# Convergence of listening and reading processing.

# Convergence of Listening and Reading Processing

A Thesis Presented

By

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Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

May 1987

Department of Psychology

Convergence of Listening and Reading Processing

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# A C K N O W L E D G E M E N T S

I would like to express my infinite thanks to Chuck Clifton who not only made this project possible but who answered the same questions over and over again. I would also like to extend a very special thanks to Arnie Well who has been with me since the very beginning. Special thanks go to my research assistant, Kara Kritis, who knows the sentences used in this experiment by heart. Finally, I would like to extend my deepest appreciation to my advisior, Mike Royer, for his infinite patience and continuing support.

ABSTRACT

CONVERGENCE OF LISTENING AND READING PROCESSING

MAY 1987

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The purpose of this thesis was to investigate the nature of the relationship of listening and reading processing. More specifically, an experiment was designed to test the point of convergence of linguistic information from the auditory and visual channels.

Chapter I begins with a discussion of two opposing theories of listening and reading processing; the unitary and dual process views. Under the unitary process view, reading and listening comprehension is the result of the same process. Any differences between the two processes are a result of perceptual differences early in the processing system. The dual process view holds that the differences between reading and listening are sufficient to propose that they are two distinct processes. The implications of these perspectives for educational practice are discussed. Chapter I also includes a discussion of processing theories which propose a particular point of convergence of the two modalities. Chapter I concludes

with a review of the rationale and method of the present study.

Chapter II describes the procedures used to conduct the experiment. It includes a description of the subjects and apparatus used as well as a description of the development of the stimulus materials and design of the study.

Chapter III describes the results of the statistical analyses that test the hypothesis concerning the point of convergence of the two modalities. Results of all other analyses are also described.

Chapter IV includes a discussion of the major conclusions based on the results of the present study. The results indicate that listening and reading processing converge at the word level. The models reviewed in Chapter I are interpreted in light of these findings. Several possible sources of the effect of processing auditory linguistic material on the processing of visual linguistic material are discussed. The chapter concludes with a discussion of implications for educational practice and recommendations for future research.

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# CHAPTER I

# INTRODUCTION

## Two Models of Listening and Reading Processing

Unitary process view. Much of the research in reading and listening comprehension makes the assumption that, after word identification, the cognitive processes and the mental representations elicited by the two modes of input are the same (e.g. Fries, 1963; Goodman, 1966; Kavanagh & Mattingly, 1972; Sticht, 1974; Perfetti, 1985). In other words, a unitary comprehension process is activated regardless of the mode of input (Danks, 1980).

Under the unitary process view, reading consists of listening comprehension plus decoding. Once decoding is mastered, reading is not viewed as a separate skill distinct from general language skills. For example, Sticht (1974) has claimed that reading uses the same language ability and cognitive resources as listening plus the ability to search a visual display and decode print to speech.

The unitary process view suggests that there is a general language ability and reading is just a special case. One researcher who holds this view of reading as a general language ability is Charles Perfetti. Perfetti (1985) has suggested that as a child who is learning to read masters the coding system and adjusts to the

differences between the two modalities, reading becomes a "generalized linguistic activity." This suggests the interpretation of reading difficulties as general language deficits, not as specific reading deficits.

The idea that reading comprehension difficulties are part of a more general difficulty in language comprehension was investigated in a study of memory for discourse and reading comprehension. In this study, Perfetti & Goldman (1976) hypothesized that children who were unskilled in reading comprehension are unskilled in encoding linguistic information in working memory. Particularly important to this hypothesis is an examination of the use of linguistic constituents (such as sentences) as units of analysis in short-term memory. In the first of two experiments, Perfetti & Goldman examined the memory capacity of third and fifth grade children using a probe-digit task. It was found that while fifth graders outperformed third graders on this task, there was no difference between skilled and less skilled readers in the same grade. Skilled and less skilled readers were defined using the Metropolitan Achievement Test.

The second experiment in the study was designed to test memory capacity using a task that was more representative of the process of language comprehension. The same subjects were presented a story a few sentences

long auditorily. Periodically, the story was interrupted and subjects were presented with a probe word from an earlier part of the story. Their task was to provide the word that had followed the probe word in the story. This time, skilled readers did outperform less skilled readers. Perfetti & Goldman concluded that memory for discourse was related to reading comprehension even if short-term memory capacity for digits was not. They interpreted this as an indication that the two tasks were possibly measuring somewhat different factors of memory. Since the differences between the skilled and less skilled readers in memory were obtained in a listening task Perfetti & Goldman interpret their results as supporting the conclusion that reading comprehension difficulties are language comprehension difficulties.

In another study, Berger & Perfetti (1977) compared skilled and unskilled readers in both reading and listening and found that skilled readers outperformed unskilled readers in both modes. Subjects, who were fifth-graders, either listened to or read a passage and were then asked to free recall the story in their own words. They were also asked verbatim comprehension questions. These were questions based directly on what was read or heard and required no inferencing. Skilled readers performed better on both tasks in both modes. This was considered to

suggest that less skilled readers may have less ability to comprehend language in general.

The assumptions that reading is a special case of a more general language ability and that following word identification, the processes of comprehending speech and print do not differ, suggest a number of hypotheses concerning the relationship of reading and listening performance. Sticht asserts several hypotheses concerning listening and reading performance in his book, "Auding and Reading: A Developmental Model" (1974), which exemplifies the unitary process position.

The first hypothesis is that performance in listening will exceed performance in reading until reading skill is mastered, at which time reading and listening comprehension performance will become equal. The second hypothesis is that after decoding skills are mastered, measures of listening comprehension performance will be predictive of performance on measures of reading comprehension Finally, Sticht states that instruction of a particular task in comprehending in listening (e.g. listening for the main idea) will transfer to reading when that skill is acquired.

An important implication of the hypothesis that listening performance exceeds reading performance until reading skills are mastered is the concept of 'reading

potential.' The assumption is that a student's listening comprehension ability level sets an upper limit or potential for their level of reading comprehension ability (Sticht, 1984).

The hypothesis that listening comprehension ability places a cap on reading comprehension ability has also been suggested by Durrell (1969) and Royer, Kulhavy, Lee, & Peterson (1986). Durrell (1969) proposed a reading-listening ratio such that a fully developed reader will have a ratio of 100, a non-reader 0, and developing readers will score somewhere between 0 and 100. Royer et. al., (1986) suggest that given an accurate measure of listening and reading comprehension, students could be classified according to those who are reading at or near their listening abilities and those that are reading well below their listening abilities.

John Carroll (1977) has also written about a concept similar to reading potential. Carroll has proposed a W-O-C Scale (written, oral, and cognitive conceptual ability) to index relative levels of these abilities. According to Carroll, the scores on the written scale should never exceed the scores on the oral scale. Carroll suggests that it is quite difficult to separate reading comprehension skills from more general language comprehension skills or cognitive ability. The idea of the scale is to have some

way of indexing reading comprehension relative to more general language comprehension.

Dual process view. Some researchers have enumerated the differences between the two modalities and have found the list lengthy enough to question the assumption of a unitary process. The dual process position maintains that, although reading and listening share some common elements, there are important differences. The nature of the arguments that there are separate processes for written and spoken language emphasize the ontogenetic development of the two skills, the historical development of speech and writing, or the differences in the nature of the two modalities.

Those researchers who emphasize the differences in the development of the two skills in the individual note such factors as the differences in the acquisition of the two skills. Mattingly (1972) objects to the notion that input by written text and input by speech have a common internal representation early in the processing system for a number of reasons. He suggests that listening is a more natural process than reading because every normal child develops the ability to understand his or her native spoken language. In contrast, children must be deliberately taught to read, and yet many fail to learn to do so despite adequate listening skills.

Miller (1972) has noted that, historically, writing is a much more recent development than spoken language. Further, he notes that writing did not originate as a record of speech but rather that it evolved from pictographs as an alternate form of communication. Danks (1980) has noted that while the historical development of the two modalities is not evidence of any differences in the processing of spoken and written language, it does suggest that the two processes may not be identical.

Other researchers have noted that the two modalities are sufficiently different in their form so as to call for different processing strategies. Mattingly (1972) has noted that auditory linguistic cues must be separated from irrelevant acoustic signals. Moreover the cues are not discrete events but rather consonant and vowels sounds blend into one another. In contrast, information in printed text is presented in discrete units.

Carroll & Slowiaczek (1985) have outlined some of what they consider to be the important differences in form between listening and reading. In listening, the signal decays rapidly; in reading, information is relatively permanent. The rate of information is controlled by the producer in listening; and by the perceiver in reading. Sentences in listening are often fragments; in reading, sentences are usually complete and grammatical. In

listening, there is a great deal of prosodic information; in reading, there is no prosodic information except for what punctuation provides. Carroll & Slowiaczek did a series of experiments showing the importance of prosodic information in listening. They have argued that in listening, the representation of a sentence is affected by information unique to the modality, specifically the prosodic structure in speech.

Kleiman & Schallert (1978) have also noted the importance of intonation and stress in speech. Readers depend on syntactic and semantic cues to determine boundaries. These cues are not as obvious as intonation. Some of the other differences they feel have been largely ignored in research result from the fact that speech and writing are usually intended for different purposes. In speech, the producer and the perceiver are often in the same place and therefore share a nonlinguistic context. They also note that speech tends to be more redundant than reading and contains shorter and more frequently used words.

The idea that the speaker and the listener share a nonlinguistic context is similar to the notion of a 'spatial context' that has been developed by Rubin (1980). The speaker and the listener in the same context can take advantage of a number of gestures that contribute to their

'extralinguistic communication.' Gestures, facial expressions, a nod of the head, all contribute to communication. Words such as 'here' and 'there' can be understood without explanation when the speaker and listener share the same context.

Some researchers have noted that the differences in the two modalities merely reflect the differences involved in the processing of the written and spoken language. Horowitz & Berkowitz (1967) found that subjects differed significantly in their reproductions of a story dependent on their mode of acquisition (listening or reading) and their mode of reproduction (speaking or writing). For example, one of their findings indicates that subjects who listened to the story produced more ideas, and had fewer omissions than those who read. Listeners also produced more distortions of the story. Horowitz & Berkowitz claim that their overall findings show the similarity of speaking and listening on the one hand, and reading and writing on the other; and that the differences between the two modes are both linguistic and cognitive. Their claim is that these differences are not attributable to the mode itself but rather to the thought processes associated with each mode.

Another study that emphasized the differences in processing in the two modalities was Sachs' (1974)

investigation of memory for discourse at short time intervals, presented in both visual and auditory modes. Subjects were presented with a passage in one of the two modes. Passages were interrupted with the presentation of a test sentence which subjects were to judge as either identical to a sentence in the previous passage, or as changed in meaning or form. Subjects did not remember the exact wording of a sentence after 80 syllables of intervening discourse. These results support the notion that linguistic material in a sentence is encoded in an abstract representation. The general pattern of retention of auditory and visually presented information was similar. At zero intervening syllables, changes in meaning and form were well recognized in both modalities. However, as intervening syllables were introduced into the task, differences between the modalities began to appear. One important difference in the pattern of results for the two modalities is the difference found between the two modes in the recognition of active/passive changes. After 40 syllables of intervening material in the auditory condition, semantic changes were recognized better than changes in form. Active/passive changes were recognized as well as other changes in form. In the visual condition, however, active/passive changes were recognized nearly as well as the semantic changes, and both were recognized

better than other changes in form. This conflicts with the view that auditorily and visually presented sentences are encoded as the same abstract representation.

Sachs offered two possible hypotheses to explain this finding. The first is that a change in active/passive voice may be a change in focus or emphasis that is conveyed in speech by stress and inflection. The only cues to this change in reading are the visual arrangement of the words. This may demand that the reader pay more attention to form to discern this change when reading than when listening. The second hypothesis is that the nonlinguistic visual properties of reading may make the spatial reorganization of a sentence a salient change. Active/passive changes were most visually different because they had the greatest rearrangement of words. Both hypotheses propose differences in reading and listening processing.

Sachs found another difference between the two modalities. At the shortest delay interval tested, the auditory information was remembered better than the visual information. This was attributed to a special acoustic-phonetic store that would allow auditory input to be processed by units rather than sequentially. This suggests that the initial processing of reading and listening is different.

Educational implications

Danks (1980) has suggested that the unitary process view has had a notable effect on educational practice. He points out that, in many elementary schools, reading is only taught as a separate subject in the first few grades. Then, reading is no longer explicitly taught but is replaced by the teaching of language arts or English. The practice of teaching reading only until decoding skills are mastered reflects the position that the processes of reading and listening do not differ.

Sticht (1985) has noted that the millions of dollars spent on early intervention programs aimed at increasing children's oral language skills are appropriated in large part with the expectation that skills in oral language ability will transfer to higher reading ability later in school. The implication is that in order to teach reading, listening skills must be improved first.

As noted earlier, some researchers have suggested that listening comprehension ability places an upper bound on reading comprehension ability (Sticht, 1974; Durrell, 1969, Royer, et. al., 1986). The educational implication of this distinction is that it should be possible to produce instructional gains in the reading performance of students who are not reading up to their listening ability.

Danks (1980) has suggested several teaching strategies that might be adopted if, in fact, a dual process view were

more accurate. First, he suggests that the teaching of reading should continue even after children have become skilled decoders. Further, he suggests that skills specific to reading should be emphasized, such as; outlining, analyzing the structure of paragraphs, and learning how to follow styles of argument development. Danks (1980) points out that any knowledge of how the two modalities differ would be useful information in designing specialized reading curricula.

Convergence of Listening and Reading Processing

Despite differing points of view, most unitary and dual process theorists agree that listening and reading share a common processing system at some point along the processing continuum. There is little research aimed at discovering just where these two systems converge.

Kirsner & Smith (1974) in a study regarding modality effects in word identification, examined how information regarding modality of linguistic stimuli is maintained in memory. Two hypotheses were proposed. One possibility is that information regarding the modality of verbal stimuli is available when a unit of the lexicon is activated. If this effect could be demonstrated, it would be evidence in support of separate visual and auditory lexicons. Another possibility is that there is a single lexicon, and

information regarding the modality of verbal stimuli resides elsewhere in memory.

Subjects in the Kirsner & Smith study were presented a lexical decision task visually or auditorily. Each item was repeated a second time, visually or auditorily, after one of four possible pause intervals (0, 3, 15, or 63 seconds). The dependent measure was the decrease in lexical decision time for the second presentation of the stimulus. All stimuli were presented in both modes allowing for comparisons of both intramodality (auditory-auditory and visual-visual) and cross-modality (auditory-visual and visual-auditory) facilitation effects.

If the information regarding the modality of a stimulus is made available through activation of modality-specific lexicons, then facilitation would be expected in the intramodal condition for words, but not for nonwords (assuming that nonwords have no lexical representation), and no facilitation would be expected in the cross-modality condition for words (as separate lexica would have been activated). If there is a single lexicon, facilitation would be expected to occur in the intramodality condition for nonwords as well as words but, no facilitation would be expected in the cross-modality nonword conditions.

Kirsner & Smith suggest several reasons why facilitation may occur in the cross-modality condition for

words. There may be a single lexicon, there may be activation between modality-specific lexicons, and there may be a common phonological encoding component involved in the analysis of visual and auditory verbal stimuli. The design of their experiment, however, distinguishes between the physical and conceptual components involved in the storage of modality information. Both the physical and the conceptual components are present in the intramodal word conditions, the physical component in present in the intramodal nonword condition, the conceptual component in present in the cross-modality word condition, and neither component in present in the cross-modality nonword condition.

Kirsner & Smith's results showed that word recognition time is less for the second presentation of a word when both presentations were in the same modality. This effect diminished as the interval between presentation of the two words increased. A similar pattern of facilitation was present in the cross-modality word condition, although to a lesser extent. In the nonword condition, there was facilitation of time to decide that the stimulus was not a word in the intramodality condition only. There was no response facilitation in the nonword cross-modality condition.

These results suggest several conclusions. First, they indicate that information about the modality of verbal stimuli persists in memory for many seconds. Second, in regard to the locus of this information, while the presence of facilitation in the cross-modality word condition supports the notion of a common lexicon, the presence of greater facilitation in the intra-modality word condition suggests the effect of modality-specific information prior to the convergence of the auditory and visual pathways. Finally, the presence of facilitation in the intramodal nonword condition indicates that modality-specific information is stored in a part of memory that is distinct from the common lexicon.

More recently, Hanson (1981) examined the possible common processing of words presented in both modalities. She presented a written word and a spoken word simultaneously to subjects while varying the level of stimulus analysis needed for response decisions by changing the task instructions. Subjects were to attend to one modality and to make a decision about the semantic, phonological, or physical properties of the attended word. In the semantic task, subjects were asked to decide if the word in the attended modality was a member of a particular semantic category. In the phonological task, subjects were asked to decide if the attended word contained a target phoneme.

The physical task involved decisions about nonlinguistic properties of the stimulus. When the attended modality was vision, the task was to decide whether the word was in upper or lower case. When attending to the auditory modality, the subject was to decide if the stimulus was presented in a male or female voice. Hanson argued that if there is a common representation at any of these levels, then decisions involving that level of analysis of the attended word should be influenced by the unattended word.

Her findings indicate that there was response facilitation in the semantic and phonological tasks, but not in the physical task. In the semantic task, there was facilitation of the response to decide if the attended word was in a particular category when the unattended word was the same word or was a member of the same category. (Redundant trials produced greater facilitations.) In the phonological task, there was facilitation of the response to decide if a target phoneme had been present in the auditory attend condition when the word in the unattended visual modality was the same. No facilitation however, was found in the phonological condition when the attended modality was visual. Two possible explanations were offered for the finding that written words influenced decisions about the phonological properties of spoken words but, spoken words did not influence decisions about

phonological properties of written words. The first is the possible influence of the temporal differences in the presentation of written and spoken words. That is, the phonemic decision in the visual attend condition may be made before the information from the spoken unattended word has a chance to influence responding. The second possibility offered is that subjects in the visual attend condition may have been responding on the basis of the graphemic representation of the word rather than the phonological representation. For example, subjects may have been conducting a visual letter search for the letter 'S' rather than monitoring for the target phoneme spelled with other letters such as 'C.'

In contrast to the results for the semantic and phonological conditions, there was no facilitation of the physical decision for redundant trials for either the auditory or visual conditions. In the auditory attend condition, there was no facilitation of the response to decide if the information was presented in a male or female voice when the visually presented word was the same. In the visual condition, there was no facilitation of the response to decide if the word was presented in upper or lower case when the auditorily presented word was the same.

Hanson concluded that written and spoken words share semantic and phonological processing but there are separate codes specific to each modality that operate on information prior to the point of convergence of the two inputs.

Morton has argued, in his logogen model, that the same system is responsible for verbal responses to written and spoken words (e.g., Morton, 1964c, Morton, 1970). According to Morton, a logogen is a counting device which increments with the input into the logogen system of an attribute. Attributes can be visual properties such as 'three-letter word' or auditory properties. When the logogen count exceeds the critical theshold value an appropriate response can be made (Morton, 1970). The logogen model would account for facilitation effects of the prior presentation of a word by arguing that the operation of a logogen reduces its threshold, and fewer attributes are necessary for a subsequent response. According to the model, a facilitation effect would be expected regardless of the modality of the prior stimulus.

Winnick & Daniel (1970) provided evidence that conflicts with the logogen model. In a study examining the effects of response priming in a tachistoscopic recognition task, they presented subjects with cards which showed either a typewritten word, a picture, or a definition of a word and were asked to respond with the word depicted on

the card. Later, words from the cards, and control words, were shown to the subjects tachistoscopically in a recognition task. The results showed that the thresholds for the words previously seen printed on the cards was lower than the thresholds for words that subjects had given in response to the pictures or definitions, and lower than that of the control words. In fact, there were no apparent differences in thresholds between the picture, definition, and control conditions.

Winnick & Daniel's results were interpreted as showing a perceptual advantage when words have been seen in the same form in the familiarization trials as in the recognition test. Morton (1979) replicated these findings and revised his logogen model accordingly. Prior to the Winnick and Daniel experiment, the logogen model claimed that facilitation could occur through either experience with a word or its production. According to this position, producing a response to the picture condition should have shown the same facilitation as was evidenced in the printed word condition. In light of the Winnick and Daniel results, and the Morton replication, the logogen model was revised to include distinct visual input logogens, auditory input logogens, and output logogens.

The results of these two experiments, and the changes in the logogen model support the view that the visual and

auditory processing systems may even be separate at the word level.

Royer, (1985) in his model of reading from the perspective of a biological metaphor, proposes a convergence of the two modalities at a point in the model called the syntactic/ conceptual level.

The model is hierarchically organized with each level or 'echelon' corresponding to a higher level of analysis of the linguistic input. The nodes, which are at each echelon in the hierarchy, are called 'nurons.' Nurons have many of the basic properties of neurons. That is, they can be excititory or inhibitory; they have thesholds for firing; and they can connect with other nurons. Connections between nurons form when two nurons are activated simultaneously. Networks of interconnected nurons, formed when nurons become simultaneously activated, are called 'nurogens.' Nurogens have similar properties to nurons in that they have thresholds for firing, and they can spread activation to other nurogens.

In reading, visual input causes feature detectors to fire. Nurogens corresponding to letters at the lowest echelon are formed by the simultaneous activation of a set of features detectors that correspond to a particular letter. Nurogens at the letter echelon spread activation to the spelling pattern echelon where nurogens correspond

to orthographic regularities found in English. Nurogens at the word echelon respond to input from the spelling pattern echelon. Word nurogens activate the next level, the syntactic/conceptual echelon. These nurogens consist of syntactic and conceptual categories. For example, there is a concept nurogen for a word as well as a syntactic nurogen that represents its part of speech. Following the syntactic/conceptual level is the episodic echelon. Information concerning frequently occurring events is represented by nurogens at this level. The highest echelon in the hierarchy is the echelon where scriptal knowledge is represented. (See Figure 1 taken from Royer, 1985, p. 163.)

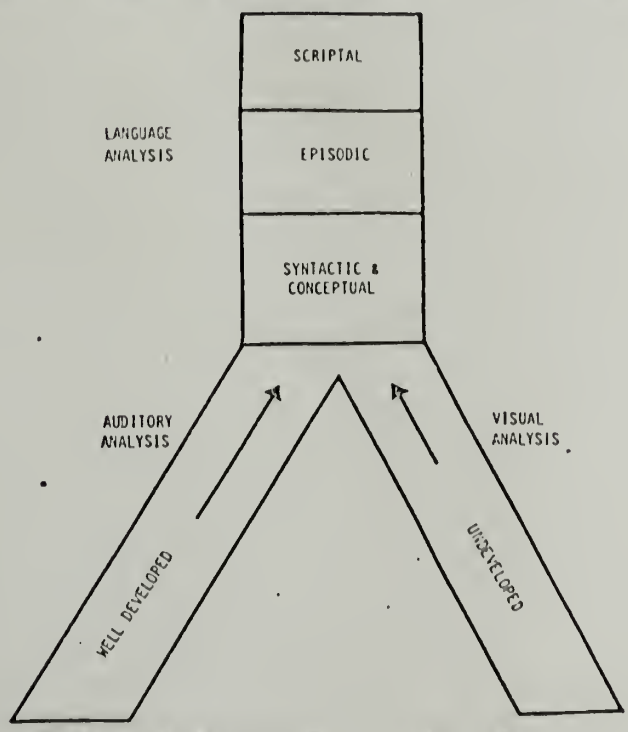



Figure 1. The hierarchical organization of the nurogen.

Auditory input follows an analogous pathway that merges with visual input at the syntactic/conceptual echelon, where nurogens correspond to syntactic and conceptual categories. The assumption that auditory and visual input converge at the syntactic/conceptual level is based on the idea that this level is already highly developed in beginning readers as a function of their experience with spoken language. Also well developed is the auditory analysis branch of speech input, but the nurogens for the visual letter echelon, visual spelling pattern echelon, and visual word echelon for analysis of written input are underdeveloped at this time. (See Figure 2 taken from Royer, 1985, p. 170.)

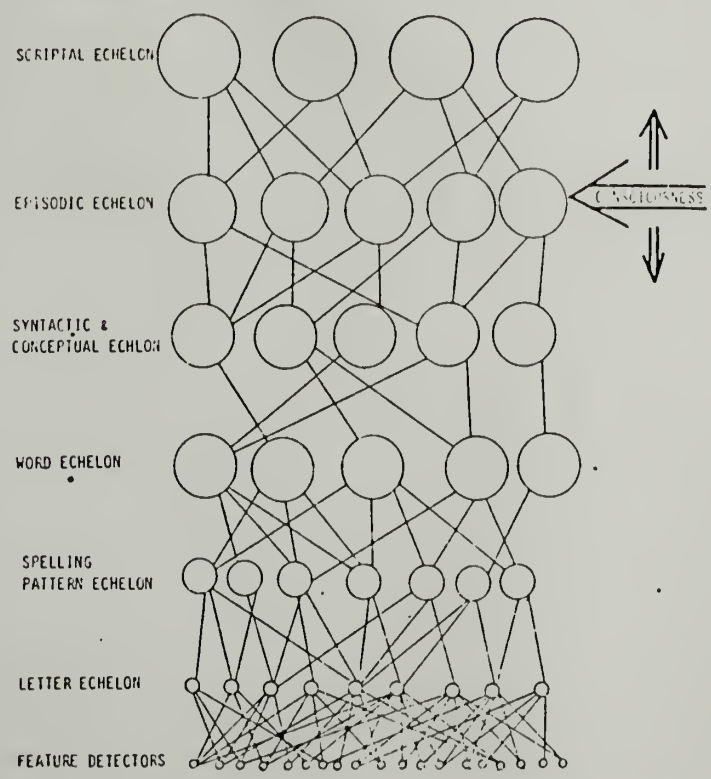



Figure 2. The language analysis system of a beginning reader.

During linguistic processing, nurogens pass excitation through the hierarchy. Activation can spread in an ascending or descending direction. Consciousness rests at the highest echelon where nurogens are currently active. This means that when the reader or listener is having no difficulty comprehending, consciousness rests at the higher echelons. That is, even though the lower levels will be constantly active, the reader or listener will not be consciously aware of letters, words, or even the conceptual nature of the incoming material. Rather, the reader or listener will be aware of the material at the episodic or scriptal level. Consciousness of the reader or listener can, however, be directed to lower levels as needed.

Present Research

In the present study, subjects listened to linguistic stimuli that were designed to activate different levels in the processing system. Shortly after the presentation of an auditory stimulus, subjects were presented with two visual stimuli. The first visual stimulus was either identical to the auditory stimulus, or completely different. The two visual stimuli were either identical to each other or different by one word. The subject's task was to compare the two visual stimuli.

Several studies have used visual same/different matching tasks to analyze sentence processing. Forster,

(1979) in a discussion of the logic of the same/different matching task has noted that response times in the task consist of the following components: 1) the time needed to establish a mental representation of the two stimuli, 2) the time needed to compare the representations, and 3) the time needed to evaluate the outcome of the comparison in terms of the task decision. Forester notes that the technique has been used successfully in the area of word recognition and, that by varying the nature of the stimuli, it can be used to investigate the levels of processing involved in sentence processing. Forester presented semantically plausible sentences, semantically implausible sentences, ungrammatical word strings, and strings of pronounceable nonwords with function words randomly interspersed, in a same/different matching task. Subjects reported using two different strategies for completing the task; one was to read all the words in the first string and then make a comparison, and the other was to compare the two strings word by word. The results showed the fastest decision times for the semantically plausible sentences, followed by the semantically implausible sentences, the ungrammatical word strings, and finally, the nonwords strings. The results indicated that, despite the use of different strategies, subjects were still attempting to interpret the input strings. Forester interpreted these

results as having implications for the utility of the same/different matching task in the analysis of sentence processing.

In another experiment, Freedman & Forster (1985) showed the the effectiveness of the same/different matching task in the investigation of the effects of processing ungrammatical sentences. While a review of the results and interpretations of this experiment are beyond the scope of the present discussion, their procedure is relevant. Subjects were visually presented with two sequences of words, one above the other. A short delay was introduced between the two word sequences to encourage the subject to read the first stimulus in its entirety before comparing it to the second stimulus. In half of the trials, the two stimuli were identical, in the other half they differed by one word, to ensure that the subject was doing the task. Freedman and Forster state that the basic premise underlying the usefulness of this task in analyzing sentence processing is that any linguistic stimuli can be represented at a number of levels at the same time. A visually presented word may be represented as a set of visual features, a letter sequence, a sequence of syllables, or as a word. In order to compare two linguistic stimuli, both must be represented at the same

level, and each element of the representations must be compared.

In a discussion of the Freedman & Forester experiment, Crain & Fodor (1985) provide a different interpretation the results, however, they do not question that the technique of sentence matching can be used to analyze sentence processing.

The purpose of the present research was to test several hypotheses concerning the point of convergence of the processing of aural and written material. While this has been attempted with single words, researchers have not yet investigated this phenomenon using complete sentences.

The present study involved presenting stimuli that may activate various levels of the processing system. For example, linguistic material that is semantically and syntactically correct should be represented up to the meaning level in the processing system. The stimuli in the present experiment that were used to evoke this level of processing are sentences that are semantically and syntactically correct. These stimuli are referred to as 'full good sentences.'

Linguistic material with no possible semantic interpretation cannot have a semantic representation and therefore cannot be represented at a level in the

processing hierarchy where the meaning of sentences is preserved. However, syntactically correct material that has no meaning could be represented at a level where the syntax and the conceptual meaning of individual words was preserved. The stimuli that were used in the present experiment to evoke a representation below that of complete sentences in the processing hierarchy are syntactically correct but have no possible semantic interpretation. These stimuli are referred to as 'syntactic nonsense strings.'

Lists of random words could have a lexical representation but could not be processed up a level representing the meaning of sentences. Groups of real words that together have no semantic interpretation and are not syntactically coherent were used to evoke processing up to the word level. These stimuli are referred to as 'random word strings.'

Nonsense words may be processed up to a phonemic level, but no lexical representation would be activated. Pronounceable nonwords, used to evoke this level of processing, constitute the set of stimuli called 'nonword strings.'

Subjects in the present experiment were presented with a stimulus auditorily, then presented with two visual stimuli of the same type (e.g., all three stimuli were full

good sentences). The auditory stimulus was either the same as the first visual stimulus or different. The two visual stimuli were either the same or different. Subjects were asked to compare the two visual stimuli and decide whether they were the same or different.

The logic behind the study is that the presentation of an auditory stimulus that is represented prior to the point of convergence of the two modalities will have no effect on the processing of similar visual stimuli; whereas an auditory stimulus that can be represented beyond the point of convergence of the two modalities will have an effect on the processing of a similar visual stimulus.

In the present experiment, an auditory stimulus is expected to affect the processing of an identical visual stimulus when the auditory and visual stimuli share a common representation. In other words, the processing of an auditory stimulus may facilitate or inhibit the encoding of a visual stimulus.

Forster (1979) noted that one component of the same/different matching task is the decision process. It may be that the processing of an auditory stimulus may also affect this decision process. In other words, a match between the auditory and visual stimuli may set up an expectation of a match between the two visual stimuli. This leads to the prediction that when there is an effect

of an auditory stimulus on either the encoding of the visual stimuli, the decision process component of the matching task, or both the encoding and the decision processes, there will be an effect on the time necessary to make a response.

In the condition where the auditory stimulus matches both visual stimuli (all three stimuli are identical) there may be an effect on both the encoding of the visual stimuli and the decision process for those stimuli that are processed beyond the convergence of the auditory and visual pathways. In other words, the processing of an auditory stimulus may facilitate the processing of an identical visual stimulus if they share a common representation. When the auditory stimulus is the same as the first visual stimulus this may also affect the decision process in the matching task as subjects' may be primed to say 'same.'

In the condition where the auditory stimulus is the same as the first visual stimulus but the two visual stimuli mismatch, there may be facilitation of the encoding of the first visual stimulus for those stimuli that share a common representation, but there should be no facilitation of the decision process. In fact, as the auditory stimulus is different from the first visual stimulus this may set up an expectation of a mismatch between the two visual stimuli which may inhibition the decision process.

When the auditory stimulus is different from the visual stimuli and the visual stimuli match, there may be inhibition of both the encoding and the decision processes for those stimuli that share a common representation. Finally, when all three stimuli are different they may be inhibition of the encoding process for those stimuli that share a representation, but facilitation of the decision process.

When the auditory and visual stimuli do not share a common representation there may be evidence of the effects on the decision process as described above, but the auditory stimulus should neither facilitate nor inhibit the encoding of the visual stimuli.

If the auditory and visual pathways do not converge until the point in the processing system where the meaning of sentences is represented then an effect of the auditory stimulus on the encoding of the visual stimuli would be expected for the full good sentences stimulus set only. If the two pathways converge at a point in the processing system where syntactical information is represented than the auditory stimulus would be expected to affect the encoding for the full good sentences and syntactic nonsense strings stimulus sets, but not for the random word strings nor the nonword strings. If in fact the auditory and visual pathways converge at the word level, an encoding

effect would be expected when the auditory stimulus is the same as the first visual stimulus for the random word string stimulus set as well as the full good sentence and syntactic nonsense string stimulus sets. And if the two converge at a point prior to the word level, an encoding effect would be expected when the auditory stimulus is the same as the first visual stimulus in the nonword string stimulus set as well as the other three stimulus sets. Finally, if the auditory and visual pathways do not converge, there should be no effect of an auditory stimulus on the encoding of a visual stimulus for any of the stimulus types.

The hypothesis that an auditory stimulus will have an effect on the processing of a visual stimulus, if they share a common representation, will be tested by a comparison of the auditory same and auditory different conditions for each stimulus type. While this comparison does not distinguish between effects due to encoding and effects due to the decision process, a separate comparison of the effect of the auditory stimulus on response times for the visual match/visual mismatch conditions should reveal any effects due to the decsion process alone.

# CHAPTER II

# METHOD

## Subjects

Subjects were 40 undergraduates at the University of Massachusetts recruited from psychology classes. All received class credit for their participation in the experiment.

## Apparatus

The computer used to conduct this experiment was a Godbout CompuPro dual processor which runs CP/M-80 and CP/M-86 operating systems. This system was used to control the presentation of both the auditory and the visual stimuli. Subjects were seated at a CRT that was connected to the computer in an adjacent room. All written stimuli were presented on the computer screen. Subjects were wearing headphones through which all auditory stimuli were presented. In front of the subject, were three buttons on a desk; one on the left and two on the right, which were connected to the computer. Subjects began a set of trials by pushing the button on their left marked 'START.' The two buttons on the right were labeled 'SAME' and 'DIFFERENT.' Subjects used these buttons for responding to the decision task. These response buttons enabled the computer to measure response reaction time.

Materials

The 192 sentences from which stimuli were developed were simple five- to nine-word sentences. They were taken from examples presented in three style manuals (see reference page). These semantically and syntactically correct simple sentences were randomly divided into four groups of 48 sentences each. Each of the four stimulus types were generated from a different set of sentences to eliminate excessive repetition of the same words across trials.

The first set of sentences were used in their original form and they constituted the first stimulus type which were called 'full good sentences.' (See Appendix A for all stimulus sets.)

The next stimulus type to be developed were sentences that were syntactically correct, but have no semantic interpretation. Stimuli for this second stimulus type were generated by replacing words in the second set of sentences with words (of the same part of speech) randomly selected from other sentences in the group. For example, if the first sentence in the group contained a noun, a verb, and a noun; then a noun, a verb, and a noun were randomly selected from the other sentences in the group to form the syntactic string. Function words such as a, and, and the were not replaced. Verbs were changed to agree in number with nouns as necessary. If the resulting sentence could

be considered meaningful, some words were reselected until a syntactic, but meaningless sentence resulted. This process was used to create a 'syntactic nonsense string' for every sentence in the set.

The third stimulus type was the 'random word strings.' These were lists of words that were neither semantically nor syntactically related. These stimuli were generated by scrambling the words in the third sentence set. Function words, prepositions, conjunctions, quantifiers, and auxiliary verbs were omitted to control for differences in reading time between stimulus types as sentences are read more quickly than lists of random words. The length of these stimuli was three or four words long.

The last type of stimuli were 'nonword strings' which were generated by replacing one or two consonants and/or vowels in each content word in the sentences in set four to produce a pronounceable nonword. Function words, prepositions, conjunctions, quantifiers, and auxiliary verbs were omitted from the sentences. Stimuli were limited to three nonwords in each stimulus string.

The lengths of each of the stimulus types was determined in a pilot study. A group of ten subjects listened to all four stimulus types presented at various lengths. (For example, random word strings were presented at lengths of four, five, and six words.) After the

presentation of the stimulus, subjects were asked to do a mental arithmetic problem before recalling what they had heard. For each stimulus type, the number of people who correctly recalled the stimulus was averaged for each length. The length that showed the highest average number correct was selected for use in the study. (Appendix B contains the data from this pilot study.)

A pilot study was also conducted to norm the spelling of the nonwords. Ten subjects listened to the nonwords on the tape recording that was to be used in the experiment. Subjects wrote down their best guess of how each nonword should be spelled. The frequency of the different spelling was tallied. Those nonwords with no clearly preferred spelling were administered again to five more subjects. The most frequently obtained spelling was used in the visual presentation of the nonwords. (Appendix C contains the data from this pilot study.)

For the trials that called for the auditory sentence to be different from either visual sentence, 16 sentences from each group of 48 were randomly selected to be used as 'auditory foils.' These are sentences that were presented auditorily when the condition called for a mismatch between the auditory stimulus and the first visual stimulus.

For trials that called for a subject to compare two visual stimuli and respond 'same' the same stimulus simply

appeared twice in the trial. For the remaining half of the trials, subjects compared two visual stimuli that were different in some way. Changes in the stimuli for the different condition were made by changing the wording of the stimulus string rather than significantly changing the meaning of any of the individual words in the string. This was done in an effort to keep the task demands relatively consistent across trials. In other words, it might be possible for subjects to make a meaning judgment on the full good sentences and the random word strings, but not on the syntactic nonsense strings, nor the nonword strings. By keeping the replacement words similar in meaning, subjects must respond that the two visual stimuli are different even if they have the same meaning. This forces the subject to make wording judgments on all four stimulus types, thus keeping the task consistant on all trials.

To produce the stimuli for the 'different' trials for the semantically and syntactically correct full good sentences, one content word in each of the remaining 32 sentences was replaced with a word of the same length that was similar in meaning; thereby changing the wording of the sentence, but not notably changing the meaning.

Stimuli to be used in trials that called for a response of 'different' for the syntactic nonsense strings were generated in the same manner. This again creates a

change in wording, but leaves the meaning of the individual words in the stimulus string relatively unchanged.

The different stimuli for the random word strings were created by replacing a word, in each of the stimuli, with a word of the same length that was similar in meaning. Again, this creates a different stimulus that differs in wording only, not in meaning of the individual random words in the stimulus string.

Nonword strings were changed for the different condition by replacing a nonword with another nonword of the same length. The difference in these trials was in the letter configurations of the nonwords. All replacement words for the different stimuli were of the same length as the word or nonword being replaced so that subjects could not make judgments based on the relative length of the stimulus strings.

Design

A 4 (stimulus type) x 2 (auditory same/different) x 2 (visual match/mismatch) completely within-subjects design was used. The four stimulus types were the full good sentences, syntactic nonsense strings, random word strings, and nonword strings. The second factor was the relation of the auditory stimulus to the first visual stimulus. The auditory stimulus was either the same as the first visual stimulus or different. The third factor was the relation

of the two visual stimuli to one another. The two visual stimuli were either the same or different.

The four stimulus types within each of four conditions resulted in a total of 16 experimental conditions. On each trial in each experimental condition, subjects were presented with three stimuli, one auditory stimulus and two visual stimuli. The three stimuli were always of the same type (three full good sentences, three syntactic nonsense strings, three random word strings, or three nonword strings). Subjects were asked to make a comparison of the two visual stimuli only.

The relationship of the auditory and visual stimuli in each of the four conditions is depicted in Table 1. In condition one, all three stimuli were identical. That is, the auditory stimulus matched the first visual stimulus; and the two visual stimuli were identical, thus calling for a response of 'same.' In condition two, the auditory stimulus matched the first visual stimulus; but the second visual stimulus differed from the first visual stimulus according to the above description of how the stimuli were generated. This conditions called for a response of 'different.' In the third condition, the auditory stimulus was a completely different stimulus (one of the auditory foils described above) than the two visual stimuli, however it was still of the same stimulus type. The two visual

stimuli were identical to one another. This condition called for a 'same' response. In the fourth condition, the auditory stimulus and the first visual stimulus were

Table 1

Stimulus Sets and Conditions

| Condition | Stimulus Sets | | | |
|---|---|---|---|---|
| | Full Good Sentences | Syntactic Nonsense Strings | Random Word Strings | Nonword Strings |
| 1) All Stimuli Identical (A1=V1=V2) | Samea | Same | Same | Same |
| 2) Auditory and Visual Stimulus 1 Identical (A1=V1≠V2) | Different | Different | Different | Different |
| 3) Visual Stimulus 1 and 2 Identical (A1≠V1=V2) | Same | Same | Same | Same |
| 4) All Stimuli Different (A1≠V1≠V2) | Different | Different | Different | Different |

Note. A1 = auditory stimulus; V1 = first visual stimulus; V2 = second visual stimulus.

aJudgments.

completely different, but were still of the same stimulus type (again, one of the auditory foils). The first visual

stimulus and the second visual stimulus were different from each other according the above description. This condition called for a 'different' response.

Procedure

When subjects arrived at the experiment they were asked to sign a written consent form. This form stated that they were free to leave the experiment at any time and still receive their experimental credit. (A copy of the form is included in Appendix D.) When they had completed the form and had agreed to participate in the experiment, the experimenter familiarized them with the nature of their task and how to use the response buttons by reading the following instructions:

> "I am interested in the nature of the processes involved in listening and reading comprehension. I will be asking you to listen to some information that will be presented over your headphones, and to respond to written information that will be presented on the computer screen. When you are comfortable, you may begin the experiment by pressing the button on your left."
>
> "At the beginning of each trial the message, "Press left button for next trial" will appear on the computer screen. You will start each trial by pressing the button on your left. When you press this button, you will hear some sentences, words, or nonsense words over the headphones. Please listen carefully to what you hear. Immediately after you hear this information, watch the screen. Two lines containing sentences, words, or groups of letters will appear on the screen, one at a time. Your task is to make a judgement about these two lines. If the two lines on the screen are exactly the same, respond by pressing the button labeled "SAME" in

> front of you on your right. If there is <u>any</u> difference in any of the words or letters in the two lines on the computer screen, respond by pressing the button labeled "DIFFERENT" in front of you on your right. Respond as quickly, but as accurately as you can. After each trial you will receive feedback as to whether you have responded correctly. If you find that you are making more than a couple errors, you are probably responding too quickly. The idea is to respond as quickly as you can, while making as few errors as possible.
>
> You may want to rest your fingers on this center button, respond by hitting the appropriate button, and then return your fingers back to the center button between responses like this. (experimenter demonstrates) Do you have any questions?"

If subjects had any questions they were answered by the experimenter at this time. The experimenter then said,

> "If you feel you understand the task, you may begin a set of eight practice trials by pressing the start button on your left."

When the subject understood the task, they were presented with eight practice trials, two from each of the four conditions using two sentences from each stimulus type. Therefore, they had the opportunity to respond SAME in four trials and DIFFERENT in four trials, as well as to see each of the four different stimulus types. If subjects responded correctly to all eight practice trials they were instructed as follows:

> "Very good. You answered each of those trials correctly. I will leave you now to respond to the rest of the trials on your own. However, I will be in the adjacent room if you have any questions. Remember, begin each trial by

pressing the button on your left. You will have the opportunity to take a break now and then during the experiment. When you have completed all the trials, I will be back to give you your experimental credit. At that time I will provide you with written feedback, and I will answer any questions you may have concerning the intended purpose of the experiment. It should take you about a 20 minutes to complete all the trials."

If subjects made any errors, the experimenter said:

"You answered (number) of the eight trials correctly. Remember, while it is important to respond quickly, accuracy is also very important. You may need to take a bit more time to make sure you are correct before responding."

If the subject understood the nature of their errors they were then instructed to begin as described above. At this time, the experimenter went to the adjacent computer room. Each trial began with the words "Press left button for next trial" displayed on the screen. Subjects were instructed to begin a trial by pressing the left-hand button. Upon pressing this button the message went off the screen and subjects were immediately presented with an auditory stimulus. Two visual stimuli were then presented on the computer screen following the auditory stimulus. The first visual stimulus was presented immediately at the offset of the auditory stimulus. All the words or letters of the visual stimulus appeared on the screen simultaneously. Following the presentation of the first visual stimulus, a half-second pause was introduced to encourage the subjects to read the first stimulus in its

entirety. (See Freedman and Forster, 1985 for a similar procedure.) Following the pause, the second visual stimulus appeared on the screen in its entirety. This stimulus was positioned below the first visual stimulus such the two stimuli were vertically aligned. Both visual stimuli remained on the screen until the subject had made a response of 'same' or 'different' by pressing one of the two response buttons in front of them.

Upon making a response, subjects were given feedback as to whether their response was correct. When they were correct, the word "CORRECT" would appear on the screen immediately following their response. If they had made an incorrect decision, the word "ERROR" would appear on the screen immediately following their response. Subjects were given feedback for two reasons. First, so that they would be reminded on each trial they were making their decision based on the comparison of the two visual stimuli and not a comparison of the auditory stimulus and the first visual stimulus. Secondly, they were given feedback so that they could monitor their accuracy so as to keep a reasonable balance of accuracy and speed.

Reaction time to make the response was automatically measured by the computer. Timing for the reaction time measure began at the onset of the second visual stimulus and ended when the subject made a response. Subjects

completed 128 trials, during which each subject saw every stimulus type presented in every condition.

Experimental conditions and stimulus types were presented in one of four random orders to minimize the effects of order of presentation. Development of the four random orders involved several steps. First, the stimuli in each group (excluding the auditory foils) were numbered from 1 to 128. The full good sentences were numbered from 1 to 32, the syntactic nonsense strings were numbered from 33 to 64, the random word strings were numbered from 65 to 96, and the nonword strings were numbered from 97 to 128. Four random orderings of the numbers 1 to 128 were then generated by computer. This determined the order of presentation of the stimuli. The condition each stimulus would appear in was determined in such a manner that each stimulus would appear in different conditions in each of the four orders (see Table 2). The same stimulus must appear in every condition, but not for the same subject, in order for the appropriate comparisons to be made.

Tape recordings of the auditory stimuli were made in these four orders substituting an auditory foil whenever the auditory stimulus was to appear in a different condition (condition 3 or 4). Four orders of the visual stimuli were developed in correspondence with the four tape recordings such that subjects who listened to a particular tape would

see the appropriate visual stimuli presented on the computer screen. Subjects were randomly assigned one of the four presentation orders. After subjects completed all trials, and prior to being dismissed, they were

Table 2

Assignment of Stimuli to Conditions

| | Random Orderings | | | |
|---|---|---|---|---|
| Stimulus Number | A | B | C | D |
| 1,2,9,10,17,18,25,26 . . .a | 1b | 2 | 3 | 4 |
| 3,4,11,12,19,20,27,28. . . | 2 | 3 | 4 | 1 |
| 5,6,13,14,21,22,29,30. . . | 3 | 4 | 1 | 2 |
| 7,8,15,16,23,24,31,32. . . | 4 | 1 | 2 | 3 |

aNumbers continue in this manner through 128.
bNumbers represent conditions 1-4 (see Table 1 for conditions).

provided with written feedback. (A copy of the written feedback form is included in Appendix D.)

# CHAPTER III

# RESULTS

A preliminary analysis of variance (ANOVA) revealed that there were no significant differences due to order of presentation of the trials. The average percentage correct response rate across all conditions was 95%. Four subjects were replaced; one due to equipment problems, and three whose response times were above 5000 milliseconds (msec.) on two or more trials. Separate analyses of variance were conducted on stimulus items and on subjects. Table 3 shows the means and standard deviations for all conditions for the subjects analysis.

## Test of Reading and Listening Processing Models

Analyses were conducted to test the hypothesis that reading and listening converge at some point along the processing continuum. The results were analyzed using a 4 (stimulus type - full good sentences, syntactic nonsense strings, random word strings, nonword strings) x 2 (auditory stimulus same/different) x 2 (visual stimuli match/mismatch) completely within-subjects analysis of variance (ANOVA) in which time to decide whether the two visual stimuli were the same was the dependent measure. Table 4 presents the results of this analysis.

The analysis that tested the hypothesis that the

processing of an auditory stimulus would affect the processing

Table 3

Means and Standard Deviations For All Stimulus Types and Experimental Conditions

| Condition | Stimulus Type | | | |
|---|---|---|---|---|
| | Full Good Sentences | Syntactic Nonsense Strings | Random Word Strings | Nonword Strings |
| 1) Auditory Match/ Visual Match (A1=V1=V2) | 1714a<br>378b | 1964<br>469 | 1597<br>351 | 1700<br>448 |
| 2) Auditory Match/ Visual Mismatch (A1=V1≠V2) | 1422<br>304 | 1554<br>327 | 1393<br>285 | 1340<br>330 |
| 3) Auditory Mismatch/ Visual Match (A1≠V1=V2) | 1993<br>489 | 2276<br>601 | 1887<br>417 | 1891<br>536 |
| 4) Auditory Mismatch/ Visual Mismatch (A1≠V1≠V2) | 1595<br>335 | 1669<br>450 | 1469<br>344 | 1285<br>316 |

Note. A1 = auditory stimulus; V1 = first visual stimulus; V2 = second visual stimulus.

aMean reaction time rounded to the nearest msec.
bStandard deviation rounded to the nearest msec.of a visual

stimulus, when the two stimuli share a common representation, was the interaction between the auditory stimulus same/different conditions and stimulus type. This analysis was significant in the subjects analysis [$F(3, 117) = 5.95$, $p < .01$] and in the items analysis [$F(3, 124) = 5.66$, $p < .01$.

Table 4

ANOVA TABLE

| SV | DF | MS | F-VALUE | P< |
|---|---|---|---|---|
| Stimulus Type (A) | 3 | 3093120.09 | 63.26 | .01 |
| Error | 117 | 48891.62 | | |
| Auditory Stimulus Same/Different (B) | 1 | 4832255.84 | 57.13 | .01 |
| Error | 39 | 84575.17 | | |
| Visual Comparison (C) | 1 | 27300865.65 | 158.11 | .01 |
| Error | 39 | 172665.45 | | |
| AB | 3 | 211199.99 | 5.95 | .01 |
| Error | 117 | 35439.59 | | |
| AC | 3 | 397183.99 | 10.41 | .01 |
| Error | 117 | 38152.75 | | |
| BC | 1 | 1419903.99 | 44.21 | .01 |
| Error | 39 | 32114.87 | | |
| ABC | 3 | 35882.67 | 1.01 | .39 |
| Error | 117 | 35443.96 | | |

Bonferroni t tests were used to identify the source of the interaction. A family-wise error rate of .0125 was used based on the number of contrasts involving two means. For three of the four stimulus types, reaction times to decide if the two visual stimuli were the same or different were significantly faster when the auditory stimulus was

the same as the first visual stimulus than when the auditory stimulus was different. The three stimulus types for which this difference was significant were: full good sentences, $t(39) = 5.596$, $p < .0125$, syntactic nonsense strings, $t(39) = 5.785$, $p < .0125$, and random word strings, $t(39) = 6.369$, $p < .0125$. There was no significant difference in reaction time, however, between the two auditory conditions for the nonword strings, $t(39) = 2.208$, $p > .0125$. Figure 3 shows the graph of the interaction.

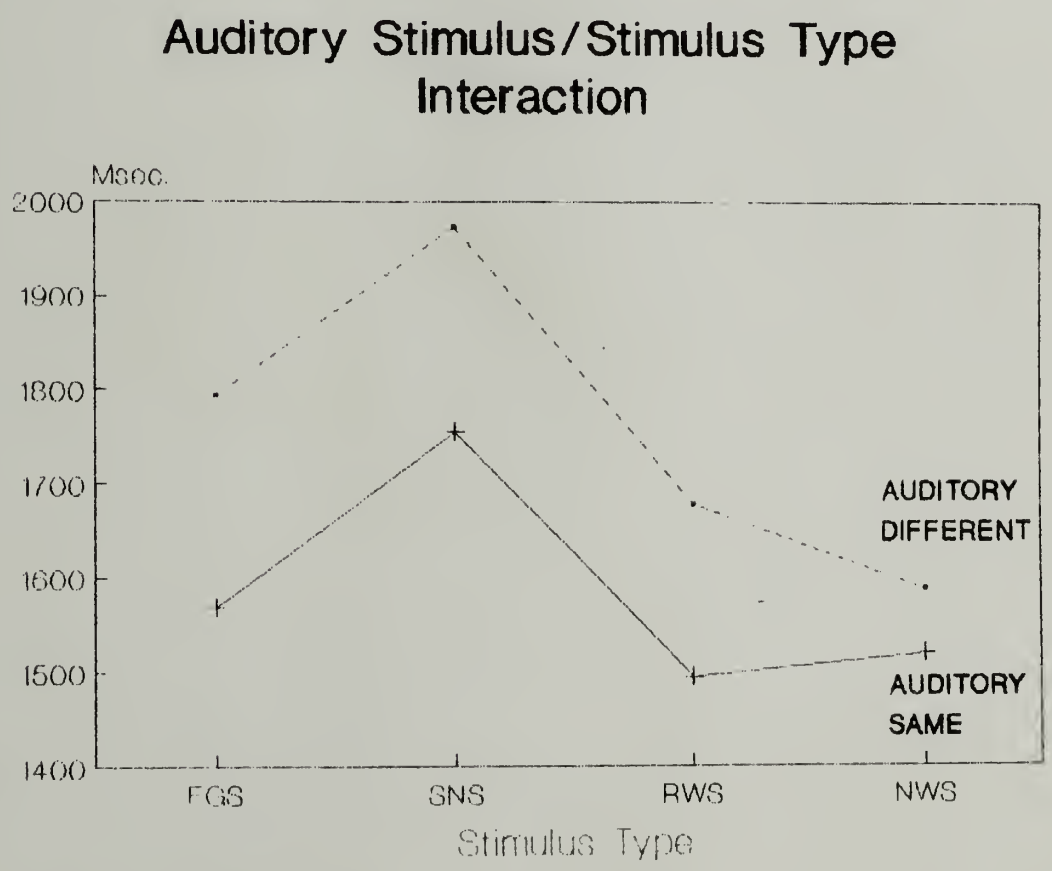



Figure 3. Mean reaction times under auditory same and auditory different conditions for each stimulus type.

Contrasts were also used to compare the differences between the auditory same and auditory different conditions for each stimulus type. A family-wise error rate of .01 was used based on the number of contrasts involving four means. Comparisons between the magnitude of these differences for the three stimulus types, which were significant in the previous analysis, revealed no significant differences. That is, the differences between the auditory same and auditory different conditions for the full good sentences, syntactic nonsense strings, and random word strings were comparable.

These analyses demonstrated that if the auditory stimulus was the same as the first visual stimulus there was an effect on the time to decide if the two visual stimuli were the same or different for full good sentences, syntactic nonsense strings and random word strings. Moreover, for the three stimulus types that showed a significant effect of the auditory stimulus, the magnitude of the effect was not significantly different.

Although not significant, there was a 68 msec. difference between the auditory same and auditory different conditions for the nonword strings. An examination of the interaction of auditory stimulus and stimulus type, separately for the visual match and visual mismatch conditions, revealed that the source of this effect for the

nonword strings is the significant difference between the auditory same and auditory different conditions when the visual stimuli matched. (This difference was significant for all four stimulus types at the .0125 level.) No significant difference was found between the auditory same and auditory different conditions for the nonword strings, however, when the visual stimuli mismatched ($p > .05$). This difference was significant, however, for the full good sentences, and syntactic nonsense strings ($p < .0125$) and marginally significant for the random word strings ($p = .062$).

Figures 4 and 5 show the auditory stimulus/stimulus type interaction for the visual match and visual mismatch conditions separately.

Comparisons of the differences between the auditory same and auditory different conditions for each stimulus type, reveal that the magnitude of these differences were comparable for the match condition. For the mismatch condition, the magnitude of these differences were comparable for the full good sentences, syntactic nonsense strings, and random word strings. This difference for the nonword strings, however, was significantly different from each of the other three stimulus types. (Appendix E contains a tables of the means, t-values, and p-values for all the above contrasts.)

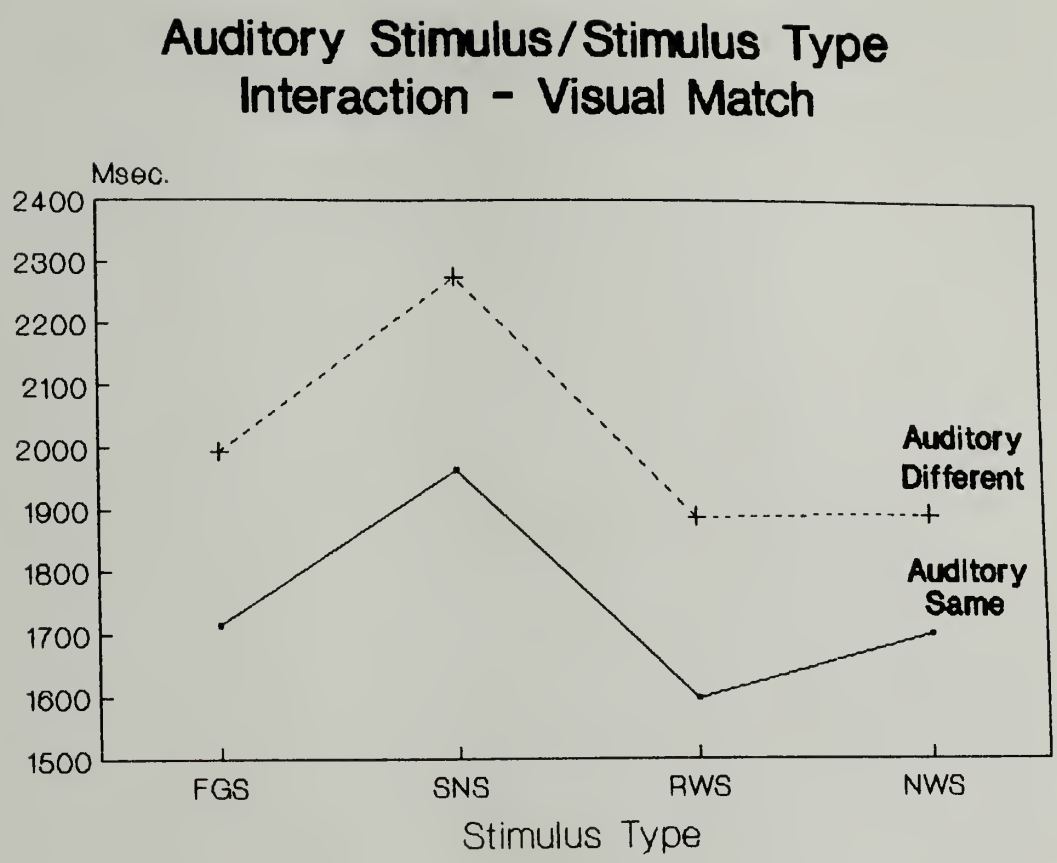



Figure 4. Mean reaction time for auditory stimulus/stimulus type interaction for the visual match condition.

Other Results

Effect of stimulus type. The analysis of variance revealed a significant main effect for stimulus type both in the analysis of subjects [$F(3, 117) = 63.26$, $p < .01$] and in the analysis of items [$F(3, 124) = 9.74$ $p < .01$]. The mean reaction times for groups in msec. were: full good sentences = 1681, syntactic nonsense strings = 1863, random word strings = 1586, and nonword strings = 1554. Note that the nonword strings, which show the fastest reaction time, were the shortest in length (three nonwords

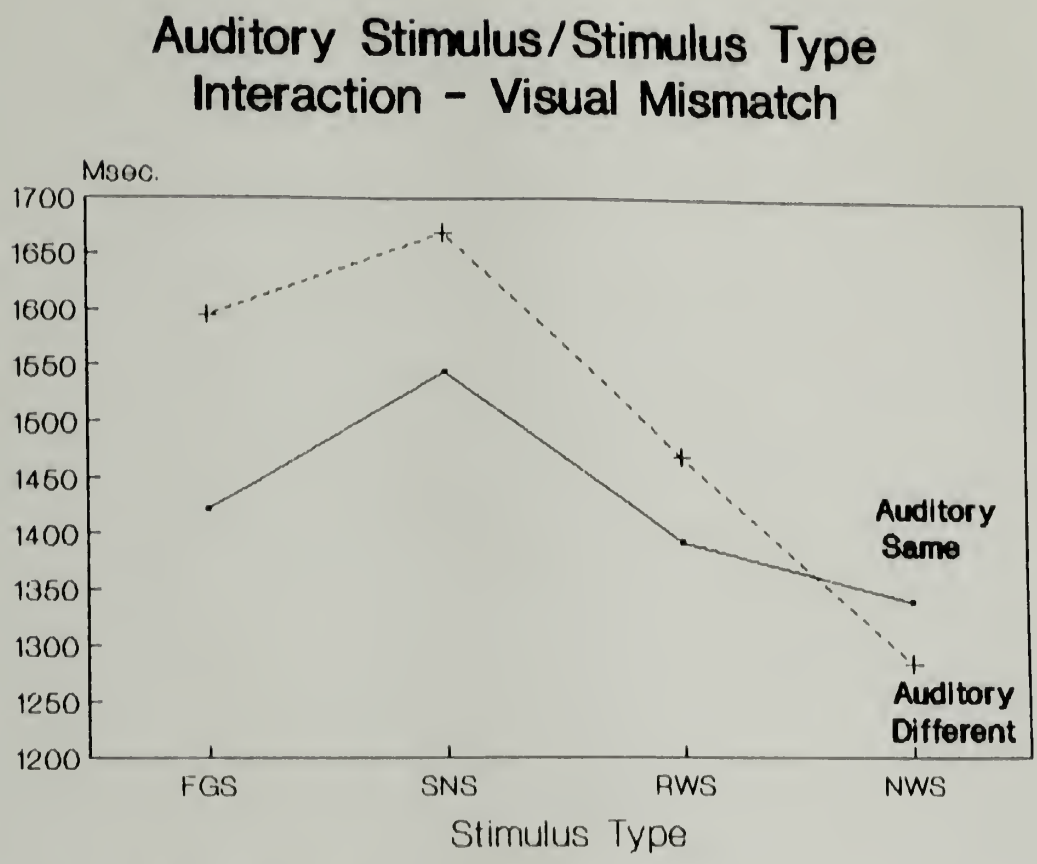



Figure 5. Mean reaction time for auditory stimulus/stimulus type interaction for the visual mismatch condition.

in a string). The syntactic nonsense strings, which show the slowest reaction time, were of the same length as the full good sentences (seven to nine words) but less familiar to subjects than common sentences. The random word strings were three to four words in length.

By dividing the mean reaction time for each stimulus type by the number of words in the string, a mean reaction time per unit was calculated. These means per unit in msec. were as follows: full good sentences = 210, syntactic

nonsense strings = 232, random word strings = 453, and nonword strings 518.

Effect of visual comparison. The main effect for the comparison of the two visual stimuli was also significant for both subjects [$F(1, 39) = 158.11$, $p < .01$] and items [$F(1,124) = 325.16$, $p < .01$]. When the two visual stimuli matched each other, the mean reaction time was 1878 msec. When there was a mismatch between the two visual stimuli the mean reaction time was 1465 msec. The means for the two groups show that subjects were on average 413 msec. faster to decide if the two visual stimuli were the same or different when they were in fact different. This effect shows that subjects were faster to make a decision about two visual stimuli when they did not match than when they did match for every stimulus type. This result is sensible if it is assumed that when faced with a comparison task subjects need to compare both stimuli in their entirety to make accurate judgments when the two stimuli are identical. When they are different a subject can terminate the comparison process as soon as they read one word in the second stimulus that does not match a word in the first stimulus.

Interaction of visual comparison and stimulus type. The interaction between the visual comparison and the stimulus type was significant in the subjects analysis

[$F(3, 117) = 10.41$, $p < .01$] as well as in the items analysis [$F(3,124) = 5.35$, $p < .01$]. Figure 6 shows a graph of the interaction.

Contrasts using the Bonferroni t procedure showed that for all four stimulus types reaction times were always faster when the two visual stimuli were different from one another. Based on the number of contrasts involving two means, a family-wise error rate of .0125 was used.

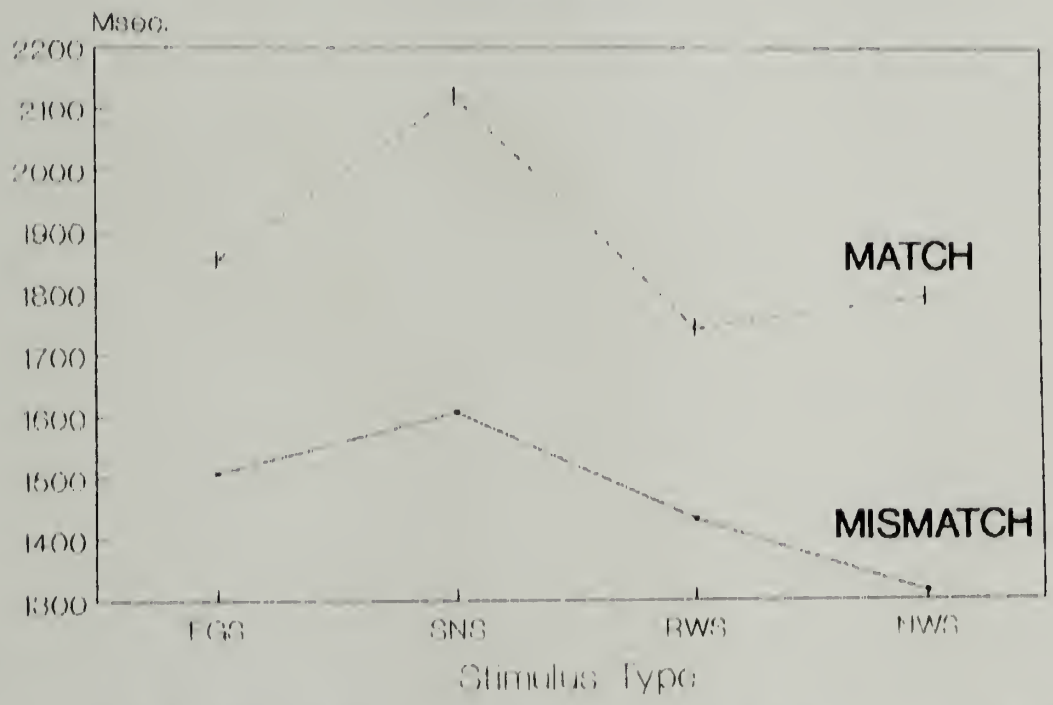
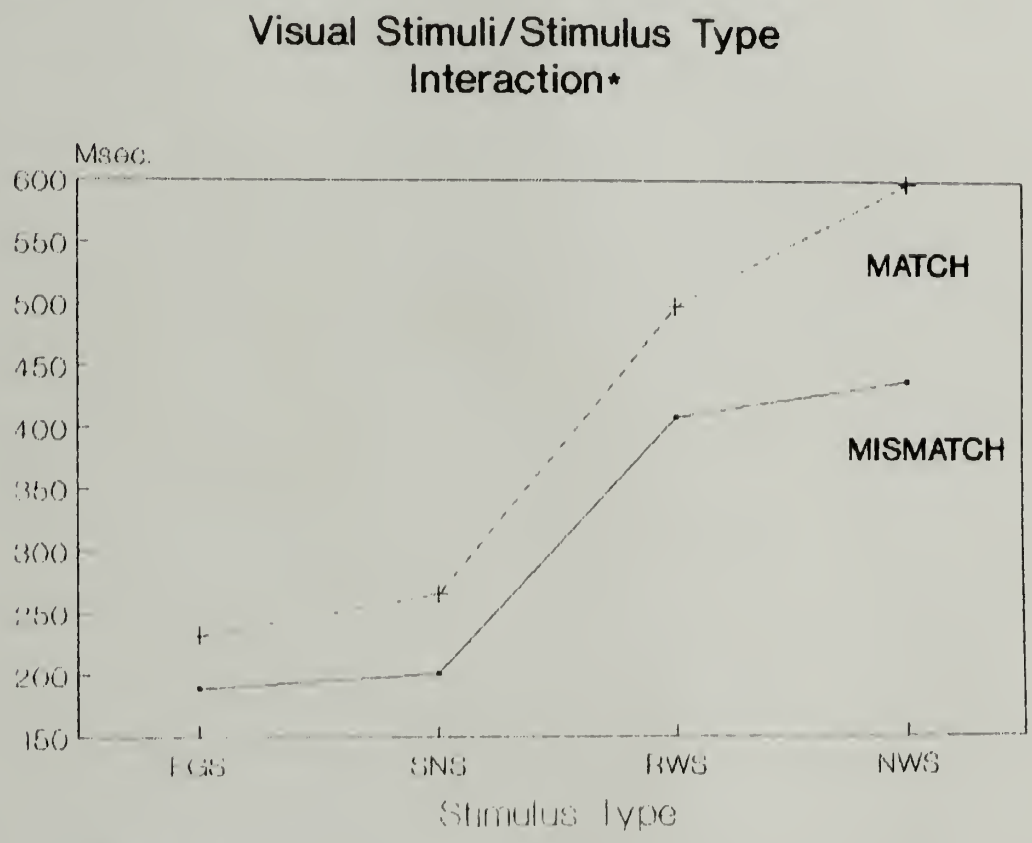



Figure 6. Mean reaction times for the visual match/visual mismatch conditions for each stimulus type.

The visual mismatch condition was significantly faster than the visual match condition for the full good sentences,

$t(39) = 9.087$, $p < .0125$, the syntactic nonsense strings, $t(39) = 11.714$, $p < .0125$, the random word strings, $t(39) = 8.277$, $p < .0125$, and the nonword strings, $t(39) = 9.851$, $p < .0125$. No further contrasts to investigate the source of the interaction were done as there was a confounding between stimulus type and stimulus length. However, unit processing times were calculated and Figure 7 shows the interaction depicted in unit processing time.




*in unit processing time

Figure 7. Mean reaction times for for the visual match/visual mismatch conditions for each stimulus type.

Note that there was a steady increase in the difference between the match and mismatch conditions across the four stimulus types. For full good sentences this difference was 43 msec., for syntactic nonsense strings it was 64 msec. This differences increased to 89 msec. for random word strings and to 161 msec. for nonword strings.

Effect of auditory stimulus. The main effect of auditory stimulus was also significant for subjects [$F(1, 39) = 57.13$, $p < .01$] as well as items [$F(1,124) = 114.18$, $p < .01$]. The mean reaction time when the auditory stimulus was the same as the first visual stimulus was 1584 msec. When the auditory stimulus was different from the first visual stimulus the mean reaction time was 1758 msec. The means for the two conditions showed a difference of 173 msec., on average, of time to respond to the visual stimuli when the same stimulus had been presented auditorily as compared to when a different auditory stimulus had been presented. This effect shows that on average subjects were faster to respond to two visual stimuli when they have been preceded by a matching auditory stimulus than when the preceding auditory stimulus was unrelated. This result provides support for the notion of cross-modality effects in general.

Interaction of auditory stimulus and visual comparison. The interaction between the auditory stimulus

same/different conditions and the visual stimuli match/mismatch conditions was significant both in the subjects analysis [$F(1, 39) = 44.21$, $p < .01$] and in the items analysis [$F(1, 124) = 28.30$, $p < .01$]. Figure 8 shows the graph of the interaction.

Contrasts revealed that there was a significant difference between the auditory conditions when the two visual stimuli matched, $t(39) = 8.67$, $p < .0125$, as well as when the visual stimuli did not match $t(39) = 3.55$, $p < .0125$. There was also a significant difference between the visual match and mismatch conditions both when the auditory stimulus was the same $t(39) = 9.44$, $p < .0125$, and when the auditory stimulus was different $t(39) = 13.46$ $p < .0125$. This indicates that decisions about two dissimilar visual stimuli were always faster than decisions about two identical visual stimuli regardless of whether the auditory stimulus was the same or different. It also indicates an effect of a matching auditory stimulus both when the visual stimuli matched and when they mismatched.

This interaction shows that there was an advantage of the self-terminating search in the visual mismatch condition over the exhaustive search for the visual match condition both when the auditory stimulus was the same as the first visual stimulus and when it was unrelated to the first visual stimulus. It also shows that there was an

effect when the auditory stimulus matched the first visual stimulus even when the two visual stimuli did not match.

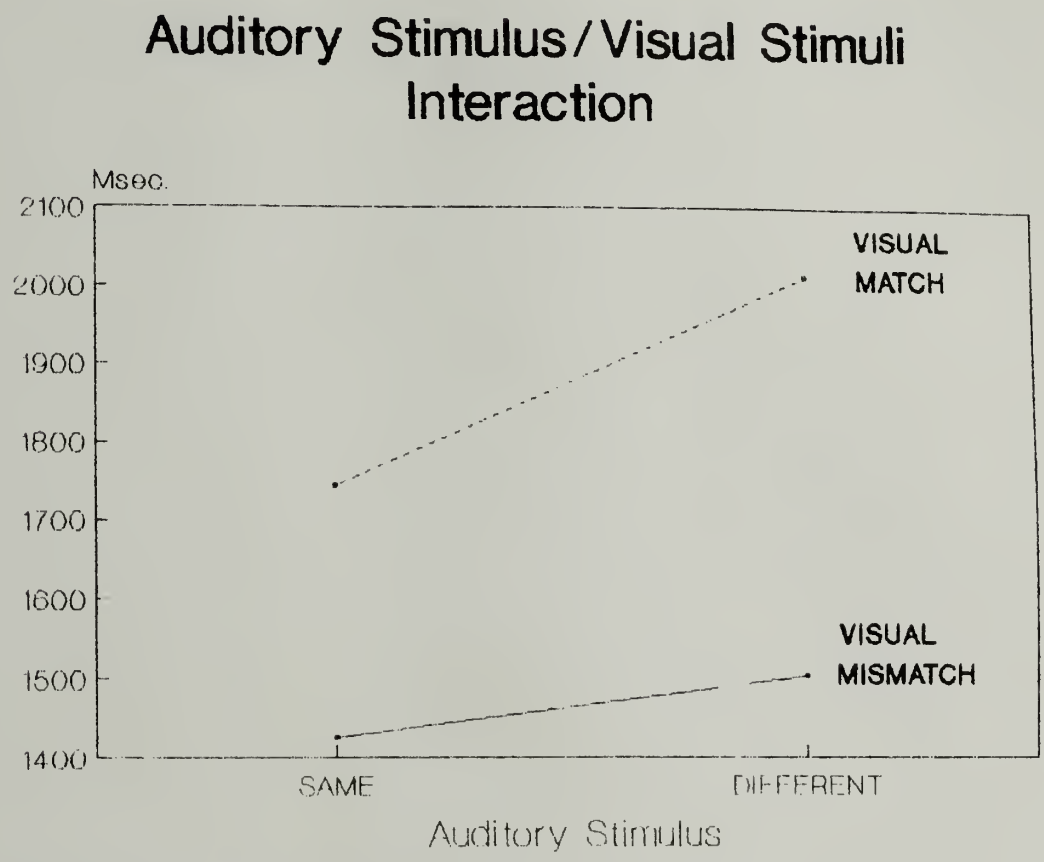



Figure 8. Mean reaction times under auditory same and auditory different conditions for visual match and visual mismatch.

The separate analyses of the visual match and visual mismatch revealed that the auditory same condition was signficantly faster than the auditory different condition for the full good sentences and syntactic nonsense strings, and marginally significant for the random word strings. The significant difference between the auditory same and auditory different conditions for the visual mismatch

condition shows that the auditory stimulus is having an effect on the processing of the visual stimulus. In other words, differences between the auditory conditions cannot be accounted for by an effect on the decision process in the visual comparison task alone.

# CHAPTER IV

# DISCUSSION

## Test of Reading and Listening Processing Models

The results show that there is an effect of listening to an auditory stimulus on the time to decide if two visual stimuli are the same or different. This effect occurs for stimuli that have a linguistic representation beyond the phonemic level.

The results of the interaction of stimulus type and auditory same/different conditions directly address the hypothesis concerning the point of convergence of listening and reading processing. These results show that there is a cross-modality effect for those stimuli that have some linguistic representation possible at the semantic, syntactic, or word level; namely the full good sentences, the syntactic nonsense strings, and the random word strings. There was no significant effect when the stimulus material had no linguistic representation possible beyond the phonemic level (nonword strings).

There are several possible sources of this cross-modality effect. First, there is the possibility that hearing an auditory stimulus facilitates the process of encoding the same stimulus presented visually. For example, according to the nurogen model, the auditory stimulus passes excitation up the auditory pathway to the

highest echelon possible. The presentation of the visual stimulus passes activatation up the visual pathway. The processing of the visual stimulus would be facilitated at the echelons where the auditory stimulus has activated the same nurogens. This would result in faster reaction times when the auditory stimulus matches the first visual stimulus.

It is also likely that reading this first visual stimulus facilitates the encoding of the second visual stimulus when the two visual stimuli are the same. Under the nurogen model, this would be expected as the second visual stimulus would activate the same nurogens as the first visual stimulus. There may also be some carry over of the facilitation from the auditory stimulus to the second visual stimulus.

Another possibility, when all three stimuli are identical, is they may be facilitation of the decision process. For example, when the auditory and first visual stimulus match, it may set up the expectation that the two visual stimuli will also match.

It is also possible that these faster reaction times in the auditory same condition could all be the result of inhibition when the two visual stimuli do not match. For example, it could be that hearing a different auditory stimulus prior to the presentation of the two visual

stimuli inhibits the encoding and/or decision processes. For example, when the auditory stimulus is the same as the first visual stimuli and the two visual stimuli do not match, the response of 'different' may conflict with the expectation of a match set up by the auditory and first visual stimulus. While is not possible to distinguishing between facilitation effects and inhibition effects in the present study, the separate analyses of the auditory stimulus/stimulus type interaction for the visual match and visual mismatch conditions do present a potential way to distinguish between the effects on the encoding process and effects on the decision process.

These separate analyses for the visual match and visual mismatch conditions show a significant difference between the auditory same and auditory different conditions for all stimulus types when the two visual stimuli match. However, when the two visual stimuli mismatch these comparisons reveal that there is a effect of the auditory stimulus for the full good sentences and the syntactic nonsense strings, and a marginally significant effect of the random words strings. There is no significant difference, however, between the auditory conditions for the nonword strings. In other words, the source of the 68 msec. difference between the auditory same and auditory different conditions for the nonword strings is due to the significant

difference between these two conditions when the visual stimuli match. The fact that this difference is significant for the visual match condition only suggests that this difference is due to an effect on the decision process, and not an effect of the auditory nonword string on the encoding of the visual nonword string. The failure of this difference to reach significance in the mismatch condition for the random word strings would suggest that the effect for the random words strings is also an effect on the decision process alone. However, the comparisons of the magnitude of the differences between the auditory conditions for each stimulus type reveal that the difference between the auditory same and auditory different conditions for the random word strings is comparable to the those for the full good sentences and syntactic nonsense string, and significantly different from that of the nonword strings.

By showing that there is an effect of an auditory stimulus on the encoding of visual stimuli for those stimuli that have a representation beyond the phonemic level, the results of the present study rule out any dual process models of listening and reading that claim that the two processes are completely separate. The results also provide reason to doubt any unitary process theories that make the claim that the two processes are the same after

any initial perceptual differences that are due to modality.

The results, which show an effect of the auditory stimulus on the encoding of the visual stimulus for every stimulus type except nonword strings, indicate a point of convergence of listening and reading processing at the word level. Models that make a claim for a particular point of convergence of the two processes must be examined in light of these findings.

According to Royer's nurogen model, the point of convergence should be at the syntactic/conceptual level. Recall that, when a sentence is heard, excitation passes up through the auditory processing hierarchy from auditory feature detectors to the auditory spelling pattern echelon, the auditory word echelon, the syntactic/conceptual echelon and then to the episodic echelon. Immediately reading the same sentence would send excitation up the visual pathway. The syntactic/conceptual nurogens would have been activated by the auditory sentence and would have an elevated firing potential. To show unambiguous support for this model, the results of the present study would have had to show an effect of the auditory stimulus for the full good sentences and syntactic nonsense strings only and no effect for the random word strings or nonword strings.

One possibility, however, that could explain the present findings within the constraints of the nurogen model is that excitation of the syntactic/conceptual nurogens from the auditory stimulus could spread activation down the visual pathway to nurogens at the visual word echelon. Recall that the pattern of excitation is such that excitation can be excitatory or inhibitory and can move through the processing hierarchy in an ascending or descending direction.

One possible way to investigate if in fact the nurogen model can account for the present findings as described above, is to use the same paradigm to present the random word strings in two different types of auditory match conditions; one in which all words in the auditory stimulus are the same as those in the visual stimuli and, one in which the words in the visual stimuli are either synonyms or category instances of the words in the auditory stimulus. According to the nurogen model, both these conditions should show an effect of the auditory stimulus. If the auditory and visual pathways converge at the syntactic/conceptual level, the model would predict that the semantically similar condition may even show faster response time than the same word condition.

Kirsner & Smith (1974) conclude from their study, in which they present words and nonwords in the same and

different modalities, that written and spoken words share a common lexicon. Their findings showed a facilitation of a lexical decision for the second presentation of a word when the two words were presented in the same modality and a lesser effect when the two words were presented in different modalities. Facilitation of lexical decisions were also found for the second nonword presented in the same modality, but not when the two nonwords were presented in different modalities. The results of the present study show a similar effect. There was an effect on the response decision when words are presented auditorily then visually, but no effect, other than that on the decision process, was found for cross-modality presentation of nonwords. The present results lend support to Kirsner & Smith's conclusion that there is a common lexicon.

Hanson (1981) concluded that written and spoken words share phonological processing. Recall that in her experiment, subjects were presented with a written or a spoken word and while attending to one or the other modality, made decisions regarding semantic, phonological or physical properties of the attended word. Her results showed significant facilitation of the semantic decision in the auditory attend and the visual attend conditions. In the phonological condition, there was only facilitation of phonological decision when the attended modality was

vision. In other words, while written words influenced phonological decisions about spoken words, spoken words did not influence decisions about the phonological properties of written words.

Hanson offered two possible reasons for the asymmetric pattern of results in the phonological condition. The first is the temporal difference in the presentation of auditory versus visual stimuli. The second is that subjects may have been making graphemic rather than phonological decisions in the visual attend condition. Hanson further investigated both of these possibilities and while the temporal argument remained unsupported she found some evidence that indicates subjects may have been searching for graphemes. Hanson concluded that spoken and written words do share a common phonological processing system.

The results of the present study would have had to show facilitation of the encoding of the nonword strings to support the notion of convergence of the two modalities at the phonological level.

Moreover, Hanson's points concerning the lack of facilitation in her visual attend condition would be inadequate to explain the lack of effect for nonwords in the present experiment. First, if temporal incongruity results in the lack of auditory to visual facilitation then

no effect would be expected for any stimulus type in the present experiment because the auditory stimulus was always presented in its entirety before the presentation of the visual stimulus.

Second, she claims subjects in her visual attend condition merely searched the visually presented letters for graphemes rather than monitoring for the target phonemes. This explanation can not account for the lack of effect in the nonword condition in the present study for two reasons. First, subjects were listening to nonwords and, therefore, would not be as familiar with the stimulus material to expect specific graphemes to be present in the visual condition as would subjects viewing words. Second, subjects in the present experiment were not asked to make a decision based on phonemes, but rather to compare to visually presented stimuli. The task demands are sufficiently different so that it is unlikely that subjects would be using the strategy of searching for and making decisions based on the presence of certain graphemes.

Interpretation of other results in terms of unit processing times.

The main effect of stimulus type revealed that there were significant differences in reaction times between stimulus types. These differences are most probably related to stimulus length. A more interesting result, however, is

that when the mean reaction time for each stimulus type was divided by the number of units to obtain a processing time per unit, the fastest processing time was for the stimulus type with a possible representation at a meaning level (the full good sentences). The next slowest was the stimulus type with a possible representation at the syntactic level (syntactic nonsense strings). Random word strings, which have a possible representation at the word level were the next slowest. The stimulus type with the slowest processing time per unit was the stimulus type with no possible representation beyond the phonemic level (the nonsense strings). These comparisons reveal that the higher linguistic information may be represented in the processing hierarchy, the faster decisions regarding that material can be made.

The results of the interaction of stimulus type and visual match/mismatch conditions show that subjects are faster in the match condition presumably due to the difference between making an exhaustive versus a self-terminating search. This difference in reaction time between the match/mismatch conditions was different for the various types of stimuli due to differences in stimulus length.

However, an examination of this interaction in terms of unit processing times reveals that there is a marked

increase in the difference between the match and mismatch conditions across each of the four stimulus types; with the full good sentences showing the smallest difference between the two conditions and the nonword strings the largest. This difference may be revealing an effect of the relative ease of comparison of two linguistic stimuli depending on the size of the processing unit necessary for making the comparison. In other words, full good sentences may be compared as single units (whole meaning units); whereas nonwords would have to be compared phoneme by phoneme, making the number of units necessary for comparison much greater despite the shorter length of this stimulus type. Random words would have to be compared word by word. Syntactic nonsense strings may be compared by comparing syntactic representations. Comparisons of the syntactic representations may involve only one unit as in full good sentences but, the syntactic nonsense strings lack the advantage of familiarity. This notion of comparing processing units would be consistent with Royer's nurogen model which suggests that a comparison of two linguistic stimuli is made at the highest level possible in the processing hierarchy. The same two full good sentences would excite the same episodic nurogen, making a comparison of the sentences as one meaning unit possible.

Educational Implications

The unitary process view, which assumes that reading and listening are the same process, has led to the practice of teaching reading as a separate subject only until decoding skills are mastered. Once decoding is mastered, reading is viewed as part of a more general language skill.

The results of the present study suggest that reading and listening share a common lexicon and therefore the results are consistent with the unitary process view's implication that after decoding is mastered, skills in one modality may transfer to skills in the other. Royer, Sinatra, & Schumer (1987) showed, however, that in the developing reader, gains in comprehension in one modality are not necessarily accompanied by gains in comprehension in the other. The idea that that the two processes may develop independently indicated that, despite the similarities in processes beyond the word level, the differences between the two processes outlined earlier remain important distinctions.

The lack of an effect for the nonwords may have implications for phonics approaches to teaching reading. If reading and listening do not share phonemic processing then phonetic approaches to teaching spelling and word recognition may not be optimal techniques.

Recommendations for Future Research

There are important questions that remain unaddressed by the present study. For example, is the effect of the auditory stimulus on the processing of the visual stimuli a facilitation effect or an inhibition effect? This question must be addressed to fully understand the implications of the present results.

One interpretation that deserves further investigation is the possibility that excitation passes down the visual pathway in the nurogen model explaining the effect of the auditory stimulus at the word level. This possibility should be examined and the nurogen model revised if necessary.

Another interpretation that warrents investigation is the explanation of the differences in unit processing times of the different stimulus types in terms of the size of the unit necessary for processing.

It would also be valuable to focus of the phonological processing of auditory and visual linguistic material. One limitation of the present research was the necessity of using nonlinguistic material for the phonological stimuli. For futher generalization of the results at the phonological level similar research using real words is necessary.

# APPENDIX A

# Stimulus Sets

Original Sentences

Set 1

1) Sue wants to go for a walk.
2) David kept his savings in an old sock.
3) I will come to see you on Thursday.
4) The project was wholly ineffectual.
5) He would not think of letting us help.
6) The bottle fell off the table.
7) She worked in the garden yesterday.
8) The data are inconclusive.
9) By late afternoon, William was exhausted.
10) The church stands in the square.
11) The young man was elected class president.
12) Ellen is the one who will succeed.
13) He worked hard because he needed the grade.
14) The policeman arrested the burglar.
15) He is living like a millionaire.
16) Sailing a boat is fun.
17) Most members are in favor of the motion.
18) I move that the nominations be closed.
19) They will consent to any arrangements.
20) He taught me to play the piano.
21) The room was full of sunlight.
22) The school offers three separate curricula.
23) The letter was signed by the author.
24) Cathy wanted a singing career.
25) He objected to the suggestion.
26) The students are organizing social activities.
27) You seem uninterested in the problem.
28) Nobody realized that the train was late.
29) We suggest that you take warm clothes with you.
30) The old house was empty.
31) I can't find my car keys.
32) He blamed the management for the dispute.

Experimental Sentences

Set 1 Full Good Sentences*

*Note that the replacement word for the different condition appears here in bold face type.

1) Sue wants to go for a walk/**ride**.
2) David kept his savings/**dollars** in an old sock.
3) I will come to see/**get** you on Thursday.
4) The project was wholly/**mostly** ineffectual.
5) He would not think of letting us/**me** help.
6) The bottle/**carafe** fell off the table.
7) She worked in the garden/**fields** yesterday.

8) The/**His** data are inconclusive.
9) By late afternoon, William was exhausted/**deficient**.
10) The church stands in the square/**common**.
11) The young man was elected class president/**treasurer**.
12) Ellen is the one who will/**must** succeed.
13) He worked hard/**alot** because he needed the grade.
14) The policeman arrested the burglar/**robber**.
15) He is living/**acting** like a millionaire.
16) Sailing a boat/**yawl** is fun.
17) Most members are in favor of the motion/**action**.
18) I move/**hold** that the nominations be closed.
19) They will consent/**concede** to any arrangements.
20) He taught/**helped** me to play the piano.
21) The room was full of sunlight/**daylight**.
22) The school offers three separate/**distinct** curricula.
23) The letter was signed by the author/**writer**.
24) Cathy wanted/**needed** a singing career.
25) He objected to the suggestion/**statements**.
26) The students are organizing social/sports activities.
27) You seem/**look** uninterested in the problem.
28) Nobody realized that the train was late/**slow**.
29) We suggest/**request** that you take warm clothes with you.
30) The old house was empty/**quite**.
31) I can't/**won't** find my car keys.
32) He blamed the management for the dispute/**quarrel**.

Original Sentences
<u>Set 2</u>

1) He had reached the end of the book.
2) It had been raining steadily for hours.
3) The play is beginning now.
4) Bill must be in the library.
5) The judge was perfectly fair.
6) He said he could not come tonight.
7) He has been reading a novel.
8) A subway runs under this street.
9) The lake was more than two miles wide.
10) Most of the crowd was indifferent.
11) I hope that you can come.
12) She left the second novel unfinished.
13) He paid a hundred dollars for his suit.
14) This plan reduces taxes and has proved workable.
15) She spent all her money abroad.
16) They arrived at the apartment door.
17) His last book shows his genius.
18) The manager closed the shop early.
19) Mary and I easily won the match.
20) I have looked for this book since February.
21) The summer heat began in late June.

22) This picture is a good imitation.
23) She had the flu last month.
24) They amused each other by telling stories.
25) Now and then we heard a twig snap.
26) Since it was late, they went home.
27) We were awakened by a loud noise.
28) It was they who signed the agreement.
29) You are as bright as Sarah.
30) We will see you next week.
31) She walked to her car and drove away.
32) He is mending the tire.

Experimental Stimuli
Set 2 Syntactic Nonsense Strings*

*Note that the replacement word for the different condition appears here in bold face type.

1) It had looked the hours of the street/**routes**.
2) He was awakened reading/**looking** early for miles.
3) The book had reached steadily/**normally**.
4) Mary must be for the novel/**books**.
5) The subway/**trains** reduces away fair.
6) I ran/**jog** he must not have now.
7) He has been raining/**pouring** a library.
8) A crowd left under/**below** two lakes.
9) The play can more than this picture/**etching** abroad.
10) Most for the heat were bright/**golden**.
11) She won/**got** that he snapped pay.
12) He drove the indifferent taxes late/**long**.
13) She amused a hundred novels all her week/**days**.
14) Summer books went home and are mending/**helping** late.
15) They were at his/**her** Sarah last.
16) I walked in the last February/**December**.
17) His wide shop/**mill** heard his agreement.
18) The match/**games** arrived the end easily.
19) He and I perfectly began/**arose** the money.
20) I have proved for this story/**tales** since June.
21) The apartment plan/**idea** is in good suit.
22) Genius managers had a workable judge/**chief**.
23) They closed/**sealed** the dollars this imitation.
24) We signed each other by beginning/**producing** month.
25) Now and then she saw a flu hope/**wish**.
26) Since they were loud, it showed twigs/**stick**.
27) You are mending in a second/**double** book.
28) He was she who came the noise/**sound**.
29) We said as unfinished/**incomplete** as Bill.
30) It has been her this door/**gate**.
31) He was by his tire/**tube** and could tonight.
32) They can spend/**waste** the car.

Original Sentences
Set 3

1) I will wake up the children.
2) The work must be done today.
3) She bought a cotton dress.
4) This is becoming a serious matter.
5) Three kinds of questions will be considered.
6) Any student caught cheating will fail the course.
7) One of the girls was playing the piano.
8) I saw a continuous line of clouds.
9) The accident happened at five o'clock.
10) This place will be up for sale next month.
11) The station is near the post office.
12) The private was asked to step forward.
13) I saw her three days ago.
14) I owe him ten dollars.
15) They are getting married tomorrow.
16) Entering the room, he heard voices.
17) This is an excellent book.
18) These shoes need to be repaired.
19) I caught them stealing apples.
20) The economy will soon return to normal.
21) He has remained calm during the whole crisis.
22) The window had been left open.
23) The demonstration reached near riot proportions.
24) This problem looks like a tricky one.
25) We reached the lake as the sun was setting.
26) She keeps sending me telegrams.
27) The gardener is cutting the grass tomorrow.
28) The voting takes place in the lobby.
29) Those flowers are very beautiful.
30) Part of the population never seeks employment.
31) Public transportation is going bankrupt.
32) I am listening to the radio.

Experimental Stimuli
Set 3 Random Word Strings*

*Note that the replacement word for the different condition appears here in bold face type.

1) owe riot month course/**routes**
2) window work/**jobs** today playing
3) bought reached/**grabbed** cotton listening
4) becoming book matter/**affairs**
5) proportions entering repaired/**adjusted**
6) student piano cutting/**slicing**
7) place girls open/**ajar** tricky

8) saw looks/**seems** line telegrams
9) grass/**lawns** demonstration setting o'clock.
10) this lobby serious/**sincere** next
11) continuous/**constantly** near post excellent
12) sending very happened/**occurred** heard
13) seeks/**looks** three saw dress ago
14) him flowers/**blossom** ten step
15) dollars/**payment** never office they
16) room/**area** married voices must
17) private tomorrow crisis apples/**fruits**
18) shoes/**boots** children this
19) need caught/**seized** considered these
20) soon forward/**leading** economy them
21) normal done/**over** calm whole
22) wake remained/**survived** employment left
23) five near cheating getting/**gaining**
24) bankrupt one caught problem/**dilemma**
25) reached lake/**pond** fall sun
26) keeps sale station like
27) transportation kinds/**types** clouds tomorrow
28) voting return/**arrive** gardener accident
29) those during place/**point** three
30) beautiful/**wonderful** population her
31) asked/**urged** public part
32) questions/**proposals** days going radio

Original Sentences
<u>Set 4</u>

1) The car is not worth selling.
2) We had dinner there yesterday.
3) Mary wrote the postcard on the bus.
4) He is considering entering the university.
5) He lost his house and his money.
6) The storm has made me uneasy.
7) The cat stopped and arched its back.
8) The girls often go to the movies together.
9) Reluctantly, they rejected the proposals.
10) Marty held several different jobs.
11) You must take that bus.
12) Periodicals may not be removed from the reading room.
13) There are two blankets for each bed.
14) The senate bill must pass the committee.
15) I'm going to buy a new coat.
16) It is important to be there on time.
17) He was forced into a November election.
18) The commission submitted its report.
19) Harry returned to California in August.
20) All things considered, the plan should work.
21) I came here for a rest.

22) Their lack of understanding was apparent.
23) He has always lived here.
24) The window was broken deliberately.
25) They have almost finished the work.
26) The office sent me these documents.
27) The team had a near perfect record.
28) I suspect that the claim is false.
29) The boy could hardly contain his curiosity.
30) My friends told me the whole story.
31) Bill didn't notice who led the orchestra.
32) He sent the children off to school.

Experimental Stimuli
Set 4 Nonword strings*

*Note that the replacement word for the different condition appears here in bold face type.

1) mar/**fot** sorth pelink
2) tinner thepe/**varps** esterway
3) trote/**lurts** nostfard tuss
4) cotridering/**tropormian** nass empering
5) nost/**dilt** touse ponet
6) storp mape/**foon** hassist
7) saff/**pake** fopt zact
8) turis othen povies/**vearns**
9) remected tropidies/**siffement** tobs
10) feid/**reit** menerap liffapent
11) tust dake/**jeat** romether
12) sitoved/**deturns** reasing poom
13) swoe blamnetz bep/**cak**
14) renake/**emeged** pilk romithy
15) goint fess/**brop** fote
16) itherant/**levetais** feasy nime
17) torst povempter/**leparates** elethion
18) romission smithed tiport/**nubilc**
19) neturned/cetordly dailmornia togust
20) trings siand/**masps** sork
21) rame teru **mest**/**rork**
22) dack asarant/**rastard** comiterid
23) anways/borked vived heary
24) dinnow terpect/**beathed** droken
25) awfost/kenner linished nork
26) offite sint/**poat** nocuments
27) peam neag neckord
28) sustec/**rimart** plame flise
29) noy sardly rotain/**mesent**
30) taid srope/**lounts** stoff
31) bonis med/**tor** dubosity
32) veth/**lext** themedrin stithoon

Auditory Foils*

*Auditory stimuli used in conditions where the auditory stimulus is different from the visual stimuli.

Foils Set 1 Full Good Sentences
1) He left home an hour ago.
2) They stopped when they reached the lake.
3) I'm going to put the books away.
4) Peter's taking them on a tour.
5) They failed to report the crime.
6) She went to the grocery store for milk.
7) He looked as if he were confident.
8) We can save fuel by using less electricity.
9) We expect to go there next week.
10) The ship broke loose from its moorings.
11) Amy is the one in the raincoat.
12) Jim gave every game his all.
13) The jurors disagreed among themselves.
14) Mr. Jones has ignored the evidence.
15) Mark persuaded him to buy some shares.
16) There will be some tickets available.

Foils Set 2 Original Sentences
1) We were caught walking on the grass.
2) The game excited the audience.
3) You must turn right at the bridge.
4) None of the students passed the examination.
5) I borrowed the tape recorder.
6) Chris wanted you to give them a present.
7) Tom read the newspaper quickly.
8) The old haunted house was empty.
9) She is liked by everyone.
10) He read only mystery novels.
11) The whole class was invited to the party.
12) They had a picnic in the afternoon.
13) The attention of the students wandered.
14) I noticed that everybody was tired.
15) That prospect seemed remote indeed.
16) If I were you, I would find out.

Foils Set 2 Syntactic Nonsense Strings
1) You are liked walking of the students.
2) The bridge turned the afternoon.
3) I was old haunted to the party.
4) None in the grass borrowed the audience.
5) She wandered the remote students.
6) Tom was you to give everyone a prospect.
7) Chris had the attention out.

8) The right tape novel was tired.
9) He is invited of them.
10) They noticed indeed empty picnics.
11) The mystery recorder must want at the class.
12) I read a house on the game.
13) The present by the newspaper passed.
14) Everybody caught that you would find.
15) That examination was whole only.
16) If you seemed me, we were excited quickly.

Folls Set 3 Original Sentences
1) All of the fruit was spoiled.
2) The secretary will let us know the results.
3) The agency found me a new job.
4) If I had studied harder, I would have passed.
5) Jane is going to sing a song for you.
6) Here is the key that unlocks the door.
7) Much education occurs outside the classroom.
8) The plan was objected to strongly.
9) That restaurant serves a special wine.
10) The students were glad the course was over.
11) Long skirts are in fashion again.
12) The telephone rang late last night.
13) The members of our club play tennis.
14) Susan liked tending the lawn and gardening.
15) The rest of the pie was eaten.
16) If it rains, the trip will be cancelled.

Folls Set 3 Random Word Strings
1) trip fruit classroom glad
2) know eaten results serves
3) door job course new
4) harder found Susan would
5) going Jane members song
6) telephone key lawn last
7) education occurs fashion
8) plan night objected
9) strongly restaurant play
10) over students long were
11) skirts unlocks again studied
12) rang sing late here
13) passed club cancelled
14) agency wine tennis tending
15) secretary pie gardening rest
16) spoiled liked rains special

Folls Set 4 Original Sentences
1) The group worked well together.
2) John demands the most from himself.
3) The problem is purely political.

4) He ran up the stairs and rang the bell.
5) They stayed home for several reasons.
6) Had he known, he would not have said that.
7) Somebody is going to buy that house.
8) They went to Europe for the holidays.
9) Harold has volunteered to mow the lawn.
10) John left his hat in our hall.
11) The doctor attended to his patients.
12) Harry searched the room for the papers.
13) There is a storm approaching.
14) We prefer red wine to white.
15) The boat races take place tomorrow.
16) The plane flew over the mountains.

Folls Set 4 Nonword strings
1) broup sorked pell
2) renands nost donether
3) troblet durely nonitical
4) san smains lang
5) stayet rome peneral
6) bront naid mell
7) golth houte mearched
8) nent nollmays neabons
9) mot wath flace
10) teft har rall
11) domnor ippennet raflents
12) roon saners bonorrow
13) prere proth whike
14) prener rud wibe
15) soat daces dape
16) clane flet dountains

# APPENDIX B

Pilot Data - Stimulus Length

| Stimulus type and length | Number of subjects responding correctly out of 10 |
|---|---|
| Full Good Sentences | |
| Length | |
| 5 | 9 |
| 6 | 10 |
| 7 | 9 |
| 8 | 9 |
| 8 | 10 |
| 8 | 10 |
| 9 | 10 |
| 9 | 9 |
| Syntactic Nonsense Strings | |
| Length | |
| 6 | 7 |
| 7 | 4 |
| 8 | 4 |
| 8 | 8 |
| 8 | 2 |
| 9 | 8 |
| 9 | 8 |
| Random Word Strings | |
| Length | |
| 4 | 5 |
| 4 | 5 |
| 4 | 6 |
| 4 | 1 |
| 4 | 7 |
| 4 | 7 |
| 4 | 7 |
| | Mean = 5.42 |
| 5 | 2 |
| 5 | 2 |
| 5 | 1 |
| 5 | 1 |
| 5 | 0 |
| 5 | 1 |
| 5 | 1 |
| | Mean = 1.14 |

| | |
|---|---|
| 6 | 3 |
| 6 | 1 |
| 6 | 3 |
| 6 | 0 |
| 6 | 2 |
| | Mean = 1.8 |

Nonword Strings

| Length | |
|---|---|
| 3 | 5 |
| 3 | 1 |
| 3 | 4 |
| 3 | 5 |
| 3 | 5 |
| 3 | 2 |
| | Mean = 3.67 |
| 4 | 1 |
| 4 | 2 |
| 4 | 0 |
| 4 | 2 |
| 4 | 2 |
| 4 | 0 |
| | Mean = 1.16 |
| 5 | 0 |
| 5 | 1 |
| 5 | 0 |
| 5 | 1 |
| 5 | 0 |
| 5 | 0 |
| | Mean = .33 |

# APPENDIX C

Pilot Data - Nonwords Spelling

| Nonwords | # agreement |
|---|---|
| 1) mar | 5(of 10) |
| 2) sorth | 3 |
| 3) pelink | 2* (of 5) |
| 4) tinner | 6 |
| 5) theep | 4 |
| 6) esterway | 3* |
| 7) trote | 6 |
| 8) nostfard | 4 |
| 9) tuss | 9 |
| 10) cotridering | 3* |
| 11) nass | 1* |
| 12) empering | 2 |
| 13) nost | 8 |
| 14) touse | 3 |
| 15) ponet | 4 |
| 16) storp | 6 |
| 17) mape | 6 |
| 18) hassist | 2 |
| 19) saff | 5 |
| 20) fopt | 1* |
| 21) zact | 3 |
| 22) turls | 3* |
| 23) othen | 1* |
| 24) povies | 3 |
| 25) remected | 5 |
| 26) tropidies | 2 |
| 27) tobs | 3 |
| 28) feid | 3 |
| 29) menerap | 5 |
| 30) iiffapent | 2 |
| 31) tust | 7 |
| 32) dake | 9 |
| 33) romether | 4* |
| 34) sitoved | 2 |
| 35) reasing | 2* |
| 36) poom | 4 |
| 37) swoe | 5 |
| 38) biamnetz | 2 |
| 39) bep | 2 |
| 40) renake | 5 |
| 41) piik | 9 |
| 42) romithy | 4 |
| 43) goint | 8 |
| 44) fess | 7 |
| 45) fote | 4 |
| 46) itherant | 4 |
| 47) feasy | 3* |
| 48) nime | 7 |

| Nonwords | # agreement |
|---|---|
| 49)torst | 5 |
| 50) povempter | 3* |
| 51) elethion | 0* |
| 52) romission | 6 |
| 53) smithed | 3* |
| 54) tiport | 4 |
| 55) neturned | 3 |
| 56) dallmornia | 6 |
| 57) togust | 2* |
| 58) trings | 5* |
| 59) siand | 8 |
| 60) sork | 9 |
| 61) rame | 5 |
| 62) teru | 2 |
| 63) mest | 8 |
| 64) dack | 5 |
| 65) asarant | 1* |
| 66) comiterid | 2* |
| 67) anways | 7 |
| 68) vived | 10 |
| 69) heary | 3 |
| 70) dinnow | 3 |
| 71) terpect | 3 |
| 72) droken | 3* |
| 73) awfost | 4* |
| 74) iinished | 7 |
| 75) nork | 9 |
| 76) offite | 5 |
| 77) sint | 3 |
| 78) nocuments | 4 |
| 79) peam | 5 |
| 80) neag | 2 |
| 81) neckord | 5 |
| 82) sustec | 3 |
| 83) piame | 3 |
| 84) fiise | 1* |
| 85) noy | 5 |
| 86) sardiy | 6 |
| 87) rotain | 2 |
| 88) taid | 3 |
| 89) srope | 2* |
| 90) stoff | 3 |
| 91) bonis | 2 |
| 92) med | 9 |
| 93) dubosity | 2* |
| 94) thef | 3 |
| 95) themedrin | 3 |
| 96) stithoon | 4 |

# APPENDIX D

Informed Consent Form

The Psychology Department requires that anyone who participates in a psychological study be informed beforehand as to the nature of the study. The present study is designed to investigate the relationship between reading and listening. You will be asked to listen to and read several sets of sentences, words, or letters. You should be able to finish the experiment in approximately 30 minutes.

You will receive one experimental credit for your participation. If at any time you decide to withdraw from the experiment, you may do so without penalty or loss of experimental credit. If you have any questions, feel free to ask the experimenter at any time.

All information and data collected in this study will be completely confidential. If you decide to participate at this point, please sign below.

Signature _____

Date _____

## Feedback

We are investigating the relationship between the cognitive processes of listening and reading. It has been shown that reaction time to decide if a written stimulus is or is not a word can be reduced by the presentation of a prior written stimulus. In the present study we are interested in the effects of prior aural material on the processing of written material.

You were given various types of stimuli (complete sentences, nonsense sentences, word lists, and nonwords) because we suspect the effects on reaction times may be different for stimuli of different qualities.

If you are interested in the outcome of this study, you may obtain further information from Gale Sinatra, Tobin 509, 545-4671. Thank you for your participation.

# APPENDIX E

Comparisons for the auditory stimulus/stimulus type interaction analysed separately for visual match/mismatch conditions

| comparisonsa | mean | t-value | p-value |
|---|---|---|---|
| | VISUAL MATCH | | |
| FGS SAME vs. | 1714 | | |
| FGS DIFF | 1993 | 5.47 | < .0125 |
| SNS SAME vs. | 1964 | | |
| SNS DIFF | 2276 | 5.39 | < .0125 |
| RWS SAME vs. | 1597 | | |
| RWS DIFF | 1887 | 7.83 | < .0125 |
| NWS SAME vs. | 1700 | | |
| NWS DIFF | 1891 | 3.82 | < .0125 |
| | VISUAL MISMATCH | | |
| FGS SAME vs. | 1422 | | |
| FGS DIFF | 1595 | 3.49 | < .0125 |
| SNS SAME vs. | 1545 | | |
| SNS DIFF | 1669 | 3.09 | < .0125 |
| RWS SAME vs. | 1393 | | |
| RWS DIFF | 1469 | 1.92 | = .062 |
| NWS SAME vs. | 1340 | | |
| NWS DIFF | 1285 | 1.25 | > .0125 |

Note. FGS = full good sentence; SNS = syntactic nonsense strings; RWS = random word strings; NWS = nonword strings.

aComparisons involve two means.

Comparisons for the auditory stimulus/stimulus type interaction analysed separtely for visual match/mismatch conditions

| comparisonsa | differenceb | t-value | p-value |
|---|---|---|---|
| | VISUAL MATCH | | |
| FGS SAME-DIFF vs. SNS SAME-DIFF | -279<br>-312 | .473 | > .05 |
| FGS SAME-DIFF vs. RWS SAME-DIFF | -279<br>-290 | .216 | > .05 |
| FGS SAME-DIFF vs. NWS SAME-DIFF | -279<br>-191 | 1.33 | > .05 |
| SNS SAME-DIFF vs. RWS SAME-DIFF | -312<br>-290 | .454 | > .05 |
| SNS SAME-DIFF vs. NWS SAME-DIFF | -312<br>-191 | 2.02 | = .05 |
| RWS SAME-DIFF vs. NWS SAME-DIFF | -290<br>-191 | 1.84 | > .05 |
| | VISUAL MISMATCH | | |
| FGS SAME-DIFF vs. SNS SAME-DIFF | -173<br>-124 | .875 | > .05 |
| FGS SAME-DIFF vs. RWS SAME-DIFF | -173<br>-76 | 1.48 | > .05 |
| FGS SAME-DIFF vs. NWS SAME-DIFF | -173<br>55 | 3.04 | < .0125 |
| SNS SAME-DIFF vs. RWS SAME-DIFF | -124<br>-76 | .836 | > .05 |
| SNS SAME-DIFF vs. NWS SAME-DIFF | -124<br>55 | 2.96 | < .0125 |
| RWS SAME-DIFF vs. NWS SAME-DIFF | -76<br>55 | 2.87 | < .0125 |

Note. FGS = full good sentence; SNS = syntactic nonsense strings; RWS = random word strings; NWS = nonword strings.
aComparisons involve four means.
bDifference between the auditory conditions for each stimulus type.

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