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Automaticity in early visual processing: ages ten to sixty

Alice Thieman Woods
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AUTOMATICITY IN EARLY VISUAL PROCESSING: AGES TEN TO SIXTY

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ABSTRACT

A priming paradigm and a paradigm requiring apparent duration judgments for tachistoscopic presentations were used to provide converging tests for prerecognition automatic semantic access and to investigate developmental changes in early processing. Subjects from four different age groups (fifth and sixth graders, college age, thirty year olds, fifty year olds) participated in each of the two experiments. In the priming task, prime stimuli were presented tachistoscopically for durations which had previously shown, for individual subjects, chance level detection of stimulus presence versus absence. In the duration judgment task, stimulus exposure durations were, for each age group, the means of the duration for chance level presence-absence detection.

The priming paradigm did not provide evidence for automatic semantic facilitation for any age group. The data suggested a need to more clearly differentiate between a global lexical and a specific semantic access to long term memory. Prerecognition processing was evident in two age groups in the apparent duration experiment, although the specific effects of lexical and semantic parameters differed from previous findings. Developmental differences were evident only in presence-absence detection thresholds; the other tasks did not reveal age-related changes.
INTRODUCTION

Evidence for developmental changes in the sensory/perceptual and memorial systems that influence visual information processing has been well documented (Corso, 1981; DiLollo, Arnett, & Kruk, 1982; LaBerge & Samuels, 1974; Salthouse, 1980). Some theorists have suggested that changes in attentional capacity, or resources available for conscious mental operations, are responsible for the improved memory performance of children as they mature (Frederich, 1974) and are also responsible for the impaired cognitive performance in older adults (Botwinick & Thompson, 1966). If attentional mechanisms are important in development, then it is important to clarify the nature of these processes and the modifying influence of maturation.

Posner and Snyder (1975) propose that there are two distinctly different systems operating very early in the perceptual process: a conscious, attention demanding limited capacity system and an automatic system which operates nonconsciously and without intention. Recently, several research paradigms have been directed toward clarifying the distinction between automatic and attention-demanding processes. Cognitive theorists have classified automatic processing as occurring without conscious involvement and attention-demanding processing as occurring only with allocation of the subject's cognitive resources. Since previous research suggests that changes in attentional capacity may be a source of age-related changes, this distinction between automatic and attention-demanding processes has been used to study developmental information processing. Hasher and Zacks (1979) have argued
that tasks which require differential allocation of attentional resources should reveal
developmental changes across the life span; contrariwise, tasks which are the domain
of automatic mental processes should show improvement in performance during the
years in which necessary knowledge or skill is acquired, but thereafter be impervious to
change.

LaBerge and Samuels (1974) state that beginning readers attend more to the
graphological and phonological characteristics of words, and after these lower level
processes become automatic, readers are better able to process higher level syntactic
and semantic information. In fact, Fletcher (1981) has labeled beginning readers,
“decoders” and older readers, “comprehenders.” If automatic processing occurs in
reading, then this development should be apparent as children develop into fluent
readers and should not decline across the life span.

Even though Hasher and Zacks suggest that automatic processing should not be
impaired in older adults, the available evidence suggests a marked decrease in the
overall efficiency of information processing (Botwinick, 1978; Burke & Light, 1981;
Corso, 1981). The majority of the aging research has attempted to locate the
processing stage or stages responsible for processing deficiencies that increase with
age. Several studies reveal changes in duration of early sensory store (e.g., Kline &
Orme-Rogers, 1978; Walsh & Thompson, 1978), encoding processes (e.g., Monge &
Hultsch, 1971; Simon, 1979), and retrieval strategies (e.g., Hultsch, 1975; Thomas,
Fozard, and Waugh, 1977) from young adults to old age.

According to Salthouse (1980), research questions should not be stage-specific—
answers to such questions are simplistic (Why would only one stage change with age?)—
but should instead be phrased in terms of a general speed-loss mechanism. Thus,
age-related changes are best studied in terms of time needed to perform simple mental operations. If the entire information processing system slows with age, it is reasonable to hypothesize some effect on automatic, as well as attention-demanding, processes.

Taking a different perspective, Rabbitt (1981) has criticized developmental researchers, arguing that models of cognition borrowed from experimental psychology have been derived from experiments on young adults, and these models do not accommodate inter- or intra-individual differences. Thus, according to Rabbitt, investigations of age-related changes must incorporate measures sensitive to individual differences and to the interaction of these factors with task parameters. For example, Rabbitt (1979) found that correct response latency and percent of errors were misleading indices of age-related changes in a choice reaction time experiment. Careful analyses revealed that overall response latencies for older subjects were as fast as for younger subjects; however, when only correct response latencies were considered, the average latency of the older subjects was longer. Interestingly, mean number of errors and average response latency for errors did not increase with age. The older subjects’ response latency distribution was more positively skewed than the younger subjects. Rabbitt concluded that, rather than a general slowing of response speed, the older subjects could not optimize the speed/accuracy tradeoff as efficiently as the younger subjects. When the older subjects responded fast, they tended to make errors. In order to compensate, these subjects would slow down and “overshoot” the optimum latency, therefore producing some very long correct response latencies. The above example illustrates the importance of developing techniques that allow us to distinguish changes that have a locus within the system from those changes which produce a decline in overall processing efficiency.
The present study was designed to further clarify the concept of automatic processing and to investigate the nature of changes in automatic processing across the life span. A set of converging operations was used to: a) test for age-related differences in stimulus detection threshold, b) test the hypothesis that visual semantic information can be processed by a nonattentional automatic system, and c) investigate developmental changes in this automatic processing.

Studies of automatic processing have limited the subjects' attentional resources by restricting the stimulus duration or requiring concurrent processing of a second stimulus; however, subjects were usually aware that some unattended information was available (Howard, Lasaga, & McAndrews, 1980; Rosinski, Golinkoff, & Kukish, 1975). Other studies have restricted stimulus input to a subliminal level, and thus subjects had no conscious awareness of the unattended information (Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1980). The following section reviews the theoretical background and relevant research from both types of automatic processing studies. Theories of automatic processing and the pertinent research are then considered in relation to life span changes in visual information processing.
LITERATURE REVIEW

The traditional information processing perspective in word recognition theories has emphasized the description of how information which impinges on the organism is transferred and/or transformed from one stage to another. An account of what happens between the observed stimulus input and observed response to that input is the goal of this type of theorizing (Estes, 1978). This perspective has tended to produce serial, discrete stage models within which researchers attempt to fit empirical data (e.g., Massaro, 1975; McClelland, 1979). Models of this type have been supported by research explicating the characteristics of each stage (e.g., Posner & Keele, 1967; Sperling, 1960; Thompson & Massaro, 1973; Tulving & Gold, 1963).

The conventional approach has conceptualized the earliest visual sensory information in terms of an iconic storage system. Typically, studies have indicated that the preperceptual visual store or the iconic stage is a literal, spatial representation unaffected by abstract codes (Averbach & Coriell, 1961; Neisser, 1967; Sperling, 1960).

Turvey (1978) suggests, however, that the icon may be the result of processing rather than the beginning of processing, and what is available in the icon for further analysis depends largely on the individual's prior knowledge about the world. Traditional concepts of the icon describe it as a visible representation. Turvey suggests that there is another type of visual representation; one that is visual but not visible—invisible because this visual information does not result in any conscious awareness on the part of the subject.
Merikle (1980) has also challenged the traditional concept of the icon and has presented evidence indicating that conceptual category membership can influence very early visual processing. In accord with several other theorists (e.g., Allport, 1977; Turvey, 1978), Merikle rejects the currently held concept of iconic storage and further suggests that information processing is better conceptualized as a continuous process rather than a series of static stages.

It is certainly plausible to hypothesize that long term memory may be the controlling mechanism in perceptual selectivity. A stimulus may be analyzed for its semantic content, and on the basis of information stored in permanent memory, the probability of the stimulus information getting into the subject's awareness or consciousness may be enhanced or reduced.

Automatic Processing

Models for automaticity in visual stimulus identification have been provided by several theorists (e.g., LaBerge & Samuels, 1974; Posner & Snyder, 1975; Shiffrin & Schneider, 1977), all of whom share the assumption that automaticity operates with learned, well-practiced associations, and that new associations require attention and allocation of cognitive resources. Testing this assumption, Regan (1981) had subjects identify English letters (familiar stimuli) and newly learned Armenian letters (unfamiliar stimuli). As expected, response latencies were longer for the Armenian letters and, more importantly, latencies increased as number of letters (set size) was increased. However, for the English letters, response latency did not increase with set size increments. These data suggested that the English letters were being processed automatically, independent of attention capacity, whereas identification of the
unfamiliar Armenian letters required increasing attentional resources with increasing set size.

Navon (1977) has argued that some automatic processes are intrinsic to the perceptual system and do not require extensive practice; for example, an analysis of the global aspects of a display may occur automatically. Therefore, Regan (1981) conducted a second experiment using stimuli that were large letter shapes constructed with repeated printings of small letters; subjects were required to name the small form. The large letters either matched or mismatched the component small letters; for example, a large B could be made up of repeated small Bs, small Ds, or one of the Armenian letters. Regan's finding that both the English and Armenian large letters interfered with small letter naming when the two forms were incompatible was in accord with Navon's (1977) argument. Furthermore, there was greater interference from English letters, thus providing support for learned automaticity models such as LaBerge and Samuels (1974), Posner and Snyder (1975), and Shiffrin and Schneider (1977).

Several other researchers have tested the automaticity hypothesis by comparing the processing of visual/graphic versus abstract levels of representation. For example, Friedman (1980) asked subjects to make letter case and identity judgments for letters presented singly and for letters presented in same case and mixed case orthographically regular pseudowords. Subjects' performance for letter identification was not influenced by the number of letters in the stimulus array (single letters versus pseudowords), which suggested that the letters were processed simultaneously and automatically. However, accuracy for reporting the case of the target letter did decline as the number of letters in the stimulus array increased. Therefore, case identification
of the target letters was considered to be a nonautomatic process requiring that attention be directed to the critical letter before case information could be processed. Letter identification was independent of stimulus length, however, suggesting an automatic process in which all letters in the display were identified in parallel.

Similar evidence was reported by McClelland (1976) who found that when subjects could make correct letter identification they were only 52% accurate in reports of letter case, and by McConkie (1979) who found no disruption in reading when letters were alternated between upper and lower case. Taken together, these studies argue convincingly that information extraction occurs at a more abstract level than visual features of letters, and that this process occurs automatically even when subjects are instructed to report visual characteristics of the display.

Carr, Davidson and Hawkins (1978) suggest that although direct visual access to the mental lexicon does occur, subjects can strategically engage in an orthographic (spelling regularity) computation process which facilitates letter string decoding. To test this hypothesis, Carr and colleagues manipulated subjects' expectations and found that recognition accuracy for words and pseudowords was equal if subjects were expecting pseudowords. However, when subjects were expecting either nonsense strings or words, recognition accuracy for words was significantly higher than that for pseudowords which did not differ from that for nonsense strings. Apparently, subjects used spelling regularity as a decoding strategy only if they were led to expect pseudowords as stimuli. Thus, the authors suggest that direct semantic access can occur without letter decoding; however, the orthographic mechanism can operate in parallel to decode words not yet stored in the lexicon. (It is assumed that pseudowords would not be permanently encoded.) Coltheart, Davelaar, Jonasson, and Besner
(1977) also concluded that the available data are compatible with parallel subsystems analyzing visual and phonological information, recognition occurring with the summation of the products of these subsystems. They also allow that the data are not incompatible with a view that familiar words access the lexicon in a direct automatic fashion whereas the phonological system may be slower and only functional with unfamiliar items such as pseudowords.

Findings such as these led Allport (1979) to suggest that letter recognition is not a necessary condition for the recognition of words and to propose an interactive system (Allport, 1977) which allows available lexical or other conceptual information to influence visual or sensory memory. Allport (1977, 1979) hypothesizes that all types of information (graphic, orthographic, phonological, syntactic, lexical, semantic, etc.) are processed in parallel and a "comparator," or some type of perceptual integration mechanism, combines all of this perceptual information. Recognition occurs when enough information from different systems has been "re-membered," or recombined, to give the subject a conscious percept.

Massaro (1979) argues staunchly against an interactive model of word recognition stating that information at each stage can only influence the neighboring stage; thus low-level information (i.e., information in preperceptual store) would not remain intact to contribute to later processing stages. However, Massaro's criticism rests precariously on the assumption that the preperceptual store or the iconic stage is a literal, precategorical representation of approximately 250 msec duration. As discussed previously, this conceptualization of the iconic stage has been questioned (e.g., Merikle, 1980; Turvey, 1978).
Semantic Facilitation

A number of studies have attempted to further clarify the dimensions of information that are available automatically and the ways in which these dimensions may interact. Semantic memory has been conceived of as an associated network such that when a particular word is accessed, semantically related entries are activated and for a short time, are more easily available to the cognitive processing system (Collins & Loftus, 1975; Quillan, 1962, 1967; Treisman, 1960). This conception of semantic memory has prompted attempts to explicate the facilitating effects of contextual information in language processing, and several experiments have specifically addressed this issue relative to semantic facilitation effects in word perception. Priming tasks have been used extensively in semantic access research. This paradigm involves sequential presentation of two (or more) words, the first word is hypothesized to "prime" or activate the associated memory network; target words that are semantically related to the prime word should therefore be more easily accessed.

Meyer and Schvaneveldt (1971) asked subjects to make a lexical decision (word/nonword discrimination) to the second of two sequentially presented letter strings. They found shorter response latencies for semantically related pairs than for unrelated pairs; for example, subjects could decide that NURSE was a word more quickly if it had been preceded by DOCTOR than if it had been preceded by BREAD. This semantic facilitation effect has also been replicated by Neely (1976) and by Shaffer and LaBerge (1979); however, both of these studies reported inhibition from a prime word on an unrelated target word. It is usually assumed that the priming effect is automatic and nonattentitional since one of the postulates of the automaticity theory
(Posner & Snyder, 1975) is that automatic processing does not interfere with other processes. Neely (1977) questioned the assumption of automaticity in the priming paradigm, given that priming may also produce inhibition. In a more rigorous evaluation of automatic semantic access, Neely (1977) orthogonally manipulated semantic access (relationship of prime and target) and conscious attention (stimulus-onset asynchronies, the time interval from prime onset to target onset, ranging from 250 to 2000 msec). The data showed that when subjects were not given time to direct their attention, semantically related primes provided facilitation and no inhibition; however, with longer SOAs (stimulus-onset asynchronies), both facilitation and inhibition were operative. Thus, Neely suggested that when both of these processes are evident, they may be resulting from a conscious mechanism and should not be solely attributed to automatic activation of the semantic network.

Other recent studies (Antos, 1979; Schvaneveldt & McDonald, 1981) have varied attention allocation and found evidence for two types of processes operating in a semantic priming task. In a tachistoscopic experiment (Schvaneveldt & McDonald, 1981) with brief, pattern masked stimuli, there was no effect of semantic priming on feature detection; but there was a priming effect for a lexical decision task. Error analysis also revealed a high proportion of false positive responses to nonwords that were physically similar to words. In a companion reaction time experiment with stimulus presentation terminated by the subject's response, there was a strong effect of semantic priming in both the lexical task and the feature detection task. False positive responses to physically similar nonwords did not occur. Based on these data, Schvaneveldt and McDonald (1981) postulate a two stage process in early visual processing: 1) an initial analysis that processes features, word shapes, etc. and
formulates a lexical hypothesis, and 2) a "second look" analysis which is driven by semantic memory and verifies or disconfirms the initial hypothesis.

Semantic activation in the form of context provided by a sentence is another variant of the semantic priming paradigm. Stanovich and West (1979) had subjects read a context sentence prior to presentation of a target word which was either semantically related or unrelated to the sentence context. Word recognition time was slowed in half the trials by visual degradation of the target word. When the target was degraded, semantic facilitation decreased and inhibition increased. Results supported the two process theory; when word recognition was slowed, attentional mechanisms were operative as evidenced by the inhibition effects. Stanovich and West suggested that poor (and/or young) readers with weak word recognition skills rely more on contextual information because they have not developed the automaticity in word processing that fluent readers have.

Several other studies have found evidence for automatic semantic access when context priming occurs with ambiguous words (Conrad, 1974; Holley-Wilcox & Blank, 1980; Schvaneveldt, Meyer, & Becker, 1976). Typically, the priming stimulus is one which has two different meanings (e.g., BALL is semantically related to ROUND or DANCE). Although there has been a controversy between a selective-access (one meaning) and a multiple-access (multiple meanings) priming effect for ambiguous words (the literature providing more support for multiple access), the pertinent point here is that these studies provide further verification for the general claim of automatic semantic access models.
Subliminal Processing

As stated earlier, the purpose of this literature review is to consider the evidence for automatic semantic processing in visual word perception. According to the criteria of Posner and Snyder's (1975) theory, the cited research supports the influence of abstract or semantic units which operate without the subject's attention and without interfering with other processes. It is necessary, however, to meet another postulate of the theory and that is: Can information influence the subject's response without giving rise to awareness? In a review of the subliminal perception literature, Dixon (1971) defined some of the problems inherent in this controversial area. For instance, if perception is considered to involve recognition, then the term "subliminal perception" is a contradiction: If it is really subliminal, it can't be consciously perceived.

The elusive concept of consciousness had, for a time, been neglected in psychology. Although questions addressing the nature of consciousness are again legitimate areas of inquiry, there is still wide disagreement as to what constitutes consciousness or awareness (Natsoulas, 1978). Even if we assume that there are subliminal (or nonconscious) effects, the question remains, what "limen" (threshold) are we referring to—Detection?—Identification? In other words, how do we differentiate conscious from nonconscious states? Although "threshold" was previously considered to be an absolute value, currently it is accepted that any threshold is a statistical concept dependent on the particular signal/noise ratio and the response criterion of the subject.

In an effort to clarify some of these issues, Dixon (1971) listed three criteria which, if satisfied, would justify the concept of subliminal perception. They are:
1. The elicitation of contingent responses by stimulation below the absolute awareness threshold, where this threshold is itself defined as the lowest level of stimulus energy at which the subject ever reports seeing anything of the stimulus.

2. The retrospective reporting by the subject that nothing of the stimulus was seen.

3. The occurrence of contingent responses, without reported awareness of the stimulus, that differ qualitatively from those elicited by the same stimulus when presented above the awareness threshold.

In studies of early visual processing, masking of a stimulus has frequently been used to limit perceptual processing. Masking refers to a secondary stimulus input which interferes with processing of the target stimulus. Since Turvey's (1973) landmark paper, it has been assumed that the effect of a pattern mask, or a mask with a pattern similar to the stimulus pattern, is termination of iconic representation and thus the interruption of any information available for perceptual processing. This type of masking has been considered to be a central phenomenon and contrasts, in Turvey's distinction, to energy, or nonpatterned, masking which operates peripherally, on sensory input.

In a series of experiments, Marcel (1980; Marcel & Patterson, 1978) used masking manipulations to vary subjects' access to stimulus information in a manner designed to meet Dixon's (1971) criteria defining subliminal processing. Three different tasks were utilized by Marcel and Patterson (1978) to determine the briefest SOA (stimulus-onset-asynchrony) at which subjects could: a) detect the presence of a stimulus, b) judge the visual form of a word, and c) determine the meaning of a word. As the SOA was reduced, first stimulus detection, then judgments of visual form, and lastly semantic
relationship judgments fell to chance level. To quote Fowler et al. (1981, p. 342) "subjects showed a sensitivity to meaning at SOAs at which they could provide no form information, and a sensitivity to form and meaning at SOAs at which they could not make presence/absence judgments."

In a more recent study, Marcel (1980) replicated Schvaneveldt et al.'s (1976) study in which word triples were presented with the associative relationship of the triples varied (e.g., HAND-PALM-WRIST, TREE-PALM-WRIST, etc.). The second word was a) not masked, b) pattern masked, or c) energy masked; subjects were required to make lexical decisions for the first and third words in each triple. Reports taken after the experimental task revealed that subjects had no awareness of the second stimulus in either of the masked conditions. Yet the data revealed that a semantic relationship between the second and third words facilitated lexical decisions for the third word more in the pattern masked condition than in the nonmasked condition. Moreover, the facilitative effects of conscious (nonmasked) and nonconscious (pattern masked) processing were qualitatively different. In the pattern masked condition, polysemous words (ambiguous words which have more than one meaning) resulted in nonselective access—i.e., both meanings were facilitated. However, in the nonmasked condition the context provided by the first word clarified the meaning of the polysemous word which resulted in only one meaning being accessed. Marcel (1980) suggests that "Conscious representation is of limited capacity in that only one representation or interpretation of an event can be entertained at a time" (p. 451), and that "Preconscious perception is nonselective and prior context does not affect it" (p. 452).

The differences in the masking conditions—associative priming was strongest in the pattern masked condition, less evident in the nonmasked condition, and absent in
the energy masked condition—demand a reevaluation of the effects of pattern masking. Apparently, energy masking precluded semantic access in the priming task; however, pattern masking allowed a nonselective semantic access, but denied subjects a conscious visible image. Marcel (1980) and others (Allport, 1977; Fowler et al., 1981) propose that pattern masking of brief visual stimuli does not terminate perceptual processing but does limit conscious processing, and therefore is a valuable methodological tool for studying preconscious or subliminal processing.

Allport (1977) found that when pattern masking was employed, subjects’ reading errors were frequently semantically, rather than graphically, related to the target words (e.g., kind read incorrectly as nice, drink as wine). In addition, when subjects were instructed to report exemplars of a particular category from a four-word pattern masked display, the category words were reported with higher frequency than the distractor words. In another experiment (Allport, 1977), target word identification was facilitated by the semantic relationship between the target and a simultaneously presented distractor word. Retrospective reports revealed that subjects were never aware that a second letter string had been presented.

Fowler and colleagues (Fowler et al., 1981) replicated Marcel and Patterson’s (1978) study with a slight modification in procedure. In order to evaluate the claim that these results were artificial (Ellis & Marshall, 1978; Williams & Parkin, 1980), a “nonexperiment” was conducted in which subjects were presented with pairs of words and asked to decide which of the words was most likely to have another word “like it” based on semantic, phonetic, and graphic criteria. Results for this experiment replicated those of the earlier masking experiments (Fowler et al., 1981, Experiments 1 & 2;
Marcel & Patterson, 1978). A variant of Allport's (1977) experiment, which asked subjects to report exemplars of a certain category, was also attempted by Fowler et al. (1981) and Allport's results were not replicated. Thus, Fowler and colleagues suggested that subjects' responses may not be the result of nonconscious processing but simply the result of subjects' strategic guessing strategies. Fowler et al. (1981) and Marcel (1980) proposed that the problem with Marcel and Patterson's (1978) task and with Allport's (1977) task was that subjects were forced to respond directly to words for which they professed no awareness, and hence they would utilize whatever knowledge was available to them to perform the experimental task. The information used could have been based on general knowledge of the English language rather than information extracted from the stimulus display.

In a final set of experiments, Fowler et al. (1981, Experiments 5 & 6) used a version of Meyer and Schvaneveldt's (1971) semantic priming paradigm for a lexical decision task and found that a semantically related prime facilitated a lexical decision for target words. Fowler and colleagues replicated the results reported by Marcel (1980). In these last experiments, subjects were not required to respond directly to the masked words, and thus the influence of the masked word was indirectly assessed. In addition, the lexical decision task was not susceptible to the bias of a guessing strategy. This series of experiments by Fowler and colleagues (1981) converge with Marcel's (1980) to provide additional evidence for preconscious semantic processing and, just as importantly, has provided valuable criticism of previous research.

In an experiment designed to expand on Marcel and Patterson's (1978) study, Huber and Johnson (Note 1) presented letter string pairs of words, nonwords, or
word/nonword combinations with the strings typed in either same or different letter case. When exposure duration was reduced so as to produce chance level performance for case discriminations, subjects were still able to make lexical decisions with above chance accuracy. In addition, semantic relatedness of the word pairs facilitated detection of sameness and appeared to interfere with difference judgments in the lexical decision task. The semantic effect was only evident with brief exposure durations; as duration was increased and subjects had more graphic information available, performance on the case task was superior to performance on the lexical task.

Research by Avant and Woods (Note 2) utilized the Huber and Johnson paradigm, and added a task in which subjects were also asked for meaning judgments. A threshold measure was established for each subject at an exposure duration which resulted in chance level performance for case decisions, and then this duration was used for the lexical and meaning decision tasks. The data indicated that when case decisions were at chance level, both meaning and lexical decisions were significantly higher. Analyses of report accuracy in the case, lexical, and meaning decision tasks revealed that letter case difference was the basis for subjects' discrimination in the case task, but in the lexical task subjects were better at detecting words than nonwords, and variation in case did not matter. In addition, a consistent response bias operated; performance was better on "same" than "different" trials and this bias was the only significant outcome in the meaning task.

This paradigm has been criticized as possibly producing artifactual results (Merikle, Note 3; Whitaker, Note 4). Since the criterion for the threshold was forced to chance level, the probability of correct letter case decisions for that task could have
reflected a measurement artifact. Huber and Johnson employed a post test for case
discriminations and eliminated subjects whose performance was then above chance,
and Avant and Woods reduced exposure duration for the case task until probability of
correct report was consistently below chance. The crucial point is that the dependent
measure for the case task was constrained in a manner that measures for the other
tasks were not.

Avant and Woods (Note 5) recently completed a followup experiment with a
modified design: Threshold was set as before by reducing exposure duration until
subjects' performance was at chance level on case decisions, then subjects performed a
case task, lexical task, and meaning task. This modification rendered a case task
measure independent of any criterion restriction used for threshold determination, and
thus the case, lexical, and meaning task measures were comparable. Differences
between mean probability correct for the case, lexical, and meaning tasks were not
statistically significant. However, when comparing average correct probabilities for
the different conditions within each task, the data revealed that when subjects were
asked to make a letter case judgment, the manipulation of case was the only variable
influencing subjects' performance; lexical status or meaning of the stimuli did not
matter. Likewise, when subjects made lexical status judgments (word/nonword), the
lexical status of the stimuli was the important attribute and the other manipulations
did not influence subjects' judgments. And, when subjects were asked to judge the
semantic relatedness of two letter strings, the only differentiating characteristic was the
meaning of the stimuli. Although subjects claimed no recognition of the stimuli,
subjects did appear to have some strategic control over which stimulus characteristics
were utilized in their decision. These data, which suggest that subjects have some volitional control over a pre-recognition stage of processing provide some difficulty for automatic processing models such as Posner and Snyder's (1975), which postulate an automatic access that is preconscious and independent of the subject's intention. A sharp distinction between automatic and attention-dependent processing may not be a tenable thesis.

Fowler et al. (1981) criticized tasks that had subjects respond directly to characteristics of stimuli that they were not aware of seeing and suggested that these tasks did not provide an appropriate measure of preconscious operations. Therefore, Avant and Woods (Note 5) conducted two additional experiments which indirectly assessed the effects of the stimulus characteristics on subjects' performance. An apparent duration paradigm (Avant & Lyman, 1975; Avant, Lyman, & Antes, 1975; Avant et al., 1977), previously used to show the effect of stimulus familiarity on prerecognition processing, was employed. The paradigm presents trials on which pairs of pre- and postmasked stimulus presentations are separated by 1 sec, and subjects are asked to judge which of the paired stimulus presentations appears to last longer. The two stimulus presentations on each trial are of equal clock time, and differences in subjective duration are produced by manipulation of the stimulus materials presented in the paired flashes. In a previous experiment (Avant et al., 1975) with 30 msec pre- and postmasked flashes, subjects judged presentations of a nonword to be longer than equal presentations of a word, which were, in turn, judged to be longer than presentations of a single letter. Again, when upright and inverted three-letter words were used as stimuli (Avant & Lyman, 1975), subjects judged presentations of the inverted words to be longer than equal presentations of the upright words.
A subset of the stimuli used in the case, lexical, and meaning decision tasks (Avant & Woods, Note 5) was used in two apparent duration tasks. In the first, letter case and lexical status of the stimuli were manipulated; in the second, letter case and the meaning of the stimuli were manipulated. In the first experiment, when letter case was the same for both letter strings, the same result occurred as in previous studies: the two nonwords were judged to be longer than the word/nonword combination, and they were both judged to be longer than the two words. However, when letter case was altered in the stimulus display, a reversal occurred, words were judged to be longer than the nonwords. This result suggests that differences in letter case disrupted the "familiarity" of the very common words. In the second experiment, there was no effect resulting from the manipulation of semantic relationship of the stimuli.

Some ambiguity exists in interpreting results from the Huber and Johnson paradigm; this operation may not be reflecting prerecognition processing. However, the results of the apparent duration experiments are clearly in support of research reported by Marcel (1980) and Fowler et al. (1981) which argue that semantic or lexical access is not the final stage in the information processing sequence, but rather that lexical access occurs automatically and influences very early processing prior to the subject's conscious recognition.

Evidence for Automaticity Across the Life Span

The preceding sections have provided empirical evidence for automatic semantic access that can occur at a nonconscious level, prior to recognition. Since the questions of interest focus directly on the development and consistency of such automatic processing, a review of the related developmental literature is pertinent.
Automaticity in Children's Semantic Processing. In the Stroop (1938) color naming task, subjects attempted to name the color of the ink in which a word was printed. When the printed word conflicted with the ink color (e.g., the word BLUE written in red ink) response latencies were longer, suggesting greater semantic interference, than latencies in a neutral condition (e.g., the word BOOK written in red ink). Findings from the Stroop task parallel the general findings in the priming paradigm. An unattended stimulus can influence the subjects' response to a related target stimulus, and the effects of the unattended stimulus can be changed with manipulation of attentional resources (Logan, 1980).

Variations of the Stroop task have been used to investigate automatic semantic access in young subjects (Ehri & Wilce, 1979; Guttentag & Haith, 1978; Rosinski, Golinkoff, & Kukish, 1975; Schadler & Thissen, 1981). For example, Rosinski et al. (1975) superimposed words over line drawings of pictures, and obtained response latency measures for both word and picture naming. Schadler and Thissen (1981) asked subjects to name the ink color of various words. Overall, response latencies were slower if the stimuli were incongruent (e.g., the word CAR superimposed on a picture of a house) than if the stimuli were congruent (e.g., the word CAR superimposed on a picture of a car); furthermore, both experiments provided evidence of interference in the incongruent condition even with early readers. There were other interesting developmental inferences. Interference from the Stroop effect peaked after two or three years of reading instruction and then declined. And interestingly, with nonreaders (kindergarteners) and beginning readers (first graders) any letter string, even the control condition, consisting of a string of Xs, produced an interference
effect; by second grade, the interference effect was strongest in the incongruent word condition (Schadler & Thissen, 1981). When Rosinski et al. (1975) asked subjects for both picture naming and word naming, they found that after only one year in school, words had a processing advantage over pictures. These data suggest that any letters superimposed on a picture seemed to "catch" very young children's attention, even though there was no semantic processing. In addition, evidence is suggestive of early development of word associations in young readers. Data from a visual search task (McCaughey, Juola, Schadler, & Ward, 1980) indicated that children learn whole word patterns prior to the development of orthographic strategies, and by second grade process familiar words very rapidly.

McFarland, Frey, and Landreth (1978) utilized a priming paradigm and varied both the name and case of prime and target letters. Second graders benefitted more from a prime that was in the same case as the target letter, whereas sixth graders benefitted equally from same and different case primes. Frederiksen (1978) varied case type (consistent versus mixed) in a lexical decision task with high school age subjects of four reading ability levels. Mixing the case of the stimulus letters did not affect lexical decision latencies for good readers; however, response latencies for poor readers almost doubled with mixed case targets. The adult literature suggested that alternating the case of letters in a word did not disrupt the reading process (McConkie, 1979); therefore, the effects reported by McFarland et al. (1978) and Frederiksen (1978) may be particularly relevant for beginning and/or less skilled readers. These less fluent readers do not evidence automatic processing but instead must attend to the physical characteristics of the display.
Schwantes (1981) tested an interactive model of word recognition with third grade children and adults. Word recognition can be slowed by stimulus degradation, and Schwantes used this technique to manipulate the time subjects attended to the visual information. Using a target exposure duration of 500 msec in a lexical decision task, Schwantes manipulated context (presence or absence of prior sentence), stimulus quality (clear or degraded), and phonology (presence or absence of rhyming words in context sentence), and found that both semantic and phonological contextual information had a facilitative effect on children's subsequent lexical decisions in both the clear and degraded stimulus conditions. However, contextual sentence information was utilized by the adult subjects only in the degraded condition, indicating that, with intact stimuli, the adults were more likely to process the words automatically, whereas the children were always influenced by the available context.

Using an apparent duration paradigm, Avant et al. (1977) compared early visual processing of children and adults. As described previously, this paradigm asks subjects to make subjective duration judgments for paired stimulus presentations which are of equal clock time. When the stimuli were a letter (A) and a digit (4), both adults and children (four and five year olds) systematically judged rotated stimuli (unfamiliar) to be of longer duration than upright stimuli (familiar). These data suggest that automatic processing may not depend on maturational changes, but may instead depend on experience with certain forms and the resultant strength of memorial encoding. A second experiment was conducted using good and poor dot pattern Gestalts. Only the adult subjects discriminated between forms, and the direction of the duration judgments was different than hypothesized: Good patterns were judged to be
of longer duration than poor patterns. The authors suggested that processing of spatial forms differed from verbal materials for both age groups. In addition, children's processing appeared to be slower than adults. With 50 msec presentations, the children performed at chance level on a post experiment recognition task, while 30 msec presentations resulted in high recognition probabilities for the adults.

Automaticity in Aging Birren (1974) argues that age related changes in information processing cannot be accounted for by decrements in sensory input or motor output, but instead are due to a fundamental change in central nervous system activity. In support of Birren's hypothesis, several studies have found evidence for longer stimulus persistence in the elderly (Kline & Orme-Rogers, 1978; Kline & Szafrań, 1975; Walsh, Williams, & Hertzog, 1979) and, using a partial report procedure (Sperling, 1960), Cerella, Poon, and Fozard (1982) found that elderly men showed a decline in information encoded from iconic store. DiLollo, Arnett, and Kruk (1982) used both backward masking tasks and temporal integration tasks to investigate age-related changes in stimulus persistence. The results were supportive of increased sensory persistence with age; however, DiLollo et al. carefully differentiated age-related changes in two different systems.

As mentioned previously, stimulus persistence, or iconic memory, may well be the product of a cognitive process rather than the initial stage of information processing (Turvey, 1978). DiLollo et al. adhere to this view and therefore suggest that the increased stimulus persistence evident in older subjects reflects the increased time necessary for the earlier encoding process. And, the greater susceptibility of the elderly to backward pattern masking reflects a reduction in the rate of central cognitive processing speed.
If age-related changes are pervasive throughout the entire information processing system, then decrements in performance should be evident in both attention-demanding and automatic tasks. If automatic processes are not affected by increasing age, the hypothesis of an overall slowing of neural processes must be questioned (Birren, 1974; Salthouse, 1980).

According to a review by Hasher and Zacks (1979), frequency of occurrence judgments are easily made by both young and old subjects, and this information appears to be independent of other information encoded in memory. Hasher and colleagues (Attig & Hasher, 1980; Hasher & Chromiak, 1977; Hasher & Zacks, 1979; Zacks, Hasher, & Sanft, 1982) have conducted a series of studies exploring the developmental aspects of automatic processing employing frequency of occurrence judgments as the experimental task. This paradigm presents lists of items (pictures or words) and varies the number of item repetitions. After list presentation, subjects are then required to estimate the frequency with which each item occurred. Taken together, these studies support the following conclusions: a) There were no developmental differences evident in performance in ages ranging from kindergarten to the elderly (mean age = 68 years). b) Estimates of frequency of occurrence correlated with actual occurrence at .74 and .80 for the elderly and college students, respectively. c) It made no difference if recall instructions were given before or after list presentation; instructed subjects' performance was equivalent to naive subjects. d) Practice did not influence frequency judgments. e) Performance was not inhibited by competing demands such as preparing for an additional experimental task.

The basic frequency of occurrence paradigm was recently utilized in several other studies. Kausler and Puckett (1980) obtained frequency of occurrence judgments,
including incidental and intentional learning conditions (see Attig & Hasher, 1980 and Hasher & Zacks, 1979), and added a paired associate memory task. The data replicated previous research; the frequency of occurrence task revealed high probabilities of correct judgments, no differences were evident between learning conditions, and the elderly subjects performed just as accurately as did the young subjects. Performance on the paired associate task correlated negatively with age. In addition, correlations between performance on the frequency judgment task and performance on the paired associate task did not reach significance, suggesting that separate processes mediated the two tasks.

A distinction has been made by Hasher and Zacks (1979) between automatic processes which are genetically inherent (for which the organism is “pre-wired”) and those automatic processes which are learned through practice. The frequency of occurrence paradigm used by Hasher and colleagues is an example of the former, while processes, such as word perception, that occur in reading, belong to the latter category.

Howard, Lasaga, and McAndrews (1980) employed a Stroop-like task to study the effect of color-naming interference arising from automatic word encoding. Howard et al. (1980) had subjects hold a subspan list of related or unrelated words in immediate memory, while naming the ink color of a tachistoscopically presented word; immediately thereafter, subjects were to recall the memory list. The target word was either unrelated to the memory list, an exemplar of the list, or the category name for the items in the memory list. Interference effects on color-naming were evident in the list-category-name condition, but were greatest in the list-exemplar condition. The older subjects produced longer response latencies, although the latency
differences between the age groups did not reach statistical significance. Most impor-
tantly, there were no significant interactions with age on any of the variables,
suggesting age differences did not affect semantic activation.

Priming effects in older subjects have also been investigated by Rabbitt (1979). In
a letter naming task, priming effects with physically identical stimuli (A-A) were not
affected by age. When a name prime (a-A) was used, however, the prime facilitated
letter naming for the young subjects but not for the older subjects.

Using a different procedure, Madden and Nebes (1980) investigated the
development of automaticity of visual search with young and older subjects. The task
was a paradigm (Schneider & Shiffrin, 1977) in which subjects are given a fixed set of
items to hold in memory and then must decide if a test item is a member of the
memory set. The general outcome with this paradigm indicates that, with consistent
mapping or practice with the same set, automaticity develops accompanied by a
corresponding drop in response latency. Madden and Nebes found that the rate of
automaticity development was the same for both age groups; however, there were
intercept differences, suggesting that the rate of search for the older subjects was
significantly slower.

Research Paradigm

Although considerable evidence supporting a direct semantic access model is
available in the literature (e.g., Fowler et al., 1981; Neely, 1977; Schvaneveldt et al.,
1976), the present research was designed to test automaticity specifically at prerecogni-
tion levels of processing within a developmental framework. Automaticity appears to
operate with children after only one year of reading experience (e.g., Rosinski, et al.,
1975) and persists relatively unchanged across the life span (e.g., Hasher & Zacks, 1979); however, these results accrue from different paradigms, and the focus has differed across studies. In addition to these questions, the particular experimental tasks employed in the present study make it possible to differentiate between age related changes in stimulus detection versus cognitive processing.

In the present study, a semantic priming experiment and an apparent duration experiment were conducted. The priming experiment was modeled after the general paradigm used by Fowler et al. (1981), Marcel (1980), and Meyer and Schvaneveldt (1971). This methodology has shown consistent and reliable effects of semantic access on preconscious processing. Although this particular paradigm has not been used previously with children, category priming (McCauley, Weil, & Sperber, 1976; Ragain, 1980) and lexical decision tasks (Schwantes, 1981) have both been used successfully with young children (second and third graders).

The apparent duration task has provided evidence for the effects of familiarity on prerecognition processing (Avant & Lyman, 1975; Avant, Lyman, & Antes, 1975; Avant et al., 1977). Subjects in this paradigm are never asked to respond directly to verbal information; thus, this experiment has the advantage of providing an indirect measure of the effects of lexical parameters on prerecognition operations. The dependent measure results from operations that are different from the attended operations of the subject, and is, therefore, not influenced by subjects' conscious processing.
EXPERIMENT 1

Method

Subjects

Subjects were 17 fifth and sixth grade children (mean age = 11.7, range = 10.7 to 12.4 years), 13 college students (mean age = 19.9, range = 18.5 to 23.6 years), 15 adults in the 30-40 year age group (mean age = 34.7, range = 30.3 to 39.4 years), and 14 adults in the 50-60 year age group (mean age = 55.5, range = 50.0 to 59.9 years). The children were volunteers from St. Cecilia parochial school, Ames, Iowa, and all had Iowa Tests of Basic Skills reading scores above the 90th percentile according to local norms. The college age subjects were volunteers from undergraduate Psychology courses, and they received course credit for participation. The adult subjects were all University faculty who agreed to participate when contacted by letter or phone.

Stimulus Materials

The stimuli were nouns, ranging from three to six letters, chosen from the Snodgrass and Vanderwart (1980) norms with selection criteria being high imageability and high frequency of occurrence in printed English. Nine conceptual categories (animals, utensils, furniture, body parts, food, tools, clothing, vehicles, and insects) with several exemplars chosen from each category yielded 18 semantically related word pairs which are presented in Table 1. Nonwords were constructed by making anagrams of the words, with letters sequenced to obtain the lowest possible spatial
frequency count according to Mayzner and Tresselt's (1965) single-letter norms. A control condition was included in which the prime was a row of six Xs. Stimulus slides were 2” x 2” transparencies made by typing the letter strings onto Mylar plastic. The vertical visual angle for all letters was 53’, and the horizontal visual angle ranged from 1°19’ for 3-letter stimuli to 2°39’ for 6-letter stimuli. The mask slide consisted of three rows of seven superimposed Xs and Os which subtended a vertical visual angle of 1°33’ and a horizontal visual angle of 3°5’.

Initially, two stimulus sets were constructed; Set 1 was formed by designating one exemplar in each pair as the prime and the other exemplar as the target, and Set 2 was formed by reversing the exemplars used as primes and targets. Final stimulus selection for Experiment 1 was guided by the initial testing of 19 college age subjects with the two stimulus sets; 10 subjects saw Set 1 and 9 subjects saw Set 2. The data showed a marginally significant semantic priming effect only with the Set 1 stimuli (F(2,18) = 3.09, p .07). The decision was made to use the prime-target exemplars designated as Set 1 for the college age group and for all the other age groups in Experiment 1. The Set 1 word pairs are shown in Table 1.

As shown in Table 2, there were three types of semantic priming relationships, determined by the relationship between the prime and the word target: Same Category (e.g., CAT-DOG), Different Category (e.g., DESK-DOG), and Control Prime (e.g., XXXXXX-DOG). On one-half of the trials, the prime was paired with a target word and on the other half of the trials, the prime was paired with a target nonword. The priming relationships illustrated in Table 2 were devised for each of the 18 word pairs shown in Table 1, producing 6 prime-target conditions times 18 word pair exemplars to equal 108 trials for the experiment.
Table 1. Stimuli for Priming Task in Experiment 1

<table>
<thead>
<tr>
<th>Word Prime</th>
<th>Word Target</th>
<th>Nonword Target&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>LION</td>
<td>TIGER</td>
<td>EGTRI (572)</td>
</tr>
<tr>
<td>CAT</td>
<td>DOG</td>
<td>GDO (251)</td>
</tr>
<tr>
<td>BOWL</td>
<td>CUP</td>
<td>UPC (16)</td>
</tr>
<tr>
<td>FORK</td>
<td>SPOON</td>
<td>NSPOO (229)</td>
</tr>
<tr>
<td>CHAIR</td>
<td>COUCH</td>
<td>UCHOC (198)</td>
</tr>
<tr>
<td>DESK</td>
<td>TABLE</td>
<td>ELTAB (567)</td>
</tr>
<tr>
<td>ARM</td>
<td>LEG</td>
<td>EGL (166)</td>
</tr>
<tr>
<td>FOOT</td>
<td>HAND</td>
<td>NDHA (96)</td>
</tr>
<tr>
<td>APPLE</td>
<td>ORANGE</td>
<td>NGERAO (337)</td>
</tr>
<tr>
<td>POTATO</td>
<td>ONION</td>
<td>INNOO (288)</td>
</tr>
<tr>
<td>NAIL</td>
<td>HAMMER</td>
<td>EMHRAM (309)</td>
</tr>
<tr>
<td>WRENCH</td>
<td>SCREW</td>
<td>ERSWC (435)</td>
</tr>
<tr>
<td>SHIRT</td>
<td>BLOUSE</td>
<td>UBELSO (355)</td>
</tr>
<tr>
<td>BOOT</td>
<td>SHOE</td>
<td>ESHO (291)</td>
</tr>
<tr>
<td>CAR</td>
<td>BUS</td>
<td>USB (49)</td>
</tr>
<tr>
<td>TRUCK</td>
<td>TRAIN</td>
<td>RNTAI (492)</td>
</tr>
<tr>
<td>ANT</td>
<td>SPIDER</td>
<td>EDPRSI (317)</td>
</tr>
<tr>
<td>BEE</td>
<td>FLY</td>
<td>LYF (74)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Spatial frequency count as given in Mayzner and Tresselt (1965) norms.
Table 2. Example of Prime-Target Pairs for Experiment 1

<table>
<thead>
<tr>
<th>Prime Target</th>
<th>Prime</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Category Prime</td>
<td>CAT</td>
<td>DOG</td>
</tr>
<tr>
<td>Different Category Prime</td>
<td>DESK</td>
<td>DOG</td>
</tr>
<tr>
<td>Control Prime</td>
<td>XXXXX</td>
<td>DOG</td>
</tr>
<tr>
<td>Same Category Prime</td>
<td>CAT</td>
<td>GDO</td>
</tr>
<tr>
<td>Different Category Prime</td>
<td>DESK</td>
<td>GDO</td>
</tr>
<tr>
<td>Control Prime</td>
<td>XXXXX</td>
<td>GDO</td>
</tr>
</tbody>
</table>
As is also evident in Table 2, each subject saw a particular exemplar three times during the experimental session—one when the target was paired with a semantically related prime, once when it was paired with a semantically unrelated prime, and once when it was paired with the control prime.

A different set of words was chosen from the same norms and, along with the associated low spatial frequency nonwords used for the threshold determination part of this experiment. The stimuli for the threshold task are presented in Table 3.

**Apparatus**

Stimuli were presented in a Scientific Prototype Model GB tachistoscope with luminance levels in all three fields adjusted to 21.58 cd/m² as measured by a Spectra Brightness meter with no stimuli in the fields.

Response latencies for the priming task in Experiment 1 were recorded by a Lafayette timer interfaced with the tachistoscope. The two manual response switches were mounted in a box and placed on the table directly below the tachistoscope eyepiece. Onset of the target stimulus started the clock and the subjects' response stopped it.

**Procedure and Design**

Initially, subjects were familiarized with the tachistoscope and the procedure.

During the first part of Experiment 1, a detection threshold was determined for each subject in the following manner. Stimuli were words and nonwords, pre- and post-masked, presented in the tachistoscope. The subject responded "yes" if he/she thought that a letter string had been presented or "no" if he/she thought that a blank slide had been presented.
Table 3. Stimuli for Threshold Task in Experiment 1

<table>
<thead>
<tr>
<th>Word</th>
<th>Nonword^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>BELT</td>
<td>ELTB (668)</td>
</tr>
<tr>
<td>CHERRY</td>
<td>ERHRYC (390)</td>
</tr>
<tr>
<td>DRESS</td>
<td>ESSDR (612)</td>
</tr>
<tr>
<td>DRUM</td>
<td>RMDU (197)</td>
</tr>
<tr>
<td>LADDER</td>
<td>EDLRDA (366)</td>
</tr>
<tr>
<td>LIP</td>
<td>LPI (45)</td>
</tr>
<tr>
<td>NOSE</td>
<td>ESNO (607)</td>
</tr>
<tr>
<td>PALM</td>
<td>PLMA (461)</td>
</tr>
<tr>
<td>PANTS</td>
<td>NSTPA (298)</td>
</tr>
<tr>
<td>SAW</td>
<td>SWA (330)</td>
</tr>
<tr>
<td>SHEEP</td>
<td>EESHP (541)</td>
</tr>
<tr>
<td>THUMB</td>
<td>UMTHB (325)</td>
</tr>
<tr>
<td>TURTLE</td>
<td>ETLRTU (504)</td>
</tr>
</tbody>
</table>

^aSpatial frequency count as given in Mayzner and Tresselt (1965) norms.
Beginning with an exposure duration of 50 msec, the duration was increased or decreased in 5 msec increments until performance met the following criterion for chance level performance. Trials were presented in blocks of six randomly ordered words and nonwords; performance for each subject was considered to meet the chance level criterion when an exposure duration was determined which resulted in three blocks on which the proportion of correct presence-absence responses was at .50 or less and increasing the exposure duration by 5 msec resulted in better than chance performance (four or more correct responses) on two blocks.

The second part of Experiment 1, the priming task, required subjects to make lexical decisions for the target stimuli. After giving a “ready” signal, the experimenter initiated the trial and the following sequence of stimuli was presented: a) the priming stimulus was presented at the detection threshold duration followed immediately by b) the mask field for 1 sec, c) the target stimulus for 500 msec, and d) the mask field which remained in view until the next trial. Subjects were instructed to respond as quickly and as accurately as possible; if the target stimulus was a word, they were to push the button labeled “word,” and if the target stimulus was a nonword, push the button labeled “nonword.” After the subject’s response and reaction time were recorded, the timer was reset for the next trial.

The design of Experiment 1 resulted in Age (4) as a between subjects variable with Priming Relationship (3), Target Type (2), and Half of Session (2) as within subject variables. One presentation of each prime relationship for each target type resulted in 6 trials; the experimental session included 18 replications for a total of 108 trials. The first 2 replications were considered to be practice trials and were not included in the analysis. The remaining 96 trials were divided equally for first and second half of the
session. The stimuli were independently randomized for each subject; the only constraint was that all conditions were presented equally in the first and second half of the experimental session. Average response latency for each condition was the dependent measure. These data were evaluated in balanced analyses of variance for each group and then an overall analysis was performed which included all four age groups.

Results and Discussion

Threshold Measures

Average threshold durations for the different age groups were: elementary school children, mean duration = 18.5 msec (range = 5 to 30 msec); college subjects, mean duration = 18 msec (range = 4 to 30 msec); thirty year olds, mean duration = 21 msec (range = 5 to 40 msec); fifty year olds, mean duration = 38 msec (range = 15 to 60 msec). Analysis of the threshold exposure durations for the four groups revealed a significant difference among the groups (F(3,55) = 11.78, p < .001). The Newman-Keuls test (α = .01) showed the mean threshold exposure duration for fifty year olds to be significantly greater than that for any of the other three age groups which did not differ among themselves.

Priming Task

Response latency scores for each condition were obtained by calculating, for each subject, an average response latency for all correct trials after the priming stimulus duration interval was subtracted. (The priming stimulus was presented at the subject's threshold duration and therefore was unique for each subject.) The first 12 trials,
considered to be practice trials, were not included in the data. The remaining 96 trials yielded, for each subject, eight responses to each of three types of prime (same category, different category, control) for two types of target (words, nonwords) for each of the two halves of the experiment. Means of those eight response latencies were, then, the measures submitted to analysis.

Errors

Accuracy on the lexical decision task was very high; 47% of the subjects made no errors. Averaged over subjects, errors occurred on only 3.6%, 1.2%, 0.4%, and 0.6% of the trials for the school age, college age, thirty year olds, and fifty year olds, respectively. Given the low error rate, statistical analyses were not performed on accuracy scores. For the response latency analyses, all trials on which errors occurred were omitted.

Within Group Analyses

**Target Type**  Not surprisingly, the analysis for each age group revealed a main effect of target type as words always elicited faster responses than did nonwords (school age, $F(1,15) = 3.55, p < .079$; college students, $F(1,12) = 13.76, p < .003$; thirty year olds, $F(1,14) = 14.07, p < .002$; fifty year olds, $F(1,13) = 15.27, p < .002$).

**Type of Prime: Word Targets**  The semantic relationship between the prime and the word targets was not a significant source of variance with the school age, college age, thirty year old, or fifty year old subjects.

**Type of Prime: Nonword Targets**  The analysis of response latencies for the fifty year old group revealed an interaction between type of target and type of prime that
approached statistical significant \((F(2,26) = 3.13, p < .06)\). Newman-Keuls tests failed, however, to show reliable differences among the mean response latencies for the three prime-target relationships for either word or nonword targets. However, examination of the data indicated that response latencies for control primed (XXXXXX) nonword targets (573 msec) were longer than response latencies for nonword targets primed by either type of word prime (same category = 555 msec, different category = 557 msec). Perusal of the nonword conditions for the other adult groups (college age and thirty year olds) reflects the same general trend as that indicated in the fifty year old group. That is, considering both same category and different category primed nonwords, latencies for nonword targets preceded by either type of word prime were numerically, but not significantly, shorter than those for nonword targets primed with control Xs.

Combined Analysis

Data for the entire sample were submitted to an analysis of variance procedure with Age Group (4) as a between subjects variable and Target Type (2), Priming Relationship (3), and Half of Session (2) as within subjects variables. Mean response latencies (milliseconds) for all levels of these factors are presented in Table 4.

As expected, the main effect of Target Type was significant \((F(1,55) = 31.65, p < .0001)\). Responses to words (534 msec) were 50 msec faster than responses to nonwords (584 msec).

The second half of the session benefitted from practice as shown by a main effect of Half of Session \((F(1,55) = 9.69, p < .003)\). On the average, latencies decreased from 578 msec in the first half to 540 msec in the second half of the session.
Table 4. Mean response latencies in milliseconds for conditions within age groups in experiment 1.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Fifth-Sixth Grade (N=17)</th>
<th>College Age (N=13)</th>
<th>Thirty Year Olds (N=15)</th>
<th>Fifty Year Olds (N=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Category Prime</td>
<td>674</td>
<td>518</td>
<td>486</td>
<td>504</td>
</tr>
<tr>
<td>Different Category Prime</td>
<td>645</td>
<td>503</td>
<td>496</td>
<td>540</td>
</tr>
<tr>
<td>Control Prime</td>
<td>671</td>
<td>514</td>
<td>496</td>
<td>510</td>
</tr>
</tbody>
</table>

First Half

<table>
<thead>
<tr>
<th>Condition</th>
<th>Fifth-Sixth Grade (N=17)</th>
<th>College Age (N=13)</th>
<th>Thirty Year Olds (N=15)</th>
<th>Fifty Year Olds (N=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Category Prime</td>
<td>699</td>
<td>572</td>
<td>543</td>
<td>581</td>
</tr>
<tr>
<td>Different Category Prime</td>
<td>700</td>
<td>560</td>
<td>543</td>
<td>581</td>
</tr>
<tr>
<td>Control Prime</td>
<td>678</td>
<td>600</td>
<td>550</td>
<td>599</td>
</tr>
</tbody>
</table>

Second Half

<table>
<thead>
<tr>
<th>Condition</th>
<th>Fifth-Sixth Grade (N=17)</th>
<th>College Age (N=13)</th>
<th>Thirty Year Olds (N=15)</th>
<th>Fifty Year Olds (N=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Category Prime</td>
<td>630</td>
<td>527</td>
<td>489</td>
<td>532</td>
</tr>
<tr>
<td>Different Category Prime</td>
<td>691</td>
<td>523</td>
<td>504</td>
<td>533</td>
</tr>
<tr>
<td>Control Prime</td>
<td>663</td>
<td>535</td>
<td>527</td>
<td>547</td>
</tr>
</tbody>
</table>

(\(\bar{x}=654\)) (\(\bar{x}=524\)) (\(\bar{x}=503\)) (\(\bar{x}=535\))
Average response latencies differed among groups ($F(3,55) = 4.08, p < .01$). The Newman-Keuls test indicated that the school age children had the longest mean response latency and differed significantly ($\alpha = .01$) from all other age groups. The fifty year old subjects were significantly slower than the thirty year old group ($\alpha = .05$), and the college age subjects did not differ from either adult group.

**Summary**

Results of the priming task make three noteworthy points. First, the data confirm earlier claims that perceptual encoding is slower for the aging subject (Monge & Hultsch, 1971; Simon, 1979). Detection threshold exposure duration varied only 3 msec over the age range from 11.7 years to 34.7 years, but then increased 17 msec for fifty year old subjects.

Second, response latencies for word and nonword target stimuli confirm the finding from various other paradigms that words are processed faster than nonwords (Fowler et al., 1981; Neely, 1977; Reicher, 1969; Wheeler, 1970). The data did not show differences among Age Groups in the processing of word and nonword targets. DiLollo et al., (1982) suggest that low-level sensory processes are fully developed in childhood and gradually deteriorate in the later years. In contrast, more complex cognitive tasks reach a peak later in life and deteriorate more rapidly. The threshold measure certainly represented a low level sensory process; subjects only had to report the presence or absence of a stimulus. When subjects made a lexical decision, however, it necessarily required that contact be made with the subjects' mental lexicon. Thus, according to DiLollo's thesis, this later and more complex task would not show decrements in processing until late in life. The detection threshold data from
the present experiment revealed significant changes by age fifty and thus supported DiLollo's hypothesis that low-level sensory processes gradually deteriorate across the later years. Further, the fact that response latencies for lexical decisions did not change from the college age subjects to the fifty year old subjects supported DiLollo's arguments that more complex tasks would not show decrements in processing until late in life.

Third, semantic priming was not evident for subjects of any age. For the fifty year old group, a marginal interaction between type of prime and type of target showed no differential response to word targets; however, responses to nonword targets showed a numerical, but statistically nonsignificant, influence of type of prime for nonword targets.

These trends were also evident in data for the two other adult age groups and indicate a need to distinguish between a general priming phenomenon in which the broad-range lexical storage of words in general is contacted by the prime and a more specific priming phenomenon in which the specific semantic meaning of a particular word in the lexicon is addressed. These issues will be addressed more thoroughly in the General Discussion.

Although the pattern in lexical decision times to nonwords should be noted and consideration given to possible reasons for this trend, the possibility that these effects are simply the result of a Type 1 error must also be allowed. Since semantic priming with clear statistical support did not occur with any of the four age groups, and only in one age group was there an indication of a differential effect on nonword targets, it is entirely plausible that chance probability can account for the marginal interaction involving nonword targets.
The priming paradigm utilized in Experiment 1 did not provide evidence for an automatic access of long term memory. A different paradigm was used in Experiment 2 to provide another test of early prerecognition processing.
EXPERIMENT 2

Method

Subjects

Subjects were 14 fifth and sixth graders (mean age = 11.57, range = 10.5 to 12.8 years), 10 college students (mean age = 19.30, range = 18.7 to 22.3 years), 15 thirty year old adults (mean age = 34.67, range = 30.0 to 38.4 years), and 14 fifty year old adults (mean age = 54.57, range = 50.7 to 59.3 years). Subjects were selected by the methods described in Experiment 1.

Stimulus Materials

Stimuli were chosen to provide a manipulation of lexical status (words versus nonwords) and a manipulation of the specific semantic relationship among words. Three words (HAND, FOOT, DESK), a subset of the words used in Experiment 1, were chosen to provide the semantic manipulation; two of the three words were from the same conceptual category and the third word was from a different category. Three sets of nonword anagrams were generated from the above three words to obtain nonwords with low, medium, and high spatial frequency counts according to the Mayzner and Tresselt (1965) norms. Initially, testing with the college age subjects (N=30) was conducted with each of the stimulus sets: Set 1, words and low spatial frequency nonwords (NDHA, OTFO, ESDK); Set 2, words and medium spatial frequency nonwords (ANHD, OTOF, EKDS); Set 3, words and high spatial frequency nonwords
Analysis of the pilot data indicated that Stimulus Set was not a significant influence, nor did Stimulus Set interact with the variables of lexical status or exemplar; however, these data did reveal a significant interaction of Exemplar and Lexical Status \( F(2,24) = 3.38, p < .04 \). Based on the testing with college age subjects, a decision was made to eliminate Stimulus Set as a variable. Stimulus Set 1, the three words (HAND, FOOT, DESK) and the three low spatial frequency nonwords (NDHA, OTFO, ESDK) were the stimuli used for Experiment 2. The low spatial frequency nonword set was chosen so as to maximize the differences in orthographic regularity between words and nonwords. Stimuli were presented in a Scientific Prototype Model GB tachistoscope, and the mask slide, luminance level, and visual angles subtended by the stimuli were as described in Experiment 1.

**Procedure and Design**

As in Experiment 1, subjects were initially familiarized with the tachistoscope and procedure. Experiment 2 required subjects to make subjective duration judgments of brief pre- and post-masked stimulus presentations which were separated by a 1 sec pattern mask. A "ready" signal cued subjects to look into the tachistoscope eyepiece and fixate the single blank letter space in the center of the mask. On each trial, the first stimulus was presented shortly after the "ready" signal; the mask returned immediately and remained for 1 sec; the second stimulus was then presented after which the mask returned immediately. Subjects were asked to judge which of the paired stimulus presentations appeared to last longer. All of the stimuli were presented for equal clock time durations, and any systematic differences in subjects' subjective
duration judgments were assumed to be produced by manipulations of the stimulus materials presented in the paired flashes. Exposure duration for stimulus presentations was set at the average detection threshold duration obtained in Experiment 1 for each age group: fifth and sixth grade subjects, 18.5 msec; college age subjects, 18 msec; thirty year old subjects, 21 msec; and fifty year old subjects, 38 msec.

The six stimuli were presented by the method of pair comparisons resulting in $N(N-1)/2 = 15$ judgments. All stimulus pairs were presented for four independently randomized replications of the procedure, resulting in 60 trials for the experimental session. For each subject, the number of “longer” judgments each stimulus received was transformed, by Woodworth and Schlosberg’s (1954, pp. 252-254) procedure, to $z'$ scores. These measures were evaluated in a balanced analysis of variance procedure with Age (4) as a between subjects factor and Lexical Status (2) and Exemplar (3) as within subjects factors. As in Experiment 1, the data for each group were initially analyzed, and then an overall analysis for all age groups was performed.

Results and Discussion

Within Group Analyses

Since automatic processes in reading skill are acquired rapidly in elementary school (LaBerge, 1979), the initial analysis for the fifth and sixth graders considered Grade as a variable so grade differences could be detected. This analysis therefore incorporated Grade (2) as a between subjects variable and Lexical Status (2) and Exemplar (3) as within subjects variables. This analysis revealed a significant interaction between Grade and Lexical Status ($F(1,12) = 6.54, p < .025$). Simple main effect tests showed that the Lexical Status manipulation produced reliable differences.
only at the fifth grade level ($F(1,12 = 4.75, p < .05$). The fifth graders judged nonword presentations to be of longer duration than words. The sixth graders did not reliably discriminate between words and nonwords, although the direction of their discriminations was in the opposite direction; words were judged to be of longer duration than nonwords.

Table 5. Mean $z'$ Scores for Grade X Lexical Status Interaction in Experiment 2: Fifth and Sixth Grade

<table>
<thead>
<tr>
<th></th>
<th>Words</th>
<th>Nonwords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 5* (n=7)</td>
<td>-.074</td>
<td>+.072</td>
</tr>
<tr>
<td>Grade 6 (n=7)</td>
<td>+.046</td>
<td>-.051</td>
</tr>
</tbody>
</table>

*p < .05.

An analysis of variance for the grade school age group was performed collapsing across grade level with Exemplar (3) and Lexical Status (2) as within subjects variables. This analysis revealed a significant interaction between Exemplar and Lexical Status ($F(2,24) = 4.01, p < .05$). This interaction is evident in Table 6 which presents the mean $z'$ scores for all age groups. Simple main effect tests revealed that subjects discriminated between the lexical status of the stimuli only for Exemplar 1, HAND and NDHA, with presentations of HAND being judged longer ($F(1,24) = 4.37, p < .05$). Similar simple main effect tests showed no differences in duration judgments for the words, FOOT, HAND, and DESK, but duration judgments for the nonwords,
NDHA, OTFO, and ESDK, did differ \( (F(2,24) = 3.87, p < .05) \). The Newman-Keuls tests showed NDHA to be judged as shorter than either OTFO or ESDK \( (\alpha = .01 \text{ and } \alpha = .05 \text{ respectively}) \) whereas duration judgments for OTFO or ESDK did not differ. There were no other statistically significant effects in the school age group data.

As discussed in the stimulus materials section, the initial analysis of the college age group data incorporated Stimulus Set as a between subjects variable. This analysis revealed a significant interaction between Lexical Status and Exemplar \( (F(2,24) = 3.38, p < .04) \). Simple main effect tests showed that subjects judged the Exemplar 2 word, FOOT, to be longer than the associated nonword anagrams of FOOT. This analysis also revealed Exemplar differences in the nonword condition \( (F(2,24) = 3.40, p < .05) \). Newman-Keuls tests showed that Exemplar 1 (e.g., NDHA) produced longer duration judgments than Exemplar 2 (e.g., OTFO) \( (\alpha = .05) \), but neither Exemplar 1 nor Exemplar 2 (e.g., NDHA, OTFO) differed from Exemplar 3 (e.g., ESDK).

Between group comparisons could not be made with the entire college age group sample as Stimulus Set was manipulated in this sample, but data for the other three age groups did not include a Stimulus Set manipulation. Therefore, for the remaining comparisons, a separate analysis of variance for the college age group was performed on the data from the 10 subjects in Stimulus Set 1 condition, and this is the analysis used for comparisons among the age groups. The analysis on the college subjects' data for Stimulus Set 1 did not reveal any significant sources of variance. Mean \( z' \) scores for the college age subjects are also presented in Table 6.

Separate analyses of variance were performed for each adult group, thirty year olds and fifty year olds, with Lexical Status (2) and Exemplar (3) as within subjects
Table 6. Mean z-scores for conditions within age groups in experiment 2

<table>
<thead>
<tr>
<th>Lexical Status X Exemplar</th>
<th>HAND FOOT</th>
<th>DESK</th>
<th>Lexical Status</th>
<th>Exemplar</th>
<th>HAND FOOT</th>
<th>DESK</th>
<th>NDHA</th>
<th>OTFO</th>
<th>ESDK</th>
<th>NDHA</th>
<th>OTFO</th>
<th>ESDK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Words</td>
<td>Nonwords</td>
<td>NDHA</td>
<td>OTFO</td>
<td>ESDK</td>
<td>NDHA</td>
<td>OTFO</td>
<td>ESDK</td>
<td>NDHA</td>
<td>OTFO</td>
<td>ESDK</td>
<td>NDHA</td>
</tr>
<tr>
<td>Fifth/Sixth Grades (N=14)</td>
<td>-0.014</td>
<td>0.011</td>
<td>-0.050</td>
<td>0.046</td>
<td>-0.001</td>
<td>0.070*</td>
<td>-0.034</td>
<td>-0.076</td>
<td>-0.168</td>
<td>0.126</td>
<td>0.074</td>
<td></td>
</tr>
<tr>
<td>College Age (N=10)</td>
<td>-0.008</td>
<td>0.008</td>
<td>0.056</td>
<td>-0.051</td>
<td>-0.006</td>
<td>-0.021</td>
<td>0.052</td>
<td>-0.055</td>
<td>0.133</td>
<td>-0.153</td>
<td>0.044</td>
<td></td>
</tr>
<tr>
<td>Thirty Year Olds (N=15)</td>
<td>0.010</td>
<td>-0.009</td>
<td>-0.042</td>
<td>0.014</td>
<td>0.030</td>
<td>-0.020</td>
<td>0.016</td>
<td>0.035</td>
<td>-0.063</td>
<td>0.012</td>
<td>0.024</td>
<td></td>
</tr>
<tr>
<td>Fifty Year Olds (N=14)</td>
<td>-0.035</td>
<td>0.033</td>
<td>-0.089*</td>
<td>0.055</td>
<td>0.031</td>
<td>-0.074</td>
<td>0.029</td>
<td>-0.061</td>
<td>-0.104</td>
<td>0.080</td>
<td>0.122</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05.
variables. Analysis for the thirty year old group revealed no significant sources of variance.

Data analysis for the fifty year old group revealed a main effect of Exemplar (F(2,26) = 3.38, p < .05); Newman-Keuls tests did not indicate reliable differences between the means. However, perusal of the means showed presentations of Exemplar 1 (HAND, NDHA) were judged to be of shorter duration than Exemplar 3 (DESK, ESDK) which, in turn, were judged to be shorter than Exemplar 2 (FOOT, OTFO). Mean z' scores for both adult groups are shown in Table 6.

Combined Analysis

The data for all four age groups were combined in an analysis of variance procedure with Age Group (4) as a between subjects variable and Lexical Status (2) and Exemplar (3) as within subjects variables. This combined analysis showed no significant sources of variance.

The same difficulties of interpretation accompany the results of the second experiment that appeared in the first experiment. When responses to the same stimulus set were evaluated for each of four age groups, and in a combined analysis for all age groups, only the individual analyses for school age children and fifty year old subjects revealed statistically significant sources of variance. This paradigm has not been used before to test these relationships among stimuli with these age groups. While the fragile effects may indicate subtle processing differences that deserve closer experimental scrutiny, they may also be parsimoniously considered Type I errors. Additional research will be needed to clarify the issue.
A TEST FOR RECOGNITION

Several theorists (Allport, 1977; Fowler, et al., 1981; Marcel, 1980) have suggested that pattern masking limits conscious awareness but does not terminate automatic perceptual processing. Subjects in two age groups in Experiment 2 appeared to discriminate between pairs of briefly presented letter strings on a basis other than clock time duration. However, subjects were always surprised to be told that the flashes were actually of equal clock time durations and that different letter strings had been presented on every trial.

To test the assumption that subjects' responses in Experiment 2 were determined by preattentive processing of which the subject was unaware, a replication of Experiment 2 was conducted and followed immediately by a post-experiment recognition test. This experiment employed three stimulus sets to replicate the conditions of Experiment 2 with college age subjects. Stimulus Set (3) was the between subjects variable, and Lexical Status (2) and Exemplar (3) were within subjects variables. All conditions exactly duplicated the conditions of the earlier experiment except that different stimuli were used. Words were SHOE, BOOT, FORK, and, as before, the anagrams for these Stimulus Sets were constructed to be low, medium, or high in spatial frequency redundancy (Mayzner & Tresselt, 1965). Therefore, Stimulus Set 1 included the words and the nonwords, ESHO, OTBO, and RKFO; Stimulus Set 2 included the words and the nonwords, HSEO, BTOO, and KROF; Stimulus Set 3 included the words and the nonwords, EHOS, TOBO, and FOKR. Six college
students participated in each Stimulus Set condition for a total of 18 subjects. Immedi­ately following the apparent duration experiment, subjects participated in a forced choice recognition test. For this test, subjects received, at the 18 msec exposure duration of Experiment 2, individual presentations of the experimental words and nonwords as well as an equal number of new words and nonwords. For each of 48 trials, the subjects' task was to report whether the presented stimulus had been used in the duration judgment experiment or was, instead, a new stimulus.

There were two important results from this additional experiment. Although of secondary importance, the Lexical Status and Exemplar interaction replicated within Stimulus Set 3, the high spatial frequency set (F(2,10) = 9.30, p < .005). Newman-Keuls tests revealed no differences between the words (SHOE, BOOT, FORK); the nonwords did differ significantly with presentations of Exemplar 1 (EHOS) and Exemplar 2 (TOBO) being judged longer than presentations of Exemplar 3 (FOKR) (α = .05 and α = .01 respectively).

The most significant result was that subjects were not able to perform at better than chance level in the forced choice recognition task. Subjects were not able to discriminate between the stimuli used in the experimental task and new stimuli. Thus, the assumption that responses in Experiment 2 were prompted by operations that occurred at a prerecognition level of processing was supported.

Summary

Results from previous research utilizing this paradigm have shown that lexical status of the stimulus input influenced subjects' judgments with relatively longer subjective durations resulting from nonword stimuli and relatively shorter subjective
durations resulting from familiar word stimuli (Avant et al., 1975; Avant & Lyman, 1975). When form familiarity was manipulated by presenting an upright and rotated letter (A) and number (4), preschoolers' processing was similar to college students as both groups judged the more familiar form (upright orientation) to be of shorter duration than the unfamiliar forms (rotated orientation).

If they represent fragile but real effects instead of Type I error, the interaction of Lexical Status and Exemplar within the Grade School Age Group and the differential effect of Exemplar with the older group, evident in Experiment 2, tentatively support the earlier studies, at least in indicating a very early prerecognition contact with long term memory. The analysis of the complete college age sample and the duplication of those conditions in the experiment that preceded the recognition test also revealed an interaction between Lexical Status and Exemplar. The college age sample that could be used for group comparisons consisted of only 10 subjects and this small sample may have hidden real effects. Since, however, the particular pattern of the effects varies with age group—reliable effects of the experimental manipulations are not evident within each group—these apparent effects cannot be clearly distinguished from statistical artifacts.

Earlier data suggested that discriminations depend upon some characteristic of the stimulus input making contact with information that the subject has previously stored. The process may be some type of global “familiarity check” that occurs in the first few milliseconds of information processing and might be easily disrupted by unusual combinations. A recent experiment from Avant's laboratory (Note 5) suggested that while subjects reliably discriminated lexical status of the stimulus input, the direction of the
discrimination was very responsive to subtle manipulations. When the letter case of the stimuli was alternated, the direction of the word/nonword discrimination was reversed. Although the operations performed in this early discrimination have not been clarified, they are certainly nonattentional and result in automatic contact with long term memory.
SUMMARY OF RESULTS FROM EXPERIMENTS 1 AND 2

The data from Experiment 1 indicated that threshold durations were essentially equivalent for the grade school, college, and thirty year old groups but increased significantly for the fifty year olds. The second part of Experiment 1 required subjects to make lexical decisions for word and nonword stimuli which had been preceded by a subliminally presented prime stimulus. Every age group responded to words faster than to nonwords. There was no evidence supporting a semantic priming effect on lexical decisions. The trend in average response latencies for nonword targets suggested that for the three adult groups, word primes marginally facilitated the lexical decision for nonword targets to a greater extent than did the control prime. However, the differences among mean response latencies were marginally significant only in the fifty year old group.

The data from Experiment 2 revealed that the lexical status of the stimuli and the particular letter strings used in this experiment influenced the subjective duration judgments of two age groups. Grade school age children and fifty year olds both showed the influence of these stimulus parameters in their duration judgments. In addition, data from college age subjects, tested with a different stimulus set, also suggested that the stimulus parameters influenced their duration judgments. And a replication of Experiment 2 with college age subjects, accompanied by a post experiment recognition test, gave no evidence that subjects had any recognition of the stimuli used in the
apparent duration task. Thus, evidence was provided that the significant variables in this experiment were operating at a prerecognition level of processing.

The manipulations of lexical status or semantic relationship among the exemplars did not result in reliable and consistent influences on subjects' lexical decisions or subjective duration judgments. As mentioned earlier, the statistically significant effects that were evident may indicate early information processing, but may also be the result of chance occurrence.
GENERAL DISCUSSION AND CONCLUSIONS

This study was designed to address three issues: a) the verification of age-related differences in stimulus detection, b) the thesis that permanently encoded information can influence early prerecognition information processing, and c) the possibility of changes in automatic processing across the life span.

The data from the threshold task in Experiment 1 provided a clear answer to the initial question. Threshold duration measures for stimulus detection did not increase until age 50. These results are in accord with the available literature (e.g., Botwinick, 1978; Corso, 1981; Poon et al., 1980; Walsh & Thompson, 1978).

Developmental Changes in Automatic Processing

There is no argument among theorists that increasing age does produce some decline in the efficiency of visual information processing. The controversy arises over the causes of this age-related change in performance. Theories of life span developmental changes can be classified in one of two ways. Some theorists (Birren, 1974; Salthouse, 1980) begin with the assumption that decrements in performance are the result of a general speed-loss mechanism. A general slowing of neural transmission, then, would inhibit every stage of information processing. This hypothesis is a parsimonious and reasonable explanation of the varied age-related deficiencies in processing.

A large volume of research has been generated from a different perspective. Although not derived from a specific theory, most of the research on developmental
changes in visual information processing has focused on locating the particular stage or stages that are most influenced by increasing age (e.g., Burke & Light, 1981; DiLollo, et al., 1982; Frederich, 1974).

An important advantage of the present study was the separation of stimulus detection from cognitive processing. As mentioned, the detection threshold task provided a measure of changes in early sensory detection. Presentation durations for the automatic processing tasks were then equated, not by clock time, but instead by individual threshold durations. The assumption, of course, was that automatic processing would then be independent of age-related changes in the stimulus detection stage and provide an answer to questions regarding changes in automatic processing across the life span. In addition, this study was intended to provide a test of the two general theories of developmentally related changes. If there is a general speed-loss that is pervasive in the system, beyond stimulus input, then automatic as well as attention demanding processes should reveal decrements. However, if sensory input is the only indication of an age effect, then automatic processing would be unaffected by age and the implication would follow that age differentially affects particular stages or types of processing.

The data did not reveal decrements in automatic processing in the fifty year old group. First of all, average response latencies, while differing from the thirty year olds, were equal to response latencies for the college age subjects. Interpretations from the priming experiment and the apparent duration experiment are made with caution as in both instances, the thirty year old group yielded null results. However, the evidence did not indicate differences in automatic processing with the fifty year old group.
Results of the apparent duration paradigm suggested automatic processing within every age group except the thirty year olds. The pattern of effects differed with particular stimulus materials, but if one considers that these subjective duration judgment differences are products of only a few milliseconds processing, then only very global, easily disruptable effects would be expected. The earlier studies using the apparent duration paradigm revealed more consistent patterns of familiarity discriminations (Avant & Lyman, 1975; Avant et al., 1975, 1977). However, the stimuli used in these earlier studies provided a more dichotomous manipulation of familiarity (e.g., upright and inverted letters and words). As the research with this paradigm has attempted to explicate the parameters of familiarity and their effect on prerecognition automatic processing, the complexity of that processing has become increasingly apparent. That stimulus parameters, such as lexical familiarity, whose very definition comes from long-term knowledge, can influence earliest processing is apparent; however, specific predictions regarding that influence remain elusive.

Hasher and colleagues (Attig & Hasher, 1980; Hasher & Chromiak, 1977; Hasher & Zacks, 1979; Zacks et al., 1982) have found that automatic processing, as measured by memory for frequency of occurrence, did not deteriorate with increasing age. However, it was pointed out earlier that a distinction can be made between innate types of automatic processing and learned automatic processing. The frequency of occurrence paradigm is considered by Hasher and colleagues to be an innate or "prewired" automatic processing skill.

Howard, Lasaga, and McAndrews (1980) found automatic processing of semantically related words, necessarily a "learned" automatic process, to be constant
from age 20 to age 80. And, assuming that they reveal fragile, but real effects, the results of this study, concur with those of Howard et al., (1980) in indicating no decline in learned automatic processing.

The Priming Paradigm

The original intent of this study was to use two paradigms, both testing automatic prerecognition access to long term memory, to provide converging evidence regarding the hypothesis of automatic semantic access. The priming experiment did not provide support for prerecognition processing. A reasonable conclusion would be that a subliminally presented stimulus has no influence on the visual information processing system. However, the influence of subliminal stimuli on subjects' judgments has been indicated in numerous studies (e.g., Allport, 1977; Fowler et al., 1981; Marcel, 1980; Philpott & Wilding, 1979). An alternative explanation could be that the experiment reported here did not replicate previous research because of a procedural difference.

Careful scrutiny of the literature revealed three relevant points. 1) A study by Schvaneveldt and McDonald (1981) found an effect of semantic relatedness when subjects had time to attend to the stimulus; however, they did not find a semantic priming effect with very brief, masked stimuli. Also, subjects made false positive word decisions to nonwords that were structurally similar to words. The authors (Schvaneveldt & McDonald, 1981) proposed a two stage process: a) an initial lexical access in which global, structural stimulus characteristics are processed, and b) a memory driven “second look” which then has full access to semantic memory.

Schvaneveldt and McDonald’s (1981) two stage process could provide a theoretical framework for the present research. The priming task revealed consistent facilitation
for word-primed nonword targets. A briefly presented word prime may succeed in contacting only the very broad characteristics of lexicality or "wordness" and therefore facilitate a conscious decision to a different kind of stimulus, a nonword. This hypothesis can be tested in the future by varying the time the subject has access to the priming stimulus.

2) The second informative point discerned from the literature was that some studies (e.g., Philpott & Wilding, 1979; Shaffer & LaBerge, 1979) found a semantic relatedness interference effect rather than semantic facilitation. The implication was that stimuli related in meaning were competing for common analyzing mechanisms.

3) The third and most important point is that the semantic network model of memory (Collins & Loftus, 1975; Quillan, 1967) has been questioned, particularly with regard to the excitatory spreading activation concept. This spreading activation has been the explanatory concept underlying the priming phenomenon; activation of word units in semantic memory excite units for associated words in the memory network and thus facilitate activation by reducing the threshold for these related word units. An assumption of the Collins and Loftus (1975) model was that semantic memory uses parallel processing; activation spreads simultaneously in all directions from an activated unit.

According to Martindale (1981), this lateral excitatory concept is incompatible with notions of lateral inhibition; closely related category instances should inhibit each other. Martindale proposes that vertical bonds—for example, category names to category exemplars—should be excitatory, and category instances should laterally inhibit other category instances. Using a priming paradigm, Rosch (1975) found evidence for both
excitatory and inhibitory effects and suggested a more complex model of semantic activation dependent on the interaction between strength of the relationship binding category instances and the typicality (high or low) of category instances. Although the semantic network (Quillan, 1967), or the spreading activation (Collins & Loftus, 1975), theory of memory has been of heuristic value, the complexities of the semantic network are not yet clear. A recent study (Koriat, 1981) did not find consistent differential facilitation effects based on the associative strength of the prime and target; but instead, found an interaction between direction of the prime (forward or backward) and amount of practice. Forward priming indicates that the prime was a category name and the target was a category exemplar (e.g., ANIMAL—CAT) whereas backward priming indicates the reverse (e.g., CAT—ANIMAL). Koriat found backward associations were effective primes during the first half of the experimental session and forward associations during the second half.

The implications of the spreading activation network hypothesis for the study reported here are obvious. The stimuli for the priming experiment were chosen as high typicality exemplars within conceptual categories, and the assumption was made that excitatory mechanisms would facilitate recognition for highly related words. However, the highly related words may have been subject to lateral inhibition rather than lateral excitation.

Similar effects would not be surprising in the apparent duration task. Inhibitory relations between semantically related stimuli are probably too subtle in their effects to be revealed by this paradigm. Research is needed to clarify the types of prerecognition operations that can be studied with this paradigm.
The studies cited (Koriat, 1981; Rosch, 1975) were focused on conscious mental operations and therefore are not directly applicable to the paradigm employed herein. However, the underlying assumptions regarding activation of semantic memory should be considered. Studies which have found support for automatic semantic activation (Fowler, 1981; Marcel, 1980; Neely, 1977) have used a variety of prime-target combinations, usually selected from association norms (e.g., Palermo & Jenkins, 1964). Associative relationships (e.g., BREAD-BUTTER) are not the same as category relationships (e.g., DOG-CAT), and thus the choice of stimuli in the present experiment may have been problematic and prohibited a predictable facilitation for highly related prime-target category pairs.

Future research in this area should focus more specifically on stimulus materials selection, first verifying pairs that provide facilitation under supraliminal presentation conditions, and then experiments can be conducted generalizing that facilitation effect to prerecognition conditions.

Summary

The apparent duration experiment provided evidence for automatic prerecognition processing under conditions that met Dixon's (1971) criteria for subliminal, or prerecognition, processing. The particular effects resulting from manipulations of semantic and lexical parameters were not consistent with previous research with this paradigm. Evidence for automatic processing was seen in the children and fifty year old group data and in the college age sample under certain conditions; however, there was no developmental pattern evident in the results from the apparent duration paradigm.
The priming paradigm did not provide evidence for automatic, prerecognition access to semantic memory. Trends in the data suggest the possibility of an early, more general, contact with long term memory which provides a discrimination of "familiarity" or the global characteristics of "wordness."

Evidence was consistent with the literature suggesting a decline in the efficiency of simple detection with age; however, there was no evidence for a decline in other cognitive processing tasks as shown by the speed with which lexical decisions were made and by the prerecognition processing in the apparent duration paradigm.
FOOTNOTE

1 Special thanks are due Juanita Sturm for her assistance in collection of these data.
REFERENCE NOTES


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