same overall pattern of results: Test SOA was significant, $F(3,9)=30.63$, $p<.001$; the difference between Session 20 scores and chance was significant, $F(1,3)=391.64$, $p<.001$; and the Test SOA x Session 20 versus chance interaction was also significant, $F(3,9)=30.63$, $p<.001$. The Set Size factor and all other interactions were not significant.

4x3 ANOVAs of Session 20 percent errors versus chance at each test SOA obtained the following results: At 50 ms, only the difference of Session 20 and chance was significant, $\underline{F}(1,3)=18{,}563.43$, $\underline{p}<.001$; at 30 ms, again only the difference of Session 20 and chance was significant, $\underline{F}(1,3)=14{,}406.00$, $\underline{p}<.001$; at 20 ms, Session 20 and chance significantly differed, $\underline{F}(1,3)=732.84$, $\underline{p}<.001$; but at the 10 ms test SOA, Session 20 scores were not significantly different than chance, $\underline{F}(1,3)=2.38$. None of the Set Size factors and interactions were significant in any of these analyses.

The interesting difference in these results is that at the 20 ms test SOA subjects were able to perform stimulus detection significantly above the chance level but were unable to perform target detection significantly above the chance level. Performance at the 10 ms test SOA was not different than the chance level in either task, and both tasks could be performed above the chance level at 30 and 50 ms test SOAs. These results suggest that additional cognitive processes are required in order to detect the presence or absence of target stimuli compared to the processes required to detect the presence or absence of any test stimuli.

Visual Report

In order to compare Session 20 report performance to Session 19 target detection performance, the following criteria were established to classify Session 20 reports as correct responses or errors: (a) Responses in which at least one letter or digit was correctly named and in which there were no incorrect attempts were classified as correct; (b) Responses which contained any incorrect reports, regardless of other correct information on that trial's response, were classified as errors; (c) Responses in which the subject was unable to report any information, and thus responded "I don't know," were classified as errors. These criteria applied only to trials in which the subject correctly reported the presence of test stimuli. Misses when test stimuli were present and blank trials were not included in the calculation of report task percent error performance.

Figure 3 presents averaged percent errors for the report data of Session 20 according to the specified accuracy criteria, plotted as a function of the 50, 30, and 20 ms test SOAs. Data for the 10 ms test SOA is not included because subjects made no attempts to name the test stimuli in that condition; all responses were I don't know whenever the subject responded yes on the stimulus present or absent judgment.

A 3x3x2 ANOVA of percent errors for Test SOA, Set Size, and Session 19 target detection scores versus Session 20 report scores calculated by applying the accuracy criteria resulted in significant differences for the Test SOA factor, $F(2,6)=25.65$, $p<.005$, and for the Test SOA x Set Size interaction, $F(4,12)=3.75$, $p<.05$. The difference between percent errors for target detection in Session 19 and for report in Session 20 was not significant, $F(1,3)= .48$. The Set Size factor and the other interactions also were not significant. These results suggest that subjects can give accurate verbal reports about at least one of the test stimuli whenever they can perform the target detection task above chance levels. However, these results do not show that target detection is more difficult than reporting at least one of the test stimuli. In this sense, target detection and verbal report are not clearly distinguished. Rather, the results suggest that the tasks may be about equally difficult.

In addition, a count was taken at the $M=1$, $T=2$ and 4 conditions of cases in which only one stimulus was reported. Subjects reported a distractor in 52% of these cases, suggesting that target stimuli may not be any more likely than distractors to be perceived at test SOAs that allow for the naming of only one stimulus. At $\underline{T}$=2 only, targets were reported on 62% of these trials.

Auditory Stimulus Detection

Auditory task percent correct responses for Session 20 stimulus detection and Session 19 target detection are plotted as a function of test SOAs in Figure 4. Percent error data for Session 20 auditory stimulus detection were calculated using the same methods described for the visual task data. Accuracy was quite high in both tasks, but appears to be better in the stimulus detection task.

A 2x3x2 ANOVA of percent errors for Test SOA, Set Size, and Session 19 target detection versus Session 20 stimulus detection confirmed a significant difference between the two tasks, $\underline{F}(1,3)=26.26$, $\underline{p}<.05$. The other factors and all of the interactions in this analysis were not significant. Subjects performed significantly better in the stimulus detection task.

Since responses in both tasks were given vocally, reaction time differences between the tasks could also be compared. A 2x3x2 ANOVA conducted on MRT scores resulted in a significant difference only for the task comparison, $\underline{F}(1,3)=13.31$, $\underline{p}<.05$. Subjects consistently responded faster in the stimulus detection task, again suggesting that this task was easier than the target detection task.

Analyses were also conducted to compare accuracy performance versus the chance level performance of 50% errors for both tasks at the 1 ms test SOA. A 3x2 ANOVA of percent errors for Set Size and Session 19 target detection to chance yielded a significant difference only for the target detection versus chance comparison, $\underline{F}(1,3)=165.59$, $\underline{p}<.001$. The same result was obtained comparing Session 20 stimulus detection to chance, $\underline{F}(1,3)=2780.45$, $\underline{p}<.001$.

Auditory Report

The accuracy criteria for classification of correct responses and errors in the auditory report task in Session 20 were as follows: (a) Subjects were correct if they responded "high" on positive trials or "low" on negative trials; (b) Opposite responses to the trial types were considered errors; and (c) I don't know responses were also considered errors.

Figure 4 presents percent correct responses, calculated using the accuracy criteria, in the Session 20 report task, plotted as a function of test SOA. As the graph indicates, report scores appear to be lower than target detection scores. (See Figure 4.) Approximately 50% of the report errors were attributable to I don't know responses, which suggests a criterion bias with some of the subjects. One of the subjects made no I don't know responses, but gave very accurate responses on the report task.

A 2x3x2 ANOVA of percent errors for Test SOA, Set Size and the Session 19 target detection task versus the Session 20 report task resulted, however, in no significant difference between tasks, $F(1,3)=3.84$. No other factors and no interactions were significant at the .05 level of significance. Auditory subjects were able to report whether a test array contained a low tone or all high tones about as accurately as they were able to perform target detection at reduced test SOAs.

Experiment 3

Experiment 3 used the visual target detection task at reduced test SOAs with the addition that the number of targets on positive trials was manipulated. In the multiple test set size conditions of $M=1$, $T=2$ and 4, the regular search task positive trial in which a single target appeared along with one or more distractors was compared to a condition in which the same target appeared in all of the set size positions. A finding of better performance in the all targets condition would suggest that activation of target detection processes is aided by the presence of multiple targets.

Method

Experiment 3 was the same as Experiments 1 and 2A except for the addition of the all targets condition and for other details explained below.

Design and Procedure

The same visual subjects from the previous experiments were given blocks of trials at M=1, T=2 and 4 for each of the test SOAs of 30, 20, and 10 ms. Half of the positive trials in a block contained the target letter in all of the relevant positions for that test set size. All Targets positive trials were randomly interspersed with regular positive and negative trials in subblocks of 16 trials.

Subjects were informed that in some of the positive trials the same target letter might appear in more than one test display position. They were also instructed to respond accurately and quickly throughout the study. Experiment 3 was conducted in a single one-hour session (Session 21) the day following completion of Experiment 2B. No feedback was given regarding correct or incorrect responses.

Results and Discussion

Data for Experiment 3 are shown in Figure 5 (see Figure 5). Percent errors and MRT scores for the two positive trial conditions only are plotted as a function of Test SOA for the visual subjects. Accuracy in the All Targets condition appears to be better than in the regular positive trial condition except at the 10 ms test SOA. Because scores for both conditions were at the chance level of performance at the 10 ms test SOAs (50% errors), an analysis was conducted comparing performance only at the 30 and 20 ms test SOAs. A 2x2x2 ANOVA of percent errors for the two positive trial conditions, Test SOA, and Set Size resulted in a significant difference between the positive trial conditions, $F(1,3)=11.03$, $p<.05$. The Set Size factor was not significant, $F(1,3)=5.20$, nor were the interactions and Test SOA factor. The same analysis of MRT scores yielded no significant factors or interactions.

Insert Figure 5 about here.

The significant improvement in accuracy performance in the all targets condition suggests that activation of the target match response is aided by the presence of multiple targets in the test display.

General Discussion

The results of these experiments are interpreted as strongly suggesting that automatic target detection in visual and auditory search tasks is a conscious attentional process. Further, the results suggest that automatic target detection requires cognitive resources in addition to those required for stimulus detection, resources usually identified with conscious central processing functions. The primary basis for this interpretation is the finding that stimulus detection was performed significantly better than target detection at reduced test SOAs. At the 20 ms test SOA, visual task subjects were unable to perform target detection but performed stimulus detection accurately. Whenever subjects performed target detection above chance accuracy, they also were able to name at least one of the test stimuli, without any misnamings on that trial and with the option of reporting that they did not know what any of the stimuli were. This result suggests that the conscious report task and target detection are similar.

The conclusion that automatic target detection is a conscious process assumes that accurate verbal report is sufficient for inferring that a particular cognitive process is conscious. Inability to provide accurate verbal reports has been challenged as a sufficient basis for inferring that a process is unconscious (James, 1890; Boyer, 1984). There is less concern, however, as to whether accurate verbal report alone indicates that a cognitive process is conscious. Nisbett and Wilson (1977) have cautioned that verbal reports of an event should be more accurate than informed speculations of the event based on predictions from similar past experiences. Randomization sequences eliminated this possible confound in the present experiments.

Comparing RT performance in Figures 1 and 2, it appears that RT scores in auditory tasks may have been slower than in visual tasks, which indicates that the auditory tasks were more difficult. The overall pattern of results was similar for the two modalities, however, suggesting that the results of search tasks can be generalized across modalities. The important exceptions were the differences in MRT scores for positive and negative trials between auditory search and memory search, and the ability of auditory subjects to perform the detection and report tasks at very brief test SOAs. These suggest important perceptual and strategic differences that require further investigation.

Visual subjects in the present experiments performed target detection in a single frame task. Errors averaged 13% at the 50 ms test SOA and 23% at the 30 ms test SOA. Errors in the multiple frame task with a 40 ms frame time in Schneider and Shiffrin's (1977) Experiment 2 averaged approximately 25-35%. These two results are reasonably consistent because the multiple frame task might be expected to be a little more difficult. The masks seemed to have little effect at these test SOAs, however, so differences in the masks between the two experiments would not be of concern.

A question may arise, however, about the effectiveness of the masks in the present experiments at test SOAs below 30 ms. Marcel's (1978, 1983) evidence for unconscious processing was obtained only with pattern masking. In his experiments, unconscious semantic activation did not occur when an energy mask was used. Can the failure to obtain results comparable to Marcel's be due to improper pattern masking? The result that target detection performance dropped to the chance level before stimulus detection performance makes this explanation highly improbable. If the masks were energy masks which prevent both conscious attentional processing and unconscious perceptual processing (Marcel, 1983), then either both should drop to the chance level at the same test SOA, or stimulus detection should drop to the chance level first. Neither energy masks nor pattern masks can account for the present results; even if the masks were completely ineffective, the conclusions would remain valid.

Shiffrin and Schneider (1977) proposed that automatic target detection involves the development of an automatic attention-getting response. According to this hypothesis, the presence of a target stimulus triggers an actional automatic response that attracts the central attentional mechanism. In the case of speeded reaction time search tasks, the appropriate response sequence is activated which bypasses the central attentional mechanism altogether. The results reported here are not in support of the interpretation that a purported central attentional mechanism which contains conscious processes is bypassed in automatic target detection.

An automatic attention-getting response might be expected to involve increased perceptual sensitivity to target stimuli. In the case where subjects were able to report only one of the test stimuli, however, there did not seem to be any more ability to report target letters than to report distractor digits. Target letters were reported in 52% of the cases. Two factors may have prevented results that support the automatic attention-getting response hypothesis. First, test periods in the $\underline{T}=4$ condition of the visual stimulus detection task (Experiment 2B) contained three distractor digits and one target letter, which might have biased against the reporting of target letters. In the $\underline{T}=2$ condition in which one target letter and one digit distractor appeared on positive trials, the target letter was reported on 62% of the trials. Second, in Schneider and Shiffrin's (1977) whole report study, subjects reported digits more accurately than letters at shorter exposure durations. In addition, it is not necessarily the case that a learned perceptual sensitivity to targets would differentially affect verbal reports at very short exposure durations in which perceptual deficits appear. Evidence against the hypothesis that an association is learned between target stimuli and positive responses was reported by Kristofferson (1977). She gave subjects extensive practice in a visual memory search task and then replaced the target letters with other letters, without a significant loss in search task performance. This important issue will require extensive additional research. (See Appendix B for a related study.)

The results of Experiment 3 contrast with the results obtained in one of Marcel's (1983) unconscious priming studies. Recall that he presented repeatedly the same words to subjects, pattern masked to prevent conscious awareness. On a subsequent lexical decision task, increased facilitation was obtained with repetitions of the words; however, subjects remained unable to identify the words by verbal report. Marcel (1983) concluded that activation of semantic lexicon entries for the words was additive with repeated presentations, but conscious awareness of the words was not subject to additive activation. Experiment 3 attempted to explore this issue in the single frame search task paradigm. The repeated presentation manipulation in this task was the simultaneous appearance of the same target letter in all valid positions of the test period on positive trials. Subjects detected targets more accurately when the same target letter appeared in all the test positions compared to the highly practiced single target condition, suggesting activation additivity for target detection. Accuracy remained close to the chance level in the single target condition at the 20 ms test SOA, similar to results in Experiment 2A. However, accuracy approached 80% correct target detections at the 20 ms test SOA in the multiple same target condition. This result suggests that multiple same targets allowed the target detection task to be performed at the 20 ms test SOA. If target detection is an unconscious process, then this result would corroborate Marcel's finding. If target detection is a conscious process, however, then it suggests that conscious processes may also be subject to some type of activation additivity. The finding of a 25-30% improvement in accuracy for the multiple target condition over the single target condition at the 30 ms test SOA in this experiment supports the conclusion that it was a conscious process which showed an activation additivity effect.

Another interesting result, obtained for both the visual and auditory tasks in Experiment 1, was that MRT scores were statistically flat across processing load levels at the beginning of practice. This result may have been partially due to an initial practice effect. All subjects received the smaller set size conditions first in Session 1, beginning with the $\underline{M}=1$, $\underline{T}=1$ condition. This probably does not entirely account for the result, however, inasmuch as similar findings of flat performance curve slopes at the beginning of practice have been reported by Boyer and Charleston (1984) in an auditory memory search task, and by Donderi and Zelnicker (1969) and Brown (1983), in visual search tasks. An important factor in obtaining these results was the categorical difference between targets and distractors used in all of these studies. When search tasks are designed such that targets are easily discriminable from distractors, they can be performed equally fast across small differences in set sizes without practice. The flat performance curve slopes capacity criterion for automatic processing can be satisfied even when automatic target detection could not have developed due to insufficient practice. This clearly points to the inadequacy of the flat performance curve slope criterion. The criterion should at least require that the task be difficult enough that flat slopes are not obtained at the beginning of practice. The more rigid capacity criterion of no interference effects in dual task performance may be more appropriate.

Logan (1978) has commented that very few search tasks actually obtain completely flat performance curve slopes across processing load levels; and even from this liberal criterion, automatic processing is rare. In the visual tasks in Experiment 1, flat slopes were not obtained for percent errors. Small differences across set sizes were significant even after 18 hours of practice. Overall accuracy performance, however, was quite high at relatively short response latencies. Several proponents of automatic processing have recently noted that small processing load effects are apparent in some purportedly automatic tasks (Posner, 1982; Shiffrin, Dumais & Schneider, 1981; LaBerge, 1981).

The findings of the studies reported here, based on the reportability criterion, add to the growing cognitive literature that does not support a strong distinction between automatic processes that are unconscious, nonattentional, unintentional and capacity unlimited; and controlled processes with the opposite characteristics (Boyer, 1984). Although there may be learned automatic processes appropriately identified by these descriptors, the most likely candidate of which is perceptual encoding processes, many purported automatic tasks vary only in the degree to which capacity limited, attentional processes are involved (Titchener, 1907; Hasher & Zacks, 1979; Eysenck, 1982; Boyer & Charleston, 1984). The human information processing system may well be equipped to develop programs for repetitive tasks that make efficient use of mental resources. But this capability does not necessarily imply that entirely separate mechanisms carry out unpracticed tasks and practiced tasks. Conscious processes may even be essential in practiced tasks, providing a unified basis for task components and allowing highly skilled performance.

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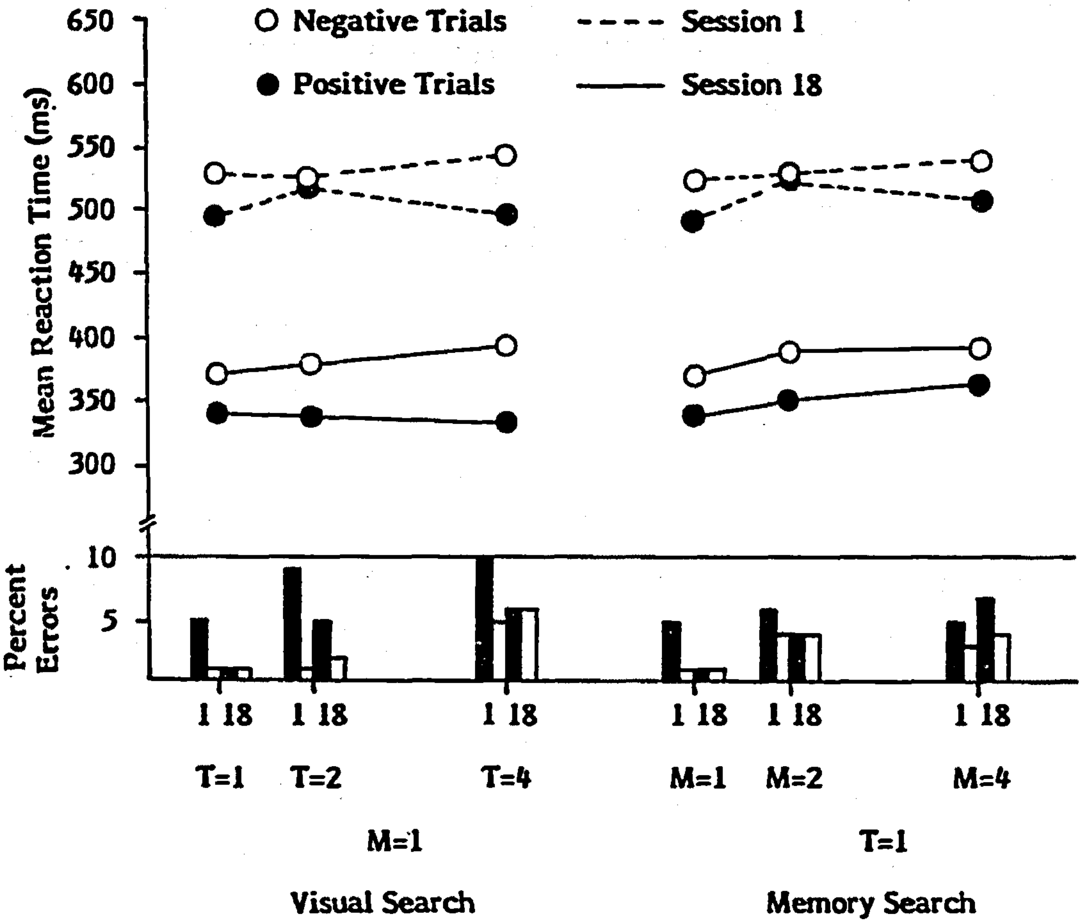
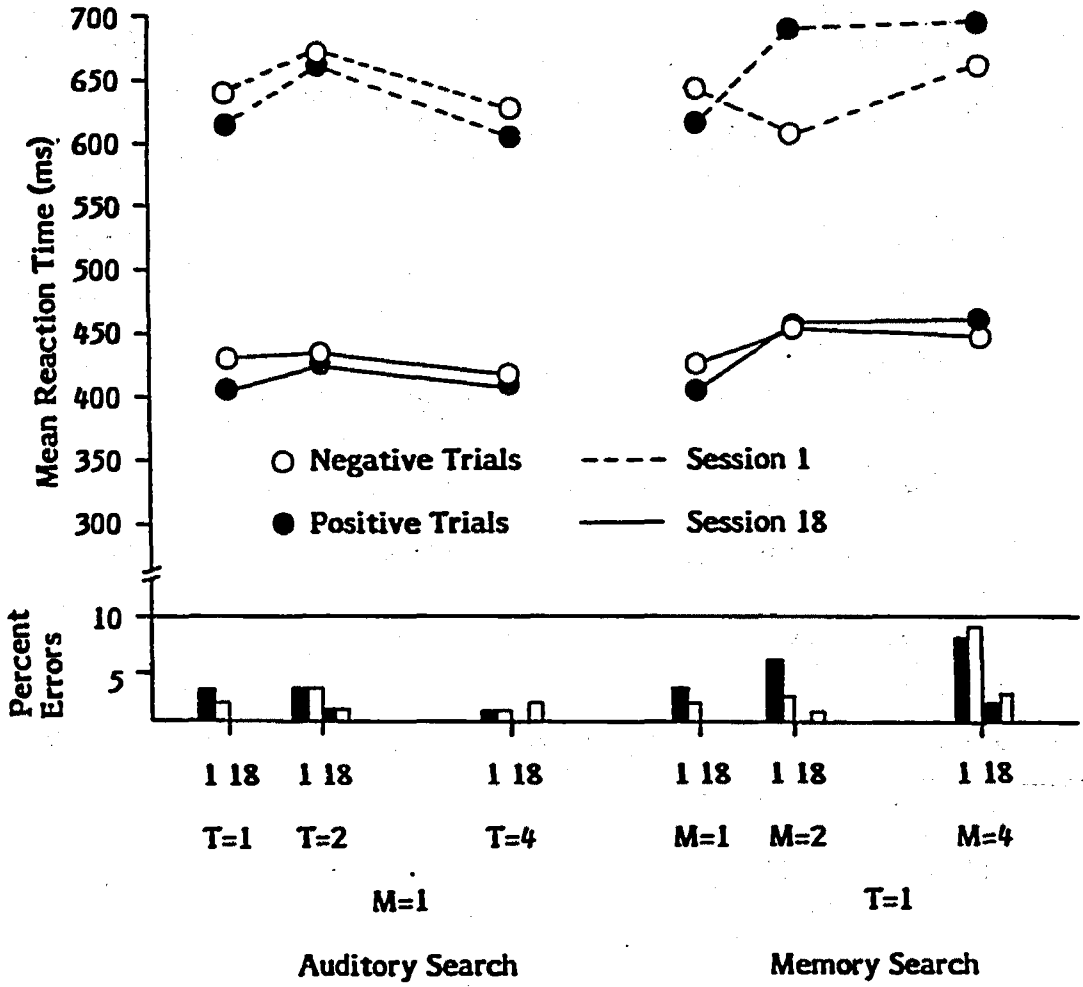
Figure 1. Percent Errors and MRT scores are plotted as a function of Positive/Negative trials, Set Size, and Session for Auditory Search and Memory Search in Experiment 1.



650
600
550
500
450
400
350
300
Mean Reaction Time (ms)
Negative Trials
Positive Trials
Session 1
Session 18
10
5
Percent Errors
1 18
1 18
1 18
1 18
1 18
1 18
T=1
T=2
T=4
M=1
M=2
M=4
M=1
T=1
Visual Search
Memory Search

Figure 2. Percent errors and MRT scores are plotted as a function of Positive/Negative Trials, Set Size, and Session for Visual Search and Memory Search in Experiment 1.



700
650
600
550
500
450
400
350
300
Mean Reaction Time (ms)
Negative Trials
Positive Trials
Session 1
Session 18
10
5
Percent Errors
1 18
1 18
1 18
1 18
1 18
1 18
T=1
T=2
T=4
M=1
M=2
M=4
M=1
T=1
Auditory Search
Memory Search

Figure 3. Percent Correct scores are plotted as a function of Test SOA for Stimulus Detection, Stimulus Report, and Target Detection in the visual tasks of Experiments 2A and 2B.

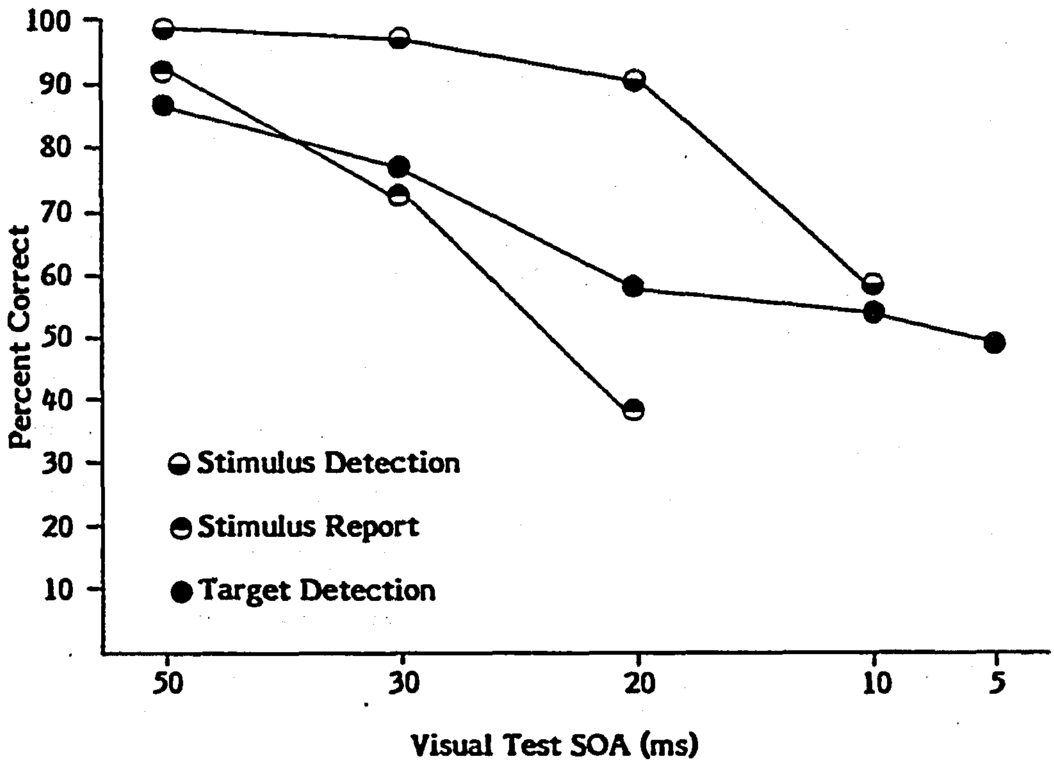
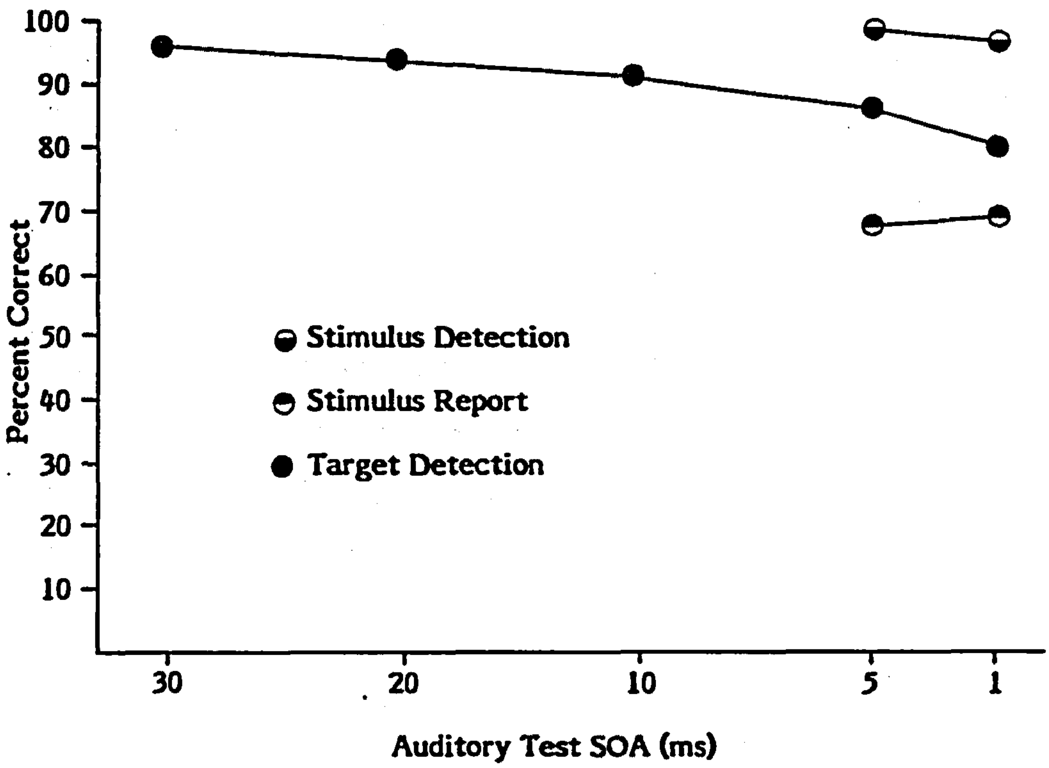
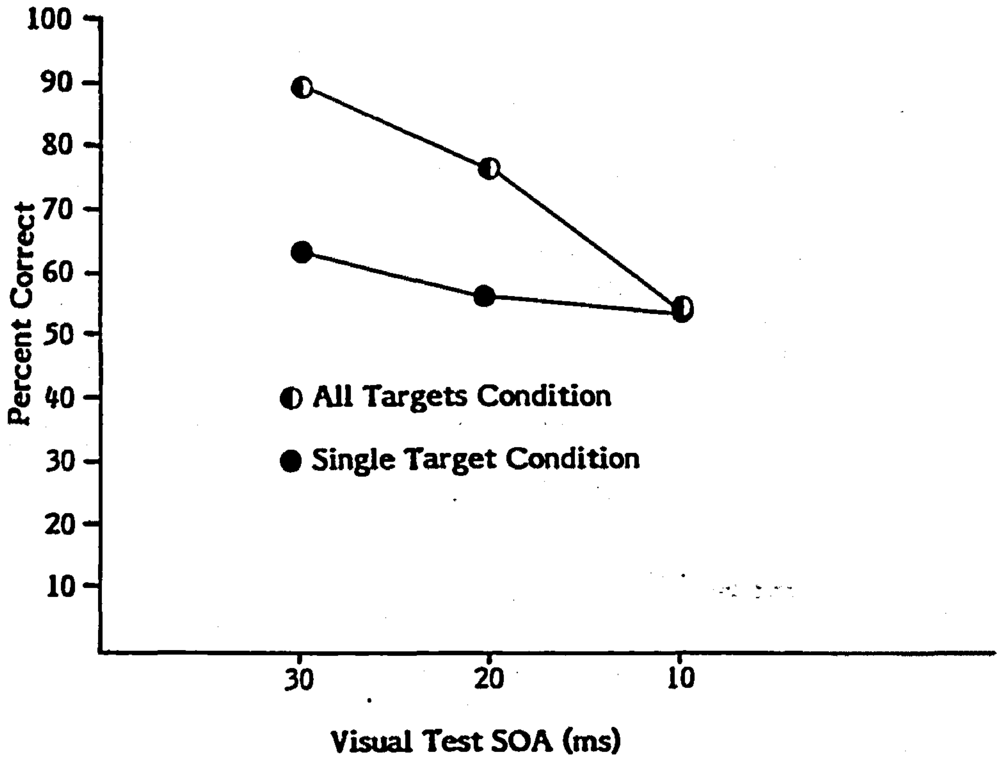

100
90
80
70
60
50
40
30
20
10
Percent Correct
Stimulus Detection
Stimulus Report
Target Detection
50
30
20
10
5
Visual Test SOA (ms)

Figure 4. Percent Correct scores are plotted as a function of Test SOA for Stimulus Detection, Stimulus Report, and Target Detection in the auditory tasks of Experiments 2A and 2B.



100
90
80
70
60
50
40
30
20
10
Percent Correct
Stimulus Detection
Stimulus Report
Target Detection
30
20
10
5
1
Auditory Test SOA (ms)

Figure 5. Percent Correct scores are plotted as a function of the All Targets and Single Targets Conditions and Visual Test SOA for positive trials only in Experiment 3.


100
90
80
70
60
50
40
30
20
10
Percent Correct
All Targets Condition
Single Target Condition
30
20
10
Visual Test SOA (ms)

Appendix A

ANOVA Summary Tables

Experiment 1

2x5x2 ANOVA of Percent Errors for Positive/Negative Trials, Set Size and Session (1 vs 18) in the Visual Memory Search Task

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	214436.88	71478.94	
Pos/Neg	1	16502.51	16502.51	9.90*
Sbj x Pos/Neg	3	5002.05	1667.35	
Set Size	4	3664.30	916.08	0.44
Sbj x Set Size	12	25098.51	2091.54	
Sess	1	496282.50	496282.50	16.59*
Sbj x Sess	3	89766.69	29922.23	
Pos/Neg x Set Size	4	3505.30	876.32	1.28
Sbj x Pos/Neg x Sess	12	8216.89	684.74	
Pos/Neg x Sess	1	725.94	725.94	1.27
Sbj x Pos/Neg x Sess	3	1721.13	573.71	
Set Size x Sess	4	810.75	202.69	0.14
Sbj x Set Size x Sess	12	17021.75	1418.48	
Pos/Neg x Set Size x Sess	4	1939.33	484.83	0.75
Sbj x Pos/Neg x Set Size x Sess	12	7748.30	645.69	
Correction Factor		15727398.01		

*Denotes a significant result at the .05 level of significance

5x1 ANOVA of MRT Scores for Set Size in Session 18
in the Visual Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	16602.95	5534.32	
Set Size	4	1506.70	376.67	1.44
Sbj x Set Size	12	3139.30	261.61	
Correction Factor		2656476.05		

5x1 ANOVA of MRT Scores for Set Size in Session 1
of the Visual Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	160490.50	53496.83	
Set Size	4	3677.70	919.42	0.34
Sbj x Set Size	12	32314.73	2692.89	
Correction Factor		5545098.05		

2x5x2 ANOVA of Percent Errors for Pos/Neg Trials, Set Size and Session (1 vs 18) in the Visual Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	493.64	164.55	
Pos/Neg	1	177.01	177.01	21.13*
Sbj x Pos/Neg	3	25.14	8.38	
Set Size	4	159.45	39.86	1.91
Sbj x Set Size	12	251.05	20.92	
Sess	1	12.01	12.01	0.22
Sbj x Sess	3	163.74	54.58	
Pos/Neg x Set Size	4	27.05	6.76	0.80
Sbj x Pos/Neg x Set Size	12	102.05	8.50	
Pos/Neg x Sess	1	46.51	46.51	3.63
Sbj x Pos/Neg x Sess	3	38.44	12.81	
Set Size x Sess	4	30.55	7.64	0.73
Sbj x Set Size x Sess	12	125.95	10.50	
Pos/Neg x Set Size x Sess	4	33.05	8.26	0.89
Sbj x Pos/Neg x Set Size x Sess	12	111.25	9.27	
Correction Factor		1386.11		

5x1 ANOVA of Percent Errors for Set Size in Session 18 of the Visual Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	58.20	19.40	
Set Size	4	54.80	13.70	4.47*
Sbj x Set Size	12	36.80	3.07	
Correction Factor		336.20		

*Denotes a significant result at the .05 level of significance

5x1 ANOVA of Percent Errors for Set Size in Session 1
of the Visual Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	272.95	90.98	
Set Size	4	46.80	11.70	0.91
Sbj x Set Size	12	154.80	12.90	
Correction Factor		470.45		

2x5x2 ANOVA of MRT Scores for Positive/Negative Trials, Set Size, and Session
(1 vs 18) in the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	361959.38	120653.13	
Pos/Neg	1	88.20	88.20	0.01
Sbj x Pos/Neg	3	34632.98	11544.33	
Set Size	4	26663.88	6665.97	3.27*
Sbj x Set Size	12	24465.75	2038.81	
Sess	1	916348.00	916348.00	5.69
Sbj x Sess	3	483276.00	161092.00	
Pos/Neg x Set Size	4	12001.42	3000.36	2.88
Sbj x Pos/Neg x Set Size	12	12507.34	1042.28	
Pos/Neg x Sess	1	1110.00	1110.00	0.33
Sbj x Pos/Neg x Sess	3	10093.00	3364.33	
Set Size x Sess	4	5796.38	1449.09	0.55
Sbj x Set Size x Sess	12	31758.88	2646.57	
Pos/Neg x Set Size x Sess	4	5469.58	1367.39	3.11
Sbj x Pos/Neg x Set Size x Sess	12	5284.64	440.39	
Correction Factor		23220125.00		

*Denotes a significant result at the .05 level of significance

5x1 ANOVA of MRT Scores for Set Size in Session 18
of the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	288978.13	96326.00	
Set Size	4	5741.80	1435.45	2.66
Sbj x Set Size	12	6480.58	540.05	
Correction Factor		3729888.45		

5x1 ANOVA of MRT Scores for Set Size in Session 18
of the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	131805.38	43935.13	
Set Size	4	22796.30	5699.07	1.96
Sbj x Set Size	12	34854.08	2904.51	
Correction Factor		8343736.20		

2x5x2 ANOVA of Percent Errors for Positive/Negative Trials, Set Size, and Session (1 vs 18) in the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	159.30	53.10	
Pos/Neg	1	0.20	0.20	0.02
Sbj x Pos/Neg	3	29.10	9.70	
Set Size	4	197.68	49.42	14.01*
Sbj x Set Size	12	42.32	3.53	
Sess	1	151.25	151.25	2.89
Sbj x Sess	3	156.85	52.28	
Pos/Neg x Set Size	4	24.43	6.11	0.61
Sbj x Pos/Neg x Sess	12	120.77	10.06	
Pos/Neg x Sess	1	6.05	6.05	0.58
Sbj x Pos/Neg x Sess	3	31.05	10.35	
Set Size x Sess	4	75.12	18.78	2.16
Sbj x Set Size x Sess	12	104.28	8.69	
Pos/Neg x Set Size x Sess	4	9.57	2.39	0.23
Sbj x Pos/Neg x Set Size x Sess	12	125.82	10.49	
Correction Factor		480.20		

5x1 ANOVA of Percent Errors for Set Size in Session 18 of the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	5.75	1.92	
Set Size	4	13.00	3.25	2.05
Sbj x Set Size	12	19.00	1.58	
Correction Factor		31.25		

*Denotes a significant result at the .05 level

5x1 ANOVA of Percent Errors for Set Size in Session 1 of the Auditory Memory Search Task of Experiment 1

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	151.75	50.58	
Set Size	4	119.20	29.80	7.77*
Sbj x Set Size	12	46.00	3.83	
Correction Factor		312.05		

*Denotes a significant result at the .05 level of significance

Experiment 2A

4x3x2 ANOVA of Percent Errors for Test SOA, Set Size, and Group
(Visual Subjects vs. Auditory Subjects)
in the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Gp	1	759.38	759.38	1.81
Sbj x Gp	6	2516.62	419.44	
SOA	3	19688.91	6562.97	86.82*
SOA x Gp	3	230.88	76.96	1.02
Sbj x Gp x SOA	18	1360.71	75.60	
Set Size	2	201.40	100.70	0.85
Set Size x Gp	2	147.44	73.72	0.62
Sbj x Gp x Set Size	12	1424.00	118.67	
SOA x Set Size	6	867.02	144.50	1.55
SOA x Set Size x Gp	6	231.31	38.55	0.41
Sbj x Gp x SOA x Set Size	36	3362.16	93.39	
Correction Factor		120700.17		

*Denotes a significant result at the .05 level of significance

4x3x2 ANOVA of MRT Scores for Test SOA, Set Size, and Group
(Visual Subjects vs. Auditory Subjects)
in the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Gp	1	1415961.00	1415961.00	4.54
Sbj x Gp	6	1871864.00	311977.31	
SOA	3	74413.31	24804.44	1.68
SOA x Gp	3	23428.69	7809.56	0.53
Sbj x Gp x SOA	18	266302.31	14794.57	
Set Size	2	16253.31	8126.66	0.42
Set Size x Gp	2	7469.69	3734.84	0.19
Sbj x Gp x Set Size	12	230091.31	19174.27	
SOA x Set Size	6	35699.38	5949.89	1.45
SOA x Set Size x Gp	6	23096.63	3849.44	0.94
Sbj x Gp x SOA x Set Size	36	147720.00	4103.33	
Correction Factor		41229641.34		

4x3x2 ANOVA of Percent Errors for Test SOA, Set Size, and Session (2 vs. 19) in the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	2998.20	999.40	
SOA	3	17786.36	5928.79	40.64*
Sbj x SOA	9	1312.84	145.87	
Set Size	2	652.94	326.47	2.55
Sbj x Set Size	6	769.65	128.27	
Sess	1	5.51	5.51	0.06
Sbj x Sess	3	286.28	95.43	
SOA x Set Size	6	1160.48	193.41	1.50
Sbj x SOA x Set Size	18	2318.94	128.83	
SOA x Sess	3	123.95	41.32	1.08
Sbj x SOA x Sess	9	343.10	38.12	
Set Size x Sess	2	41.52	20.76	0.16
Sbj x Set Size x Sess	6	762.56	127.09	
SOA x Set Size x Sess	6	503.90	83.98	1.23
Sbj x SOA x Set Size x Sess	18	1228.68	68.26	
Correction Factor		104346.09		

*Denotes a significant result at the .05 level of significance

4x3x2 ANOVA of MRT Scores for Test SOA, Set Size, and Session (2 vs. 19) in the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	363377.25	121125.75	
SOA	3	9857.83	3285.94	0.13
Sbj x SOA	9	233171.69	25907.96	
Set Size	2	15881.77	7940.88	0.50
Sbj x Set Size	6	94765.75	15794.29	
Sess	1	643865.00	643865.00	10.56*
Sbj x Sess	3	182930.75	60976.91	
SOA x Set Size	6	16073.73	2678.96	1.02
Sbj x SOA x Set Size	18	47266.71	2625.93	
SOA x Sess	3	24735.75	8245.25	0.97
Sbj x SOA x Sess	9	76209.81	8467.75	
Set Size x Sess	2	33461.88	16730.94	1.48
Sbj x Set Size x Sess	6	67861.56	11310.26	
SOA x Set Size x Sess	6	3931.27	655.21	0.42
Sbj x SOA x Set Size x Sess	18	28223.04	1567.95	
Correction Factor		19761720.17		

*Denotes a significant result at the .05 level of significance

4x3 ANOVA of Percent Errors for Test SOA and Set Size in Session 19
of the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	1040.42	346.81	
SOA	3	7972.75	2657.58	19.23*
Sbj x SOA	9	1244.08	138.23	
Set Size	2	371.29	185.65	2.76
Sbj x Set Size	6	403.71	67.28	
SOA x Set Size	6	1036.87	172.81	2.39
Sbj x SOA x Set Size	18	1300.80	72.27	
Correction Factor		52934.08		

4x3 ANOVA of MRT Scores for Test SOA and Set Size in Session 19
of the Visual Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	206441.38	68813.75	
SOA	4	19695.10	4923.77	0.54
Sbj x SOA	12	110312.06	9192.67	
Set Size	2	19467.90	9733.95	1.01
Sbj x Set Size	6	57924.91	9654.15	
SOA x Set Size	8	45170.57	5646.32	1.94
Sbj x SOA x Set Size	24	69840.50	2910.02	
Correction Factor		8271821.40		

*Denotes a significant result at the .05 level of significance

5x3 ANOVA of Percent Errors for Test SOA and Set Size for Session 19
in the Auditory Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	276.93	92.31	
SOA	4	2136.67	534.17	9.95*
Sbj x SOA	12	644.40	53.70	
Set Size	2	126.43	63.22	3.10
Sbj x Set Size	6	122.37	20.39	
SOA x Set Size	8	485.23	60.65	1.50
Sbj x SOA x Set Size	24	973.30	40.55	
Correction Factor		5606.67		

5x3 ANOVA of MRT Scores for Test SOA and Set Size
in the Auditory Search Task of Experiment 2A

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	553728.00	184576.00	
SOA	4	86644.81	21661.20	4.93*
Sbj x SOA	12	52755.06	4396.25	
Set Size	2	51130.63	25565.32	15.13*
Sbj x Set Size	6	10138.74	1689.79	
SOA x Set Size	8	9764.37	1220.55	0.98
Sbj x SOA x Set Size	24	29988.89	1249.54	
Correction Factor		14002170.42		

*Denotes a significant result at the .05 level of significance

Experiment 2B

4x3x2 ANOVA of Percent Errors for Test SOA, Set Size, and Task
(Session 19 Target Detection vs. Session 20 Stimulus Detection)
in the Visual Tasks of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	492.03	164.01	
SOA	3	16971.61	5657.20	29.48*
Sbj x SOA	9	1727.26	191.92	
Set Size	2	124.33	62.17	1.95
Sbj x Set Size	6	191.00	31.83	
Task	1	8011.76	8011.76	20.38*
Sbj x Task	3	1179.36	393.12	
SOA x Set Size	6	668.17	111.36	1.92
Sbj x SOA x Set Size	18	1041.84	57.88	
SOA x Task	3	2182.78	727.60	9.50*
Sbj x SOA x Task	9	689.60	76.62	
Set Size x Task	2	465.08	232.54	3.61
Sbj x Set Size x Task	6	386.92	64.49	
SOA x Set Size x Task	6	607.75	101.29	1.83
Sbj x SOA x Set Size x Task	18	994.25	55.24	
Correction Factor		50279.26		

*Denotes a significant result at the .05 level of significance

4x3x2 ANOVA of Percent Errors for Test SOA, Set Size and Task
(Session 19 Target Detection vs. Chance)
in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Set Size	2	185.65	92.82	1.16
Sbj x Set Size	9	722.06	80.23	
SOA	3	3986.38	1328.79	28.20*
SOA x Set Size	6	518.43	86.41	1.83
Sbj x Set Size x SOA	27	1272.44	47.13	
Task	1	6767.04	6767.04	84.35*
Task x Set Size	2	185.64	92.82	1.16
Sbj x Set Size x Task	9	722.06	80.23	
SOA x Task	3	3986.38	1328.79	28.20*
SOA x Task x Set Size	6	518.44	86.41	1.83
Sbj x Set Size x SOA x Task	27	1272.44	47.13	
Correction Factor		166167.04		

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 19 Target Detection vs. Chance)
at the 50 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	176.83	58.94	
Set Size	2	172.75	86.38	5.89*
Sbj x Set Size	6	87.92	14.65	
Task	1	7561.50	7561.50	128.29*
Sbj x Task	3	176.83	58.94	
Set Size x Task	2	172.75	86.38	5.89*
Sbj x Set Size x Task	6	87.92	14.65	
Correction Factor		24961.50		

*Denotes a significant result at the .05 level of significance

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 19 Target Detection vs. Chance)
at the 30 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	765.12	255.04	
Set Size	2	84.00	42.00	0.91
Sbj x Set Size	6	278.00	46.33	
Task	1	3675.38	3675.38	14.41*
Sbj x Task	3	765.12	255.04	
Set Size x Task	2	84.00	42.00	0.91
Sbj x Set Size x Task	6	278.00	46.33	
Correction Factor		33975.38		

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 19 Target Detection vs. Chance)
at the 20 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	292.83	97.61	
Set Size	2	174.33	87.17	3.10
Sbj x Set Size	6	168.67	28.11	
Task	1	308.17	308.17	3.16
Sbj x Task	3	292.83	97.61	
Set Size x Task	2	174.33	87.17	3.10
Sbj x Set Size x Task	6	168.67	28.11	
Correction Factor		51708.17		

*Denotes a significant result at the .05 level of significance

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 19 Target Detection vs. Chance)
at the 10 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	311400.81	103800.25	
Set Size	2	1607.25	803.63	0.75
Sbj x Set Size	6	6444.44	1074.07	
Task	1	94501.50	94501.50	0.91
Sbj x Task	3	311400.81	103800.25	
Set Size x Task	2	1607.25	803.63	0.75
Sbj x Set Size x Task	6	6444.44	1074.07	
Correction Factor		305101.50		

4x3x2 ANOVA of Percent Errors for Test SOA, Set Size, and Task
(Session 20 Stimulus Detection vs. Chance)
in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	241.58	80.53	
SOA	3	5854.58	1951.53	30.63*
Sbj x SOA	9	573.33	63.70	
Set Size	2	46.31	23.16	1.81
Sbj x Set Size	6	76.85	12.81	
Task	1	31537.50	31537.50	391.64*
Sbj x Task	3	241.58	80.53	
SOA x Set Size	6	90.11	15.02	0.69
Sbj x SOA x Set Size	18	392.73	21.82	
SOA x Task	3	5854.58	1951.53	30.63*
Sbj x SOA x Task	9	573.34	63.70	
Set Size x Task	2	46.31	23.16	1.81
Sbj x Set Size x Task	6	76.86	12.81	
SOA x Set Size x Task	6	90.11	15.02	0.69
Sbj x SOA x Set Size x Task	18	392.72	21.82	
Correction Factor		97537.50		

*Denotes a significant result at the .05 level

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 20 Stimulus Detection vs. Chance)
at the 50 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	2.33	0.78	
Set Size	2	3.00	1.50	1.17
Sbj x Set Size	6	7.67	1.28	
Task	1	14406.00	14406.00	18563.43*
Sbj x Task	3	2.33	0.78	
Set Size x Task	2	3.00	1.50	1.17
Sbj x Set Size x Task	6	7.67	1.28	
Correction Factor		15606.00		

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 20 Stimulus Detection vs. Chance)
at the 30 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	3.00	1.00	
Set Size	2	5.25	2.63	4.20
Sbj x Set Size	6	3.75	0.63	
Task	1	14406.00	14406.00	14406.00*
Sbj x Task	3	3.00	1.00	
Set Size x Task	2	5.25	2.63	4.20
Sbj x Set Size x Task	6	3.75	0.63	
Correction Factor		15606.00		

*Denotes a significant result at the .05 level

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 20 Stimulus Detection vs. Chance)
at the 20 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	38.00	12.67	
Set Size	2	9.33	4.67	0.22
Sbj x Set Size	6	125.00	20.83	
Task	1	9282.66	9282.66	732.84*
Sbj x Task	3	38.00	12.67	
Set Size x Task	2	9.33	4.67	0.22
Sbj x Set Size x Task	6	125.00	20.83	
Correction Factor		22082.67		

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 20 Stimulus Detection vs. Chance)
at the 10 ms Test SOA in the Visual Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	744.13	248.04	
Set Size	2	24.33	12.17	0.29
Sbj x Set Size	6	249.00	41.50	
Task	1	590.04	590.04	2.38
Sbj x Task	3	744.13	248.04	
Set Size x Task	2	24.33	12.17	0.29
Sbj x Set Size x Task	6	249.00	41.50	
Correction Factor		48690.04		

*Denotes a significant result at the .05 level

3x3x2 ANOVA of Percent Errors for Test SOA, Set Size and Task
(Session 19 Target Detection vs. Session 20 Report)
in the Visual Search Tasks of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	9781.59	3260.53	
SOA	2	18725.08	9362.54	25.65*
Sbj x SOA	6	2190.03	365.01	
Set Size	2	329.33	164.67	1.12
Sbj x Set Size	6	881.78	146.96	
Task	1	496.13	496.13	0.48
Sbj x Task	3	3084.27	1028.09	
SOA x Set Size	4	1038.58	259.65	3.75*
Sbj x SOA x Set Size	12	831.97	69.33	
SOA x Task	2	1896.08	948.04	2.94
Sbj x SOA x Task	6	1935.69	322.62	
Set Size x Task	2	534.33	267.17	0.57
Sbj x Set Size x Task	6	2829.44	471.57	
SOA x Set Size x Task	4	430.08	107.52	0.42
Sbj x SOA x Set Size x Task	12	3086.48	257.21	
Correction Factor		63546.13		

*Denotes a significant result at the .05 level

2x3x2 ANOVA of Percent Errors for Test SOA, Set Size and Task
(Session 19 Target Detection vs. Session 20 Stimulus Detection)
in the Auditory Tasks of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	242.06	80.69	
SOA	1	188.02	188.02	3.80
Sbj x SOA	3	148.56	49.52	
Set Size	2	115.63	57.81	0.99
Sbj x Set Size	6	348.88	58.15	
Task	1	2282.52	2282.52	26.26*
Sbj x Task	3	260.73	86.91	
SOA x Set Size	2	20.29	10.15	0.24
Sbj x SOA x Set Size	6	251.87	41.98	
SOA x Task	1	58.52	58.52	3.84
Sbj x SOA x Task	3	45.73	15.24	
Set Size x Task	2	177.54	88.77	3.04
Sbj x Set Size x Task	6	174.96	29.16	
SOA x Set Size x Task	2	75.04	37.52	1.40
Sbj x SOA x Set Size x Task	6	160.46	26.74	
Correction Factor		3834.19		

*Denotes a significant result at the .05 level

2x3x2 ANOVA of MRT Scores for Test SOA, Set Size and Task
(Session 19 Target Detection vs. Session 20 Stimulus Detection)
in the Auditory Tasks of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	594048.13	198016.00	
SOA	1	705.33	705.33	0.13
Sbj x SOA	3	16516.48	5505.49	
Set Size	2	9038.00	4519.00	1.76
Sbj x Set Size	6	15373.38	2562.23	
Task	1	2552.08	2552.08	0.26
Sbj x Task	3	29483.10	9827.70	
Sbj x Set Size	2	964.66	482.33	0.95
Sbj x SOA x Set Size	6	3048.02	508.00	
SOA x Task	1	14630.07	14630.07	13.31*
Sbj x SOA x Task	3	3297.70	1099.23	
Set Size x Task	2	59616.66	29808.33	4.24
Sbj x Set Size x Task	6	42163.59	7027.26	
SOA x Set Size x Task	2	272.57	136.29	0.15
Sbj x SOA x Set Size x Task	6	5297.01	882.84	
Correction Factor		13419675.00		

*Denotes a significant result at the .05 level

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 19 Target Detection vs. Chance)
in the Auditory Search Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	116.00	38.67	
Set Size	2	202.33	101.17	2.34
Sbj x Set Size	6	259.00	43.17	
Task	1	6402.66	6402.66	165.59*
Sbj x Task	3	116.00	38.67	
Set Size x Task	2	202.33	101.17	2.34
Sbj x Set Size x Task	6	259.00	43.17	
Correction Factor		27202.67		

3x2 ANOVA of Percent Errors for Set Size and Task
(Session 20 Stimulus Detection vs. Chance)
in the Auditory Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	14.46	4.82	
Set Size	2	12.25	6.13	2.55
Sbj x Set Size	6	14.42	2.40	
Task	1	13395.38	13395.38	2780.45*
Sbj x Task	3	14.45	4.82	
Set Size x Task	2	12.25	6.13	2.55
Sbj x Set Size x Task	6	14.42	2.40	
Correction Factor		16695.38		

*Denotes a significant result at the .05 level

2x3x2 ANOVA of Percent Errors for Test SOA, Set Size and Task
(Session 19 Target Detection vs. Session 20 Report)
in the Auditory Task of Experiment 2B

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	5435.06	1811.69	
SOA	1	46.02	46.02	0.72
Sbj x SOA	3	193.07	64.36	
Set Size	2	2000.54	1000.27	3.12
Sbj x Set Size	6	1924.63	320.77	
Task	1	2836.69	2836.69	3.84
Sbj x Task	3	2214.73	738.24	
SOA x Set Size	2	34.04	17.02	0.14
Sbj x SOA x Set Size	6	754.12	125.69	
SOA x Task	1	212.52	212.52	1.49
Sbj x SOA x Task	3	426.56	142.19	
Set Size x Task	2	1295.37	647.69	3.06
Sbj x Set Size x Task	6	1271.46	211.91	
SOA x Set Size x Task	2	317.04	158.52	0.97
Sbj x SOA x Set Size x Task	6	980.12	163.35	
Correction Factor		26555.02		

Experiment 3

2x2x2 ANOVA of Percent Errors for Task
(Single Target vs. Multiple Targets Position Trials),
Test SOA, and Set Sizes, in the Visual Search Task of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	2324.63	774.88	
Task	1	4371.13	4371.13	11.03*
Sbj x Task	3	1188.63	396.21	
SOA	1	684.50	684.50	2.81
Sbj x SOA	3	729.75	243.25	
Set Size	1	612.50	612.50	5.20
Sbj x Set Size	3	353.25	117.75	
Task x SOA	1	84.50	84.50	0.38
Sbj x Task x SOA	3	674.75	224.92	
Task x Set Size	1	480.50	480.50	4.06
Sbj x Task x Set Size	3	355.25	118.42	
SOA x Set Size	1	36.13	36.13	1.26
Sbj x SOA x Set Size	3	86.13	28.71	
Task x SOA x Set Size	1	171.13	171.13	2.32
Sbj x Task x SOA x Set Size	3	221.13	73.71	
Correction Factor		26106.13		

*Denotes a significant result at the .05 level of significance

2x2x2 ANOVA of MRT Scores for Task
(Single Target vs. Multiple Targets Positive Trials),
Test SOA, and Set Size in the Visual Search Task of Experiment 3

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	95442.38	31814.13	
Task	1	6555.13	6555.13	1.42
Sbj x Task	3	13860.38	4620.13	
SOA	1	2.00	2.00	0.00
Sbj x SOA	3	112842.00	37614.00	
Set Size	1	1596.13	1596.13	0.99
Sbj x Set Size	3	4849.38	1616.46	
Task x SOA	1	9112.50	9112.50	4.59
Sbj x Task x SOA	3	5949.50	1983.17	
Task x Set Size	1	1770.13	1770.13	0.78
Sbj x Task x Set Size	3	6771.38	2257.13	
SOA x Set Size	1	3200.00	3200.00	1.52
Sbj x SOA x Set Size	3	6319.00	2106.33	
Task x SOA x Set Size	1	1352.00	1352.00	4.69
Sbj x Task x SOA x Set Size	3	865.00	288.33	
Correction Factor		5166505.13		

Appendix B

Experiment 4

Kristofferson (1977) reported the surprising finding that automatic performance in a visual search task did not deteriorate when the target letter stimuli were replaced by other unpracticed letters, as long as a semantic categorical difference between targets and distractors (numbers) was preserved. She concluded that physical features are unimportant in the development of automatic search performance and proposed that semantic features provided the basis for discrimination of positive match and negative mismatch detections. This conclusion contrasts with the basic explanation of automatic target detection offered by Shiffrin and Schneider (1977) that an association is built up in long term memory between specific stimuli and a specific response category. However, the importance of physical features in automatic visual search might become apparent as the perceptual difficulty of a visual search task increased by reducing the test SOA.

The purpose of Experiment 4 was to test whether automatic target detection in a visual search task is based on the development of an automatized semantic detection of targets or an automatized perceptual discrimination of the physical features of targets. The same visual subjects from previous experiments highly practiced in the visual search task using upper case letters as targets were given the same target detection task at reduced test SOAs. However, on some of the trials the targets were lower case versions of the same letters.

The multiple targets condition of Experiment 3 was not used. It was expected that search performance would not be as high when targets were lower case letters, suggesting that the physical features of the stimuli are important in automatic search performance using semantic stimuli.

Method

All parameters in Experiment 4 were the same as in Experiment 3 except for the following details.

Design and Procedure

Subjects were presented search task trials at M=1, T=1, 2 and 4 using the test SOAs of 30, 20 and 10 ms. Half of the positive trials, in which a letter appeared in the test period, used the same upper case letters A, E, H and M with which subjects had received extensive practice in Experiments 1-3. For the other half of the positive trials, upper case letters were replaced by their lower case equivalents in the same typeface. An equal number of the two types of positive trials were randomly interspersed with negative trials in subblocks of 16 trials.

Subjects were informed that in some of the positive trials a lower case version of the memory set letter may appear and to consider it a match with the memory set letter. Experiment 4 was conducted in a single 1-hour session (Session 22) the day following the completion of Experiment 3. No feedback was given regarding correct or incorrect responses.

Results and Discussion

Accuracy data from Experiment 4 are graphed in Figure B-1 (see Figure B-1). Percent errors for the two positive trial conditions only are plotted as a function of Test SOA for the 4 visual subjects.

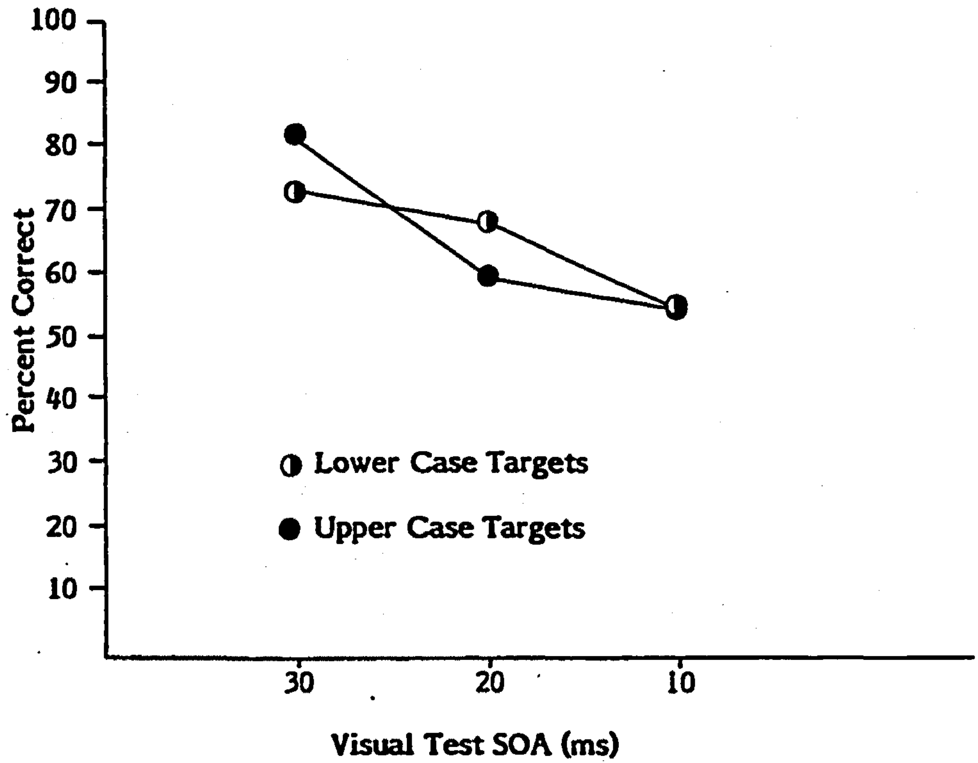
Insert Figure B-1 about here.

A 2x3x3 ANOVA of percent errors for upper case versus lower case positive trials, Test SOA, and Set Size resulted in no significant differences in any of the factors or interactions. Responses for upper case and lower case letters did not significantly differ, $F(1,3) = .10$. The other factors and interactions were not significant. The equivalent analysis using MRT data also did not yield any significant results at the .05 level of significance. The difference between upper case and lower case positive trials for MRT was not significant, $F(1,3) = .22$.

These results do not support the notion that a change in physical features of highly practiced stimuli, without a change in semantic features, would negatively affect automatized target detection performance. The literature indicating that semantic differences of the stimuli are important in the search task rather than physical differences cannot be rejected from the results of this study.

However, a physical cue was not properly controlled in Experiment 4. The height of upper case letters and number distractors was different from lower case letters. Thus, subjects could have detected a positive trial in the lower case positive trials condition by identifying a shorter item. The presence of a shorter item would signal a positive trial. Indeed, one of the subjects reported using this strategy. It is concluded that Experiment 4 does not adequately test the effect of physical and semantic attributes of target detection stimuli to bear upon the theoretical issue of the basis for automatic visual search performance. In future experiments, all parameters of the stimuli should be carefully controlled in order to test effectively the relative impact of semantic and physical stimulus features.

Figure B-1. Percent Correct scores are plotted as a function of Test SOA for Lower Case Targets and Upper Case Targets in the visual task of Experiment 4.



100
90
80
70
60
50
40
30
20
10
Percent Correct
Lower Case Targets
Upper Case Targets
30
20
10
Visual Test SOA (ms)

ANOVA Summary Table for Experiment 4

Experiment 4

2x3x3 ANOVA of Percent Errors for Upper vs. Lower Case Position Trials, Test SOA, and Set Size in the Visual Search Task of Experiment 4

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	4447.83	1482.61	
Upper/Lower	1	29.39	29.39	0.10
Sbj x Upper/Lower	3	890.06	296.69	
SOA	2	3413.08	1706.54	3.10
Sbj x SOA	6	3307.58	551.26	
Set Size	2	333.25	166.62	0.71
Sbj x Set Size	6	1413.08	235.51	
Upper/Lower x SOA	2	959.69	479.85	2.59
Sbj x Upper/Lower x SOA	6	1112.53	185.42	
Upper/Lower x Set Size	2	573.03	286.51	2.58
Sbj x Upper/Lower x Set Size	6	666.19	111.03	
Sbj x Set Size	4	1135.17	283.79	2.41
Sbj x SOA x Set Size	12	1410.50	117.54	
Upper/Lower x SOA x Set Size	4	165.39	41.35	0.21
Sbj x Upper/Lower x SOA x Set Size	12	2328.71	194.06	
Correction Factor		80400.50		

2x3x3 ANOVA of MRT Scores for Upper vs. Lower Case Position Trials, Test SOA, and Set Size in the Visual Search Task of Experiment 4

Source	df	Sum of Squares	Mean Square	F-Ratio
Sbj	3	241673.81	80557.94	
Upper/Lower	1	186.89	186.89	0.22
Sbj x Upper/Lower	3	2561.67	853.89	
SOA	2	28040.03	14020.01	0.46
Sbj x SOA	6	184720.06	30786.68	
Set Size	2	27020.86	13510.43	4.53
Sbj x Set Size	6	17876.27	2979.38	
Upper/Lower x SOA	2	1104.86	552.43	1.97
Sbj x Upper/Lower x SOA	6	1680.52	280.09	
Upper/Lower x Set Size	2	488.69	244.35	0.39
Sbj x Upper/Lower x Set Size	6	3766.37	627.73	
SOA x Set Size	4	12706.86	3176.72	1.08
Sbj x SOA x Set Size	12	35379.31	2948.28	
Upper/Lower x SOA x Set Size	4	3864.51	966.13	0.76
Sbj x Upper/Lower x SOA x Set Size	12	15160.31	1263.36	
Correction Factor		12269406.72		