Temporal and Spatial Processing of Homophonous and Non-Homophonous Words by Hearing and Hearing Impaired Children

by

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ABSTRACT

The purpose of this study was to ascertain whether there was indeed a relationship between processing strategy (temporal or spatial processing) and internal speech.

The task utilized for the study, was constructed from the tasks used by O'Connor and Hermelin (1973a), Conrad (1979), and Booth (1982). It was then administered to 71 hearing impaired and 74 hearing subjects. The groups were matched according to vocabulary level, rather than chronological age.

Results strongly indicate that there is indeed a relationship between temporal processing and internal speech for hearing threshold level groups. Age was shown to be a determining factor for choice of processing strategy for both hearing and hearing impaired groups. Severity of hearing loss was not found to have an effect on processing strategy. Profoundly deaf children, and hearing children did not demonstrate a preferred processing strategy.

It would seem necessary to continue to investigate the relationship between processing strategy and internal speech. Perhaps looking at individuals rather than heterogeneous groups would yield additional information.
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Chapter One

BACKGROUND TO THE PROBLEM

"...a pattern of growth which involves capacity to understand ordinary spoken language, to read it, to use it in thinking, and as far as possible, to speak and write it is the only one which can be considered satisfactory for any deaf child" (Ewing, 1960, p. 2-3).

Hearing children enter the scholastic world with many skills. Typically they have a large vocabulary, fluent speech and many of the prerequisite skills for reading (Conrad, 1979). These receptive and expressive skills have been acquired primarily through the child's ability to process auditory information (Ling, 1976).

By contrast, the deaf school aged child has not had the benefit of maximum auditory reception. Residual hearing may be developed through auditory training, but additional input through visual, tactile and kinesthetic modalities may serve to provide the deaf child with information necessary for the acquisition of linguistic skill (Ling, 1976). The visual channels in particular are used for reception of signals (Ling, 1976). However these channels are often "overloaded", because vision is seen by many educators of the hearing impaired as the modality through which the majority of information is transmitted and received (Ling, 1979).
Therefore, it is important to investigate the processes or strategies that the hearing impaired use to process visual information. This study will utilize a task which may determine the processing strategies employed by both the hearing and hearing impaired children when they are presented with a visual task.

Acquisition and development of language have been central concerns among educators of the hearing impaired (Kretschmer & Kretschmer, 1978). Research indicates language development of deaf children follows a similar pattern to hearing children, although skills are acquired much later in the child's development. As a result, the hearing impaired child is at a definite linguistic disadvantage when compared with hearing peers (Kretschmer & Kretschmer, 1978: Clarke et al, 1977).

O'Connor and Hermelin (1975) state that deaf children use vision as their primary mode of reception. They have conducted numerous studies to determine the effect sensory restriction has on processing strategies. Results of their work demonstrate that if the auditory system is severely damaged, reliance on acoustic information and input is diminished. The majority of severely to profoundly deaf children rely on a visual input or coding system (O'Connor & Hermelin, 1975).
Conrad (1979) found evidence to support findings of O'Connor and Hermelin (1975). He found that when auditory material was presented to the hearing impaired child, information was put into visual code, because audition could not be utilized as a primary mode of reception.

O'Connor and Hermelin (1976) expanded their theory by stating that the processing and input modality (audition or vision) may not be the same as the stimulus. Profoundly deaf children continued to process using a visual code whether or not the stimulus was auditory or visual. Results of their analyses indicated that input modality was not dependent on characteristics of the stimulus, but on whether the child could effectively utilize a representational code, or an alternate processing strategy (O'Connor & Hermelin, 1978).

Research to date (O'Connor & Hermelin, 1976;1978) has shown that hearing and hearing impaired children process visual information differently because they apply different processing strategies.

Additional studies (O'Connor & Hermelin, 1973a;1973b) used an incongruent temporal/spatial task to determine processing strategies of a hearing and hearing impaired population. The outcomes have shown that hearing impaired subjects consistently responded spatially to tasks while the responses of their hearing counterparts were temporal.
Conrad and Hull (1964) offered the explanation that in short term memory words that are coded temporally depend on accessibility of an auditory-verbal system. If the auditory system is virtually non-functional, the hearing impaired child will rely on the visual code and respond spatially to tasks which measure processing strategies (Conrad & Hull, 1964).

Linguistic information acquired through visual presentation may be processed either temporally or spatially (O'Connor & Hermelin, 1975). Deaf and hearing children are continually asked to incorporate both processing strategies during reading (Booth, 1982). For example, a child may be asked to scan print on a page spatially and then to process a dictated story temporally.

Conrad (1972;1979) acknowledged the heterogeneity of the deaf. Not all deaf children use vision as their primary mode of reception nor processed visual material spatially. The degree to which each child used vision as a mode of reception could depend on additional variable: degree of hearing loss, use of residual hearing, use of receptive and expressive language skills, and degree of intelligible speech. These variable may effect the chosen or preferred strategy (Ling, 1976).
Klapper and Birch (1971) compared hearing children's matching of auditory-temporal and visual-temporal sequencing. They found that auditory-temporal processing was more accurate at the early ages, up to age nine, then visual-temporal processing became predominant after this age.

A similar investigation by Sterritt, Martin and Rudnick (1971) found that purely spatial tasks were the simplest for hearing children up to age eight, temporal and spatial features were intermediate in difficulty, and purely temporal tasks were the most difficult. The evidence thus suggests that for hearing children the use of a temporal strategy is dependent on age. Developmentally, a hearing child will progress from processing "simple" spatial information to the processing of more difficult temporal tasks, (Klapper & Birch, 1971; Rudnick et al, 1972).

Conrad (1972;1979) tried to ascertain whether deaf children say words to themselves (internal speech) as a rehearsal technique. He devised a task for the purpose of assessing whether hearing and hearing impaired children used internal speech when processing words. Two sets of words were used for the task.

"One set designated homophone (H) would contain words which on the critical feature of the vowel sound sounded alike but looked different from one another. The second set of words would sound different from each other on the basis of the dominant phonetic features but looked alike. This would be the non-homophous (NH) set." p.94
Therefore words in the homophonous set would be words such as "do, zoo, and blue." Words comprising the non-homophonous set would be words such as "bare, bean, door, and have."

Conrad (1979) hypothesized that the errors a child made when asked to recall words from the H and the NH sets would indicate the use of internal speech. Many homophonous errors would indicate that a child was rehearsing words internally, whereas a child who recalled many homophonous words was not using internal speech.

Results of several studies (Conrad, 1972;1979) demonstrated that degree of hearing loss affected the child's use of internal speech. Conrad (1979) found a consistent decline in use of internal speech as hearing loss became more profound.

SUMMARY

The hearing child uses audition as the primary receptive mode through which most linguistic skills are acquired (Kretschmer & Kretschmer, 1978). As a result of impaired acoustic function, hearing impaired children are at a linguistic disadvantage when compared to hearing peers (Clarke et al, 1977).
Many hearing impaired develop alternate strategies to process information. Vision is typically utilized and often becomes the hearing impaired child's primary receptive mode (Ling, 1976). Profoundly deaf children typically process information visually regardless of stimulus form (O'Connor & Hermelin, 1973;1975). Results of cognitive processing studies show that hearing impaired children consistently responded spatially to visual tasks and that responses of hearing children were temporal.

These results were consistent with earlier investigations by Conrad and Hull (1964). They concluded that the coding strategy used depended on whether the child could utilize an auditory coding system. Temporal or spatial processing may be developmental, as spatial tasks were the simplest for young children and purely temporal tasks were more easily mastered by older children. Processing strategies appear to be dependent on the age of the child.

Conrad (1972;1979) hypothesized that low recall of homophonous words reflected internal speech as a rehearsal technique. As hearing loss became more severe there was a consistent decline in the child's use of internal speech.
The purpose of the study was to investigate temporal-spatial processing relationships for homophonous and non-homophonous words in hearing and hearing impaired populations.

**RESEARCH QUESTIONS**

1.a.) Is there a relationship between the strategy a hearing child may utilize and internal speech?

   b.) Is there a relationship between the strategy a hearing impaired child may utilize and internal speech?

2.a.) Do hearing children make more errors on items with homophonous words than on items with non-homophonous words?

   b.) Do hearing impaired children make fewer errors on items with homophonous words than on items with non-homophonous words?

3.a.) Does the hearing child consistently utilize a temporal or spatial strategy when asked to recall words presented randomly?

   b.) Does the hearing impaired child consistently utilize a temporal or spatial strategy when asked to recall words presented in a random order?

   c.) Are the processing strategies employed by the two populations similar or different?

4.a.) Are the strategies used by hearing impaired children dependent on additional variables such as; i) age, ii) gender, iii) reading level?

   b.) Are strategies utilized by hearing impaired children dependent on additional variables such as; i) hearing loss, ii) age, iii) gender, iv) reading level?
HYPOTHESES

MAJOR HYPOTHESES

1.a.) There will be a relationship between temporal processing and the use of internal speech in a population of hearing children.

b.) There will be a relationship between spatial processing and the use of internal speech in a population of hearing impaired children.

2.a.) Hearing children will make more errors when asked to recall homophonous words than non-homophonous words.

b.) Hearing impaired children will make fewer errors when asked to recall homophonous words.

c.) Hearing impaired children's recall of homophonous words will be dependent on degree of hearing loss.

3.a.) Hearing children will consistently use a temporal strategy when asked to recall the words on each test item.

b.) Hearing impaired children will consistently use a spatial strategy when asked to recall the words on each test item.

bii) Coding strategies used by hearing impaired children will not be dependent on vocabulary level.

MINOR HYPOTHESES

4.a.) Younger hearing impaired children will process items spatially and older hearing children will process items temporally.

b.) Coding strategies used by hearing children will not be influenced by age.
5.a.) Coding strategies used by hearing children will not be dependent on gender.

b.) Gender will not influence coding strategies used by hearing impaired children.

6.a.) Coding strategies used by hearing children will not be dependent on their vocabulary level.

b.) Vocabulary level will not influence coding strategies of hearing impaired children.

DEFINITION OF TERMS

Throughout the study the following terms will be used as defined below:

**Degree of Deafness**

Hearing loss will be defined in terms of an average hearing threshold, which is expressed in decibels (dB). This average is the arithmetic mean of the pure tone thresholds obtained at 500, 1,000, and 2,000 Hz for the child's better ear, using the criteria set by the American Standards Institute (ANSI).

**Hearing Impairment**

Hearing loss may range from a mild to profound degree.

**Sensori-Neural Hearing Loss**

Hearing impairment due to insult or injury to the cochlea, auditory nerve or both.

**Internal Speech**

The degree of verbal mediation (acoustic or articulatory) the child uses when processing visual material.

**Temporal Coding**

The degree to which visual material is recalled in correct sequential order of presentation.
Spatial Coding

The degree to which visual material is recalled in a left to right order, regardless of sequence of presentation.

Total Communication

Total communication is achieved through a combination of speechreading, audition, sign, fingerspelling, and reading. Expressive communication is through signs, and fingerspelling.

Sense Modalities

Use of audition, vision, touch and/or kinesthesia to process incoming signals.
Chapter Two

REVIEW OF THE LITERATURE

"If the principle (sic) reason for using deaf subjects is to study cognitive processes, one certain requirement is that we know what cognitive processes the deaf are using." (O'Connor & Hermelin, 1978, p.23).

Chapter two presents a review of the literature in the following areas:

research pertaining to visual memory characteristics of hearing and hearing impaired children, studies relating to the internal speech component of hearing and hearing impaired subjects, and temporal-spatial processing of the two groups.

VISUAL MEMORY

Blair (1957) investigated visual memory of the deaf as compared with the visual memory of a hearing population. He hypothesized that the two groups would perform differently on a test of memory span for digits. An array of digits, visible for a controlled period was presented to subjects either in a conventional left to right or right to left order. Results of the study indicated that visual memory for digits did differ between the two
groups. Hearing children recalled more digits in the conventional order whereas the deaf child recalled equally as well in both directions.

Blair hypothesized that the deaf child was "freed" from auditory imagery that was typically serial. It was found that deaf children relied on a visual image of the array and could read the digits equally well regardless of direction. Hearing children did not appear to rely on the visual image. Rather they retained an "auditory sequence", suggesting that they used acoustic information to aid in recall. Blair suggested that auditory recall was proficient when recalling the conventional order of sequence, but was not effective when subjects were asked to recall a sequence presented in a right to left format.

Hermelin and O'Connor (1975b) altered Blair's task by displaying digits one at a time in successive locations. They found a difference in recall between groups of hearing and hearing impaired subjects. Deaf subjects actually recalled fewer digits forward than in a backward direction.

Nunnally (1966) also found that the deaf rely more on visual memory than hearing subjects. He performed a study similar to that of Hermelin and O'Connor (1975b), where the deaf child was asked to recall a series of
digits. These were compared to a control group of hearing subjects.

Nunnally believed retention was free from interference and competing auditory vocal processes during the time when the child was retrieving information. Visual storage and retrieval cues were found to be highly efficient in the deaf population.

Blanton, Nunnally and Odam (1967) stated, "...it is assumed that the general deficiency in language used by the deaf is due to the inherent disadvantages of having to rely on the visual sense for language learning..." (p.225).

Blanton, Nunnally, and Odam (1967) constructed a task whereby deaf and hearing subjects associated a word with a stimulus word. They predicated that the deaf subject would provide words that were visually similar to the stimulus word more frequently than hearing subjects. Results verified their prediction. The deaf chose the visually similar words more often than did hearing subjects.

Conrad (1963) has shown that for hearing subjects, sequences of homophonous words (ruff, rough) were much more difficult to recall than sequences of non-homophonous words (barn, lane). Conrad hypothesized that words that sounded alike were confused in memory because they sounded the same and therefore were difficult to recall. Analysis of the errors confirmed Conrad's theory indicating a relationship does exist between memory errors and their acoustic properties.
Allen (1971) used a paired association test to examine whether a hearing loss may alter the child's perception so that emphasis is placed on sense modalities other than audition. Subjects had degrees of hearing loss ranging from mild to profound. Two lists of words were presented; those which sounded similar (e.g., sign-line) and those which looked similar (e.g., cave-have). Subjects were required to learn the two lists, and the performance measure used was the number of trials required for the subject to learn the word list. Allen predicated that those subjects with greater hearing loss would have greater difficulty learning words that sounded alike as they would not be able to use rhyme information. Subjects would depend on visual presentation of the word.

The hypothesis was not supported. Allen found the "least deaf" (0-25 dB loss) performed similarly to the "most deaf" group (91 + dB loss). The hearing subjects did not learn the word pairs that sounded alike faster than the look-alike word pairs.

Conrad and Rush (1965) compared the memory span of deaf and hearing subjects. Prior to the study it was thought that deaf children would not use a phonetic memory code, as auditory channels were impaired. If another coding system was dominant it would be reflected through the error
analysis. Conrad and Rush were not concerned with the quantity of errors, rather their objective was to analyse the errors made by the two groups.

It was found that children with hearing losses from 0 - 65 dB memorized the same number of letters as the hearing group. However they found that the hearing impaired as a group memorized letters of the alphabet using a coding procedure which was not phonetically based. The hypothesis that the child with the severe or profound hearing loss utilized another method of storing visual material received only minor support in the study.

Conrad (1970) used a procedure similar to that employed in the Conrad and Rush (1965) study. Sets of consonants for the task were grouped by the following criteria: a) K,X,Y,Z were characterized by diagonal features, b) B,C,T have acoustic and articulatory similarities, c) X,H have similar articulatory features. The number of test items were increased so that individual error matrices could be calculated for each student. A sample of 36 hearing impaired children was used, with a control group of 75 hearing subjects.

Hearing subjects showed a great deal of confusion on the tasks when letters had the same sound, but no confusion when letters were the same shape.
Results for hearing impaired subjects were divided into two groups; those which showed similar errors to hearing subjects (confusing letters that sounded alike) and those whose error pattern did not resemble the hearing subjects (confused letters that looked alike).

Conrad (1970) felt this procedure to be significant because hearing impaired children could be "classified" on the basis of the memory code they used.

**INTERNAL SPEECH**

Internal speech has been thought to have a pertinent role in thought and language processes. Sokolov (1972) referred to internal speech as the degree of acoustic mediation used when processing visual material.

Vygotsky (1962) used the term "internal speech" when describing the relationship between speech and thought.

Conrad (1979) does not believe all thought has to have a linguistic base, but regards internal speech as one form of thinking. He describes internal speech as,

"...vocal speech which at the moment when its presence is known to us, has been internalized. Specifically, it is internalized in the same sense that it is only intended for the ear of the speaker. It may therefore be overt or vocal but still private for the internal consumption in the way reading may be aloud for ourselves. Internal speech occurs when a person manipulates, generally spoken words which are required to achieve some cognitive goal" (p.9).
Using this definition of internal speech, Conrad has conducted numerous studies to investigate the "processes" used by hearing and hearing impaired children.

Conrad (1963) examined the relationship between memory errors and their acoustic correlates. Hearing subjects were presented with two unconnected word lists for immediate recall. One was compromised of five pairs of homophonous words, the other, five pairs of non-homophonous words. All words were presented visually to subjects.

Conrad hypothesized that children could be divided into two groups, those who used an articulatory code, (internal speech), and those who were non-articulatory coders (did not use internal speech). Conrad stated that articulatory coders would do better recalling a non-homophonous word list, because the words did not sound the same and would not be confused in the child's internal rehearsal system. Through analysis of the data the hypothesis was verified.

Conrad (1979) devised a task to assess the codes used when hearing and hearing impaired students process words. Words were used rather than letters as a larger number of words permitted the manipulation of both
phonetic and visual similarity. Two lists of words were used for the task; one consisting of homophonous words and one consisting of non-homophonous words. To assess the use of internal speech, recall performance on the two word sets was compared. Three scores were available, the number of errors made on the homophonous set, the number of errors on the non-homophonous set and the sum of the two.

Conrad then calculated an internal speech ratio by dividing the number of homophonous errors by the total number of errors and multiplying by 100. The child's score could range from 0 - 100. If the child's score was greater than 50, the child would have made more homophonous errors than non-homophonous. It was assumed that a speech code or internal speech was used when memorizing print.

"In behavioural terms, a very high internal speech ratio would carry the presumption of a predominating use of internal speech. A very low value would suggest predominating use of some other internal mediating code" (p. 100).

Results of the task showed that 94 percent of the hearing subjects used internal speech. Conrad found a consistent decline in the proportion of hearing impaired who used internal speech as hearing loss became more profound.

"Clearly degree of deafness is a variable of the utmost importance in determining whether or not a child develops the ability to internalize speech and to use it at least when he reads words" (p. 100).
Conrad does not state that a profound loss does not necessarily preclude
the use of internal speech. Among the population of profoundly deaf subjects
there were individuals who scored comparably with normally hearing subjects.

**TEMPORAL/SPATIAL PROCESSING**

Klapper and Birch (1971) examined the ability of children to judge temporal
sequences when they were presented through two sense modalities, audition
and vision. Hearing subjects in this study were at age levels ranging
from 3 - 11 years.

The ability to judge temporally patterned auditory and visual stimuli was
studied using a method of successive paired comparison. A standard pattern
was presented and each child was asked to judge whether a second pattern
was the same or different. The visual stimuli were flashes of light and
the auditory stimuli were clicks of a duration of half a second.

Results showed that children at various age levels do not make the same
average number of errors, regardless of whether the stimulus is visual
or auditory. Competence in judging a visual-temporal pattern was not
demonstrated by younger children, up to age nine. Children under nine

-20-
responded accurately to auditory-temporal matches while children nine or older responded with greater accuracy to visual-temporal matches.

The findings of this study indicated that the judgement of temporal distributions in the visual and auditory modalities followed a distinct developmental course. Increasing competence in visual-temporal processing was associated with age.

Sterritt et al (1971) attempted to extend the study of separate influences of temporal and spatial aspects of auditory perception. A battery of nine perceptual tests was constructed and administered to hearing children six to twelve years of age. Auditory-temporal and auditory-spatial patterns were presented through headphones and visual-temporal patterns were flashed by lights. Dot patterns were used in the task which tested visual-spatial patterns of response.

The results suggested a continuum of difficulty whereby visual-spatial patterns were simpler across age levels. Tasks involving both temporal and spatial features were at an intermediate level and the purely temporal tasks were the most difficult.
O'Connor and Hermelin (1972a) examined the effect that loss of one source of sensory input may have on cognitive processing. Deaf, blind, and normally hearing children were required to determine whether two successive series of stimuli were the same or different. Stimuli were presented auditorially (series of sounds) to the hearing and blind subjects, and visually (light flashes) to the hearing impaired subjects and control group.

It was predicted that sequences which were spatially characterized would be better remembered when the stimuli were flashes of light rather than sounds. Results verified the investigators' hypothesis. The presentation of auditory stimuli led to more correct recognitions when sequences were temporal. The reverse was true for visual stimuli where spatial sequence was better remembered than a temporal one.

O'Connor and Hermelin (1972b) continued to examine the effects of presenting stimuli using auditory or visual modality. Deaf and hearing children were presented with visual displays while blind and hearing children were presented with auditory displays. Three digits were exposed successively either in a visual display or auditorially from loudspeakers. The subjects were instructed to "tell" or "write down" the middle digit or sound.
Results showed clearly that the deaf subject who "saw" the digits chose the spatial middle, indicating that the visual display dominated the child's organization of material. Blind and hearing children chose the temporally central sound. Results established the difference between using a spatial strategy of auditorily presented material.

In another study (1973a) O'Connor and Hermelin investigated two areas: dependence on verbal storage for memory in sequential order and alternate codes a deaf child might use to retain the original order of material presented. Twenty hearing and twenty deaf children were presented with five items displayed successively in five frames. Photographs of faces and consonant-vowel-consonant word lists were used. Both materials were presented at a fast rate and then at a slow rate. The children were asked which item they saw first.

An analysis of the results indicated that tasks which demanded sequential ordering in memory were not dependent on additional strategies, namely reliance on spatial cues derived from visual displays. The authors found that the rate of presentation did not effect the order of recognition. Additional results showed that hearing children recalled the temporal position of nonsense syllables more readily than did the hearing impaired population (O'Connor & Hermelin, 1973a).
An incongruent temporal/spatial presentation technique was used in an additional study by O'Connor and Hermelin (1973b). The investigators tested hearing impaired, autistic, subnormal, and normal children to determine processing strategies utilized. If an association existed between temporal/spatial organization and modality then:

"one might expect that children lacking one of the three sensory inputs might also be impaired in the extraction of the associated temporal/spatial codes" (p. 69).

Subjects were asked to recall items in a three digit display. The presentation was ambiguous so that the child could recall either in a temporal order (first to last) or a spatial order (left to right). Digits were presented in boxes or frames at a rate of 300ms per digit over a 2 second period.

Results showed that hearing children recalled digits temporally four times as often as they did spatially. Deaf subjects recalled the digits eight times as often spatially as temporally. Deaf children gave consistent spatial responses. The investigators concluded that in short term memory temporal coding is extremely dependent on accessibility of auditory system (O'Connor and Hermelin, 1973b).

Booth (1982) used the O'Connor and Hermelin (1973b) task and found deaf subjects to be biased towards a spatial response. She hypothesized that
the time of presentation was determining choice of response, (rate of presentation was 300ms per 2 second period) and that the boxes or frames that surrounded each digit, may have emphasized that spatial arrangement. Therefore a substudy was conducted administering a modified task to forty-one of the hearing subjects. Rate of presentation for each item was changed from 2 seconds per three digits to 900ms per three digits, and the boxes or frames were eliminated from the screen.

Although high spatial responses were expected, results of the substudy showed that forty-one percent of the hearing impaired children tested had a high temporal-spatial ratio. This clearly suggested temporal coding of visual information. Fifty-nine percent of the subjects processed items spatially. These results contradicted the findings of O'Connor and Hermelin (1973b) who stated that the deaf child, "recalled eight times as often spatially" (p.99). It was also in direct opposition to an earlier study (O'Connor & Hermelin, 1973a) where it had been reported that rate and manner of presentation did not effect the child's recognition scores. Booth (1982) found that both of these elements determined the outcome of the task.

In addition to modifying the O'Connor and Hermelin (1973b) task, Booth (1982) administered Conrad's (1979) test for internal speech. The
relationship between performance on the temporal/spatial and internal speech tasks showed that subjects who were using internal speech as defined by Conrad (1979) were equally divided as to coding preference (temporal or spatial). Of the subjects with low internal speech scores, 39% responded spatially and 17% temporally.

Booth (1982) felt that her data did indicate a connection between internal speech and temporal processing, but further research should be conducted to determine the extent of the relationship.

SUMMARY

Processing Strategies

A review of the literature in three areas (visual memory, internal speech and temporal/spatial processing), has provided evidence pertinent to the study.

Visual Memory

A series of studies examined visual memory in both hearing and hearing impaired populations. Blair (1957) hypothesized that the deaf child was "freed" from auditory recall. In his study the deaf child recalled digits equally as well in both directions whereas hearing children recalled
more digits in a conventional left to right order. Nunnally (1966) found that the deaf relied on visual memory more than a hearing population. Retention of digit sequences was free from competing auditory-vocal processes during input retrieval. These studies established that a processing difference does exist between the two populations.

**Internal Speech**

Conrad (1963) concluded that there were coding differences between hearing and hearing impaired children. This was indicated by the success of recalling homophonous and non-homophonous words. Hearing children recalled more non-homophonous words, whereas hearing impaired children recalled both equally well.

Allen (1971) conducted a similar study and hypothesized that hearing impaired subjects would be more dependent on visual presentation. Results did not confirm the hypothesis nor did they support the finds of Conrad (1963).

Additional studies by Conrad (1963b) and Conrad and Rush (1965) utilized letters rather than words. When asked to recall groups of consonants, the hearing subjects recalled more letters than did the hearing impaired subjects. Investigators felt a different coding procedure was used by
hearing children.

Conrad (1979) viewed internal speech as one form of thinking. A task was devised to assess the inner "codes" used by hearing impaired children. Results verified the assumption, and the investigator concluded that hearing subjects recoded visually presented stimuli into a code based on acoustic imagery. Results of a similar task presented to hearing impaired subjects found a consistent decline in the proportion of hearing impaired children who used internal speech as hearing loss became more profound. The heterogeneity of the deaf as a group was stressed when Conrad (1979) found that a profound loss does not preclude the use of internal speech.

**Temporal/Spatial Processing**

The ability to judge temporal sequences was investigated by Klapper and Birch (1971). Information was presented through two modalities; audition and vision. Findings indicated that judgements of temporal distributions followed a distinct developmental pattern from auditory-temporal to visual-temporal processing. Sterrit et al (1971) suggested that there may be a continuum of difficulty whereby visual-spatial patterns were the simplest and purely temporal tasks were the most difficult.
The effect of loss of one sensory input system was examined by O'Connor and Hermelin (1972a). They predicted that deaf children would find visually presented spatial displays easier to recall. This prediction was verified. O'Connor and Hermelin (1973a) exposed hearing and hearing impaired children to an incongruent temporal/spatial task, to determine processing or coding preference. Hearing children recalled digits four times as often temporally as they did spatially. Deaf children gave consistent spatial responses eight times as often. They concluded that the temporal responses were dependent on an auditory-verbal system.

Booth (1982) altered the O'Connor and Hermelin task by changing the rate of presentation for the incongruent temporal/spatial task and eliminating the boxes or frames from the screen. Booth found 41% of the hearing impaired population processed temporally, while 59% of the subjects processed the visual information spatially.

The literature indicates that deaf children typically rely on visual memory because the auditory signal they receive is minimal. Hearing impaired children are "freed" from auditory imagery and use a coding procedure which may differ from the coding strategy used by hearing children, as they do not use a rehearsal technique based on internal speech. The hearing impaired child will process visual digit displays spatially.
whereas temporal responses are expected from a hearing population.
Chapter Three

METHODOLOGY

The major purpose of the study was to compare the processing strategies of two populations (hearing and hearing impaired), when they were presented with a homophonous/non-homophonous temporal/spatial task.

DESCRIPTION OF THE SAMPLE

SUBJECTS

Hearing Impaired. The sample of 71 hearing impaired students participating in the study was chosen from classes in a school for the deaf, if they met the following criteria: 1) a sensori-neural loss of 60 dB (BEA) or greater, 2) were fitted with hearing aids, 3) used a total communication methodology, 4) were between the ages of 8 - 0 and 19 - 11 as of June 1, 1982, 5) were able to complete a pencil and paper task.

The sample consisted of 31 females and 40 males. The 12 - 0 to 15 - 11 year olds comprised 46.6% of the sample due to the fact that this age group was able to complete the task. For differing reasons the hearing impaired population had more difficulty with the word task. For example many younger children did not have the linguistic skills appropriate
to the established criteria, and many of the older children had additional handicaps.

Hearing Subjects. The sample of 74 hearing students participating in the study were chosen from regular classes in a school district in a Metro area neighbouring the school for the deaf. Students were chosen from schools according to the following criteria: 1) were able to complete a pencil and paper task, 2) had no known handicaps, 3) were matched by SAT vocabulary scores to hearing impaired students.

INSTRUMENTS

Stanford Achievement Test (SAT) Form A, Vocabulary Subtest.

The SAT was administered to all hearing subjects. The vocabulary subtest was chosen as the test scores were assumed to measure a general ability level in vocabulary, and because the child's basic vocabulary was necessary to complete the task. Also Booth (1982) found in her study that degree of internal speech was significantly related to performance on tasks of vocabulary.
Stanford Achievement Test, Special Edition for the Hearing Impaired (SAT-HI)

The SAT-HI was adapted from the SAT, 1973. Test items were unchanged from the SAT, however subtests within each level of the SAT were reassigned to the next lower or higher level of the SAT-HI. Levels were changed as a result of the discrepancies in the performance between hearing and hearing impaired children (Rogers et al, 1978).

It has been further documented (Clarke et al, 1977; Rogers et al, 1978) that level of performance and rate of progress for hearing impaired students lag behind that expected for hearing students of comparable age. In addition Rogers et al (1978), found that vocabulary and comprehension achievement levels decreased with the severity of the child's loss. This means that the two groups could not be matched by age, and were therefore matched according to vocabulary subtest grade scores.

Temporal/Spatial, Homophonous/Non-homophonous Word Task

The instrument was adapted from the work of O'Connor and Hermelin (1973), Conrad (1979), and Booth (1982). Words for the task were taken from Conrad's test for internal speech. His original test consisted of 24 items of 6 words each, alternating between homophonous and non-homophonous sets. The word task used in this study was made up of
48 items with 3 words each. Two practise items were presented to each subject to ensure comprehension of the task.

O'Connor and Hermelin (1973) developed an incongruent temporal/spatial task which consisted of 24 groups of 3 digits. The digits were displayed in a random order over a 2 second time period. In any one display the spatial and the temporal orders of the digits differed so that they would never appear in a left to right succession.

<table>
<thead>
<tr>
<th>Order of presentation</th>
<th>2 3 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus</td>
<td>5 9 8</td>
</tr>
</tbody>
</table>

For example, if the digits (5,9,8) were presented in the order (2,3,1), the temporal response would be "8,5,9" and the spatial response would be "5,9,8". In this way a child could be considered a temporal processor if he/she responded temporarily to the task, and a spatial processor if he/she responded in a spatial order.

Booth (1982) altered the O'Connor and Hermelin test by changing elements of the task. The frames or boxes were eliminated from the screen as the outline surrounding each digit was thought to prejudice responses towards a spatial process. Presentation of each item was altered from 2 seconds per 3 words to 900 ms. per 3 words.
The present instrument (Appendix A) is a modification of these three tasks. Forty-eight groups of three words each were presented successively for 300 ms. per word, or 900 ms. per item. Words appeared on the screen successively in a random order either in the first, second, or third position.

There were no overlaps of presentation of words, meaning the first word disappeared before the second word appeared, the second word disappeared prior to the presentation of the third word. The exception being that the display of the items was never in the same congruent order spatially or temporally.

Each word was printed two cm. high on an Apple microcomputer screen (Video 100). Words used throughout the task were printed on a wall chart in Letraset No. 714 (96pt.). The chart consisted of two lists of words (homophonous and non-homophonous) which were displayed during the testing.

**PROCEDURE**

Procedural steps for administration were as follows: 1) each child was told that the words they would see on the T.V. screen were on the wall
chart. 2) they were told that the correct spelling was not necessary, and that they could refer to the chart whenever they wished. 3) the subject was then told that there were two practice items. 4) the test instructions given were, "Write the words you saw". The investigators controlled the rate of presentation of the 48 test items by pressing the space bar to advance to the next item. This was to ensure that each subject had the time necessary to write down the words for each item.

**ADMINISTRATION**

The study was conducted in two stages. Stage one began June, 1982, when subjects attending the school for the deaf were tested. Stage two began in January, 1983.

Stage One. Educational and audiological information was obtained from school records. SAT-HI scores for the students were obtained from the data used by Booth (1982). The temporal/spatial homophous/non-homophous task was administered and scored by the investigator.

Stage Two. The SAT vocabulary test was administered as a group test to six randomly selected classes of hearing subjects. The investigator scored all the protocols and scores were verified by school personnel.
Subjects completing the temporal/spatial, homophonous/non-homophonous task were selected on the basis of the previously established criteria.

**SCORING**

The raw scores on the vocabulary subtest were converted to grade scores from the norms accompanying the instruments. The grade scores provided a satisfactory scale for comparing relative achievement. This was necessary because the two groups were matched by grade level scores on the vocabulary subtest of the SAT and SAT-HI.

Three scores were calculated for the temporal/spatial, homophonous/non-homophonous word task; a) a total recall score; b) a recall score of either homophonous or non-homophonous words; and c) the number of words recalled in a correct temporal or spatial order: a) A total recall score for each item was calculated by tallying the number of correct responses, regardless of the temporal or spatial order. The maximum score for each item was three and could be obtained if the subject recalled the three words in the item correctly.

<table>
<thead>
<tr>
<th>Order of presentation</th>
<th>2</th>
<th>1</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus</td>
<td>flew</td>
<td>blue</td>
<td>through</td>
</tr>
</tbody>
</table>
In the above example, recall of all three words in any order would receive a score of "3". Partial credit could be given if the child recalled either two words or one word. The scores for each item were then added together, giving each subject a total recall score, ranging from 0 to 144. b) A score was obtained in a similar way for recall of homophonous words. A maximum of "3" was given to each item and partial credit of "2" or "1" was given if the subject did not recall all three words. Twenty-three items with three words each used homophonous words and twenty-three items used non-homophonous words. Scores for each item were added together. Scores for homophonous and non-homophonous word recall ranged from 0 to 72. c) The third score obtained from the temporal/spatial, homophonous/non-homophonous word task was recall of words in a temporal or spatial order. Responses for each item were coded as to whether they were written in a temporal or spatial order.

<table>
<thead>
<tr>
<th>Order of presentation</th>
<th>3</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus</td>
<td>door</td>
<td>bare</td>
<td>farm</td>
</tr>
</tbody>
</table>

If a child responded temporally the response was "bare farm door". The response would be assigned a "3", if all three words were recalled in the correct temporal order. Partial credit of "2" would be given for
the following responses:

bare, farm, ____
____, farm, door
bare, ____ , door

Likewise a score of "1" was assigned to the following responses:

bare, ____ , ____
____, ____ , door
____, farm, ____

A score of "0" was given to the item if the child did not write a response or if the words the child used were not part of the item. If the words were not in a temporal or spatial order, zero was given to the item, for example, "farm, door, bare".

Scores obtained on each item were then summed, giving a child a score which indicated the number of words recalled temporally and spatially. Scores could range from 0 - 144. Scores for the three tasks were independent and in no way tallied together. Tally sheets were constructed to ensure
confusion between scores on the three tasks did not occur. All results were coded independently by the examiner and two other trained individuals with 100% verification.

DATA AND DATA PROCESSING

Data from all subjects tested in both the hearing and hearing impaired groups were included in the analyses. To test the major and minor hypotheses, oneway analyses of variance (ANOVA) were calculated using the Statistical Package for the Social Sciences (SPSS) (Kita, 1979, 1980). If the ANOVA showed a significant value, a multiple range test was completed in order to make multiple comparisons between groups.

Multiple comparison methods were completed: namely Tukey (1949) and Duncan (1957). Both these tests are seen as inferior to the Scheffe method (Ferguson, 1982). Therefore only the results of the Scheffe Multiple Range Tests are reported in Chapter Four.
Chapter Four

RESULTS

Chapter four will present the results of the study and describe the results in relationship to the hypotheses tested.

TEMPORAL/SPATIAL, HOMOPHONOUS/NON-HOMOPHONOUS WORD TASK

One way analyses of variance (ANOVA) were used throughout to test all hypotheses. Hypotheses 1a and 1b stated:

1a) There will be a relationship between temporal processing and the use of internal speech in a population of hearing children.

b) There will not be a relationship between spatial processing and the use of internal speech in a population of hearing impaired children.

In order to test these hypotheses the populations of hearing and hearing impaired children were grouped according to hearing loss. Breakdown of the groups is presented in Table A.
<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Subjects</th>
<th>Hearing Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL 1</td>
<td>74</td>
<td>0 - 25</td>
</tr>
<tr>
<td>HTL 2</td>
<td>15</td>
<td>40 - 95</td>
</tr>
<tr>
<td>HTL 3</td>
<td>55</td>
<td>95+</td>
</tr>
</tbody>
</table>

These three hearing threshold (HTL) groups were used for many comparisons throughout the study.

When investigating the relationship between temporal processing and internal speech, temporal responses of all subjects were analyzed. The number of homophonous and non-homophonous words recalled in a temporal order was calculated. Similarly the number of homophonous and non-homophonous words recalled spatially was calculated for each subject.

Four possible scores were calculated for each subject:

1) homophonous-temporal (HT)

2) non-homophonous-temporal (NT)

3) homophonous-spatial (HS)

4) non-homophonous-spatial (NS)
Four separate oneway ANOVA's were completed comparing subjects' hearing levels and processing strategies used for recall of homophonous and non-homophonous words. Summaries are presented in Table 1, Appendix B.

Because significance at the .05 level was found for those processing non-homophonous words temporally, a Scheffe Multiple comparison was completed. The multiple comparison showed a significant difference in temporal processing and recall of non-homophonous words between HTL group 1 and HTL group III, (HTL 1 x = 43.4054, HTL III x = 34.8571, p 0.01). Thus the hypothesis (1a), that there is a relationship between temporal processing and internal speech in a population of hearing children could not be rejected. As predicted a significance was not found between spatial processing and internal speech in a population of hearing impaired children. Hence, hypothesis 1b was not rejected.

Hypotheses 2a, 2b and 2c stated:

2a) Hearing children will make more errors when asked to recall homophonous words than non-homophonous words.

b) Hearing impaired children will make fewer errors than their hearing counterparts when asked to recall homophonous words.

c) Hearing impaired children's recall of homophonous words will be dependent on hearing level. The more severe the loss the more homophonous words will be recalled.
The hypotheses were tested by comparing the recall scores of the homophonous and non-homophonous words for the three hearing threshold level groups. Summaries of the ANOVA results are presented in Table II, Appendix B.

Results of the ANOVA showed a significant relationship between recall of non-homophonous words and hearing threshold level. Therefore the Scheffe method of multiple comparison was implemented using a 0.01 level of significance. A significant difference was found between HTL III and HTL 1, when comparing the number of non-homophonous words recalled (HTL III $x = 47.1964$, HTL 1 $x = 56.5946$, $p < 0.01$).

These results caused the investigator to reject the hypothesis that hearing children will make fewer errors when asked to recall non-homophonous words.

Hypothesis 2b was rejected, as a significant difference was not found between hearing and hearing impaired subjects recall of homophonous words. Hypothesis 2c was also rejected as a significant difference was not found between hearing threshold level groups on their recall of homophonous words.
Hypotheses 3a) and 3bi) stated:

3a) Hearing children will consistently use a temporal strategy when asked to recall words in each test item.

bi) Hearing impaired children will consistently use a spatial strategy when asked to recall words in each test item.

Summaries of the ANOVA's testing these hypotheses are presented in Table IV, Appendix B.

A one-way analysis of variance showed no significant differences between the hearing and hearing impaired groups. On the basis of these results the hypotheses stated in 3a and 3bi were rejected. Processing strategy was not dependent on membership in either population.

A related hypothesis 3bii) stated that:

3bii) Processing strategies used by hearing impaired children will not depend on severity of hearing loss

One-way ANOVA's were completed comparing processing strategies with hearing threshold levels. Results are summarized in Table V, Appendix B.

There was no significant difference for processing strategies between the hearing threshold level groups. The hypothesis which stated processing
strategies would not be dependent on severity of hearing loss was accepted. Hearing loss did not affect the processing strategy utilized by the child.

**MINOR HYPOTHESES**

4a) Younger children will process items spatially and older children will process items temporally.

b) Processing strategies used by hearing impaired children will not be influenced by age.

To test these hypotheses the children in each group (hearing and hearing impaired) were divided into five subgroups according to their chronological age (in months). The breakdown of the age groups is presented in Table B.

As stated in chapter III, the groups were not matched by chronological age but by vocabulary scores on the SAT and SAT-HI. The hearing group did not have any members in subgroups CA IV or CA V. Therefore the ANOVA for hearing subjects included CA 1 - CA III only. The ANOVA for hearing impaired subjects included subjects in CA II - CA V. Results are summarized in Table VI, Appendix B.

The results of the ANOVAs for hearing subjects indicated that significant differences were found between chronological age and processing strategies.
Significant differences were found when temporal processing was compared with age, and when spatial processing and chronological age were analyzed.

Table B

Age in months for hearing and hearing impaired subjects.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Age in months</th>
<th>Hearing Subjects</th>
<th>Hearing Impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA I</td>
<td>79 thru 95</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>CA II</td>
<td>96 thru 119</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>CA III</td>
<td>120 thru 143</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>CA IV</td>
<td>144 thru 181</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>CA V</td>
<td>182 thru 240</td>
<td>0</td>
<td>38</td>
</tr>
</tbody>
</table>

Scheffe multiple comparisons were completed to determine the differences between the age groups for temporal processing. Two significantly different contrasts were identified. CA II was significantly different from CA 1, (CA II x = 91.2857, CA 1 x = 59.7586, p 0.01). CA III was also significantly different than CA 1, (CA III x = 94.333, CA 1 x = 59.7586, p 0.01).

Older hearing subjects (CA II & III) performed significantly better than the youngest hearing subjects on temporal processing tasks.
Age was also a determining factor for hearing children processing spatially. A significant difference was found between CA 1 and CA II, (CA 1 x = 42.4483, CA II x = 16.3143, p 0.01). Younger hearing subjects (CA 1) responded more often to the task spatially, than did an older group of hearing children (CA II). Therefore the hypothesis that chronological age will determine processing strategy of hearing subjects was accepted.

Hypothesis 4b examining hearing impaired subjects' age and processing relationships was tested. Table VI indicates that a significant effect is associated with age groups of hearing impaired children who processed temporally, (CA III x = 49.2857, CA V x = 94.3333, p 0.01). Older hearing impaired children (CA V), responded more often to the task temporally, than did a group of younger hearing impaired children (CA III). Significant differences were not found between groups of hearing impaired children who processed the test items spatially.

Hypotheses 5a and 5b stated:

5a) Processing strategies used by hearing children will not be dependent on gender.

b) Gender will not influence processing strategies of hearing impaired children.

-48-
To test these hypotheses ANOVAs were completed to determine whether processing strategies were dependent on gender. These results were summarized in Table III, Appendix B.

Both hypotheses were accepted as no main effects were identified.

Hypotheses 6a and 6b stated:

6a) Coding strategies used by hearing children will not depend on their vocabulary level.

b) Vocabulary level will not influence coding strategies of hearing impaired children.

To compare the variance between groups, both hearing and hearing impaired subjects were divided into three levels, according to their grade equivalent scores on the vocabulary subtest of the SAT and SAT-HI. These data are presented in Table C.
Table C

Summary of subjects' vocabulary levels

<table>
<thead>
<tr>
<th>Group</th>
<th>Grade Level</th>
<th>Hearing</th>
<th>Hearing Impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC 1</td>
<td>1.0 - 2.9</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>VOC II</td>
<td>3.0 - 4.9</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>VOC III</td>
<td>5.0+</td>
<td>21</td>
<td>17</td>
</tr>
</tbody>
</table>

74 71

Analyses of variance were completed comparing vocabulary level and processing strategies for hearing and hearing impaired subjects. Results of ANOVAs are presented in Table VII, Appendix B.

Table VII indicates that there was a significant association between hearing subjects vocabulary level and temporal processing. A Scheffe multiple comparison test was done to determine differences. Hypothesis 6a had predicted no relationship would exist between coding strategy and vocabulary level. This hypothesis was rejected as the hearing subjects of VOC III scored significantly higher than VOC 1 on processing words temporally, (VOC III x = 99.4000, VOC 1 x = 67.2258, p 0.01). No main
effect was identified when hearing subjects' vocabulary level and relationship with spatial processing were examined.

Hypothesis 6b was accepted as no significant differences were associated with hearing impaired subjects vocabulary level and processing strategy.

Chapter four has presented results of the study. The discussion of the results and a summary of conclusions will be presented in Chapter five.
Chapter five

DISCUSSION AND RESULTS

The purpose of this study was to investigate hearing and hearing impaired children's temporal/spatial processing relationships for homophonous and non-homophonous words.

DISCUSSION OF RESULTS

This study examined two dimensions: processing strategy, either temporal or spatial, and the use of internal speech as demonstrated through recall of homophonous words.

Formerly, the literature had reported these as separate dimensions. Several studies had investigated processing strategies of hearing and hearing impaired children (O'Connor & Hermelin, 1973; Klapper & Birch, 1971), while additional studies examined the concept of internal speech in the two population, (Conrad, 1971; Allen, 1971; Conrad & Hull, 1964)
Booth (1982) found evidence to support the hypothesis that a relationship existed between temporal processing and internal speech. She found 41% of the hearing impaired students in her study had a high temporal-spatial ratio, suggesting they coded information temporally.

Fifty percent of the students who had processed temporally also used an acoustic code, or internal speech. Booth suggested:

"While the study does suggest a connection between acoustic and temporal processing of information it seems more research must be conducted to determine task specificity (p. 70)."

For the purpose of the present investigation, a task was devised based on the hypothesis that a connection did exist between temporal processing and internal speech. This task incorporated activities used by Booth (1982), Conrad (1979), and O'Connor & Hermelin (1973b). The results of the use of this task, as presented in Chapter four, are discussed in this chapter.

**TEMPORAL PROCESSING, INTERNAL SPEECH AND HEARING LOSS**

A significant difference was found between responses of the two hearing threshold level groups. Hearing children in the study recalled more
non-homophonous words temporally than did the profoundly deaf group, 
(see Table 1, Appendix B).

These findings lend strong support to Booth's results (1982), but 
only minor support to the work of Conrad (1979). Booth (1982) found 
a high correlation between those processing temporally and using internal 
speech when examining responses of a hearing impaired population. 
She also hypothesized that children who use internal speech and are 
temporal processors will be competent readers. This relationship 
will be expanded upon later in this chapter.

Conrad (1979) stated:
"degree of deafness is a variable of the utmost importance in determining 
whether or not a child develops the ability to internalize speech and 
to use it at least when he reads words (p. 102)."

In the present study there was no significant difference between the 
hearing threshold level groups II and III who processed non-homophonous 
words temporally. The only significant difference was between the hearing 
(HTL I) and the profoundly deaf (HTL III) groups. This will be discussed 
when results of internal speech and hearing loss are examined.
Prior research had indicated that hearing impaired children are "highly spatial", and process visual material spatially eight times more often than they do temporally (O'Connor & Hermelin, 1973b). Conrad (1979) stated that the majority of profoundly deaf children do not use internal speech. On the basis of existing research, it was hypothesized that a relationship between spatial processing and internal speech would not exist.

Data from this study confirmed Conrad's premise. There were no significant differences between the three hearing threshold level groups for spatial processing and use of internal speech.

Booth (1982) felt it was probable that students who processed spatially would not use internal speech, and would have difficulties with reading. The present findings lend support to her prediction as no significant differences were found between hearing threshold groups.

**HEARING LOSS AND INTERNAL SPEECH**

A significant relationship between recall of non-homophonous words and hearing loss groups was found in the present study. Conrad (1979) stated:
"a substantial increase in deafness can be tolerated before it reflects a noticeable change in the use of internal speech, (p.103)."

He also believed that degree of deafness was a "variable of the utmost importance " (p. 102), when determining whether a child used internal speech.

Conrad hypothesized that there would be a change in performance at about 85dB and another change at 105dB. Conrad proposed that a child with a severe to profound loss (85dB) would use internal speech and that a child with this loss would be "linguistically different" from a child with a profound loss (105dB). Thus the child with an 85dB loss would have the potential to use internal speech, however, the child with a profound loss would not.

This suggests that hearing loss may be a determining factor in utilization of internal speech. If a child uses internal speech according to Conrad (1979), he is somehow linguistically different from those who do not.

The present study divided subjects into hearing loss groups according to the ANSI (1969) standards. Therefore the hearing loss groups are not identical to those proposed by Conrad. The data suggest a significant difference between the hearing and profoundly deaf group (+95dB) for recall of non-homophonous words.
However, the "dramatic" difference predicted by Conrad (1979) between severely and profoundly deaf subjects was not found in this study. Conrad may have overgeneralized results by stating that the child's degree of hearing loss was the determining factor for use of internal speech. He stated repeatedly that hearing loss was the "variable of utmost importance" when trying to predict whether a child will use internal speech.

Perhaps Conrad has placed undue emphasis on the variable of hearing loss when predicting whether a child has the potential to use internal speech. Indeed, a significant difference exists between a hearing and profoundly deaf population, however, members of these groups represent extremes along a continuum.

Several subjects in this study (21%) were not members of either of Conrad's hearing loss groups. Therefore it seems reasonable to hypothesize that variables other than hearing loss may influence use of internal speech.

As was discussed previously in this chapter, those children processing temporally may be predisposed to use internal speech. Additional
variables such as the child's age and vocabulary level may be influenced as to whether they will use internal speech.

One hypothesis tested was that a relationship would exist between severity of hearing loss and recall of homophonous words. The prediction was made on the basis of Conrad's studies (1979; 1971; 1963), stated that hearing children would recall fewer homophonous words if they were using internal speech. Booth (1982) verified results of Conrad's study. Her study showed recall of homophonous words was lower in a population of hearing children. Approximately 56% of the hearing subjects did use internal speech whereas 44% of the subjects did not use internal speech or an acoustic code.

In the present study however a significant difference was not found between hearing threshold level groups' recall for homophonous words. Therefore the hypothesis was rejected. The rejection of the predicted hypothesis has several implications.

Additional variables may influence whether a child uses internal speech. For example, a significant relationship was found between a temporal processing strategy and internal speech. This suggests that severity of hearing loss may not be the dominant variable which determines usage
of internal speech. The stimulus presented to the child must also be examined. O'Connor & Hermelin (1973b) presented numerals to the hearing impaired subjects to determine whether the child processed temporally or spatially. The task Booth (1982) used to determine whether the child was using internal speech, was a word task similar to that used by Conrad. The present study used the words compiled by Conrad (1979) to determine both processing preference and use of internal speech.

AGE AND PROCESSING STRATEGY

Results of this study demonstrated that for a hearing population there is no significant relationship between the child's age and processing strategy. This corresponds to the findings of Klapper and Birch (1971). The task they used was somewhat different from the one used in this study, but the outcomes are of considerable importance. They found visual-temporal tasks the most difficult for children to process. Children who were nine or older responded with "greater accuracy" to visual-temporal matches. Additional evidence (Sterrit et al, 1971) suggested a continuum of difficulty existed where visual-spatial patterns were "easier" to process while purely temporal patterns were more difficult.
Results of this study gave support to the findings of Klapper and Birch (1971) and Sterrit et al (1971). Significant values at the 0.01 level were found between age groups and preferred processing strategy. Hearing children younger than age eight seemed to process spatially with a mean recall score of 42.45 words, while ten year olds recalled an average of 22 words spatially. Children who were processing temporally recalled an average of 59.76 words at age eight, and an average of 91.2 words at age nine and older.

The continuum concept suggested by Sterrit et al (1971) seems very applicable when comparing processing strategy and age of the hearing child.

Results of the hearing impaired group were not as predicted. A significant difference was not found between spatial processing and age, however, a significant difference was found between temporal processing and age. Hearing impaired children older than twelve chose a preferred temporal strategy to process the words used for the task.

The literature indicated that the deaf as a group would process spatially (O'Connor & Hermelin, 1973b) and not use internal speech (Conrad, 1979). The variable of age as a determiner of processing strategy has not been
thoroughly examined. O'Connor and Hermelin (1973b) do not state the age of the children used in their study. They merely state the predominant processing strategy across all age levels to be "eight times as often spatially as temporally" (p.99).

This evidence led to the formation of the hypothesis that age would not determine processing strategy. On the basis of the data analysis this hypothesis was rejected.

The data do suggest hearing impaired subjects used in this study can be divided into two categories: those who, when older, process temporally, and those who, regardless of age, process spatially. A temporal processing strategy is seen as a more complex strategy and is typically used by older hearing children (Sterritt et al, 1971). Hearing impaired children utilizing this strategy may be processing print in a manner similar to their hearing counterparts. Additional variables such as severity of hearing loss, use of internal speech, and vocabulary level, may be several variables that could affect choice of strategy.

The hearing impaired subjects that process spatially regardless of age use the processing strategy which has been described by O'Connor and Hermelin (1973b). One may hypothesize that in case of the spatial
processor, the simpler strategy is being utilized by the child. Sterrit et al (1971) suggest this may be due to the age of the child, but it may also be due to the child's linguistic sophistication.

VOCABULARY LEVEL AND PROCESSING STRATEGY

Booth (1982) found that reading vocabulary scores increased with the child's age. It was found that this consistent increase in vocabulary score was not affected by the child's hearing loss. To determine vocabulary level Booth administered the SAT-HI vocabulary subtest to all subjects, the same instrument used in this study. A low positive correlation was found by Booth ($r=.35$) between recall of non-homophonous words (measuring internal speech) and vocabulary subtest scores.

Booth's findings gave minor support to those of Conrad (1979) who found that degree of deafness was not a major factor in reading ability. What seemed much more important was whether the child had acquired internal speech. Conrad (1979) states:

"The average value of reading ability for a given level of hearing loss depends on the proportion of children using internal speech (p. 158)."

Booth (1982) hypothesized that the relationship between internal speech and vocabulary test scores may exist due to the format of the test.
It was thought that in order to complete the vocabulary subtest, the subject would have to "comprehend word meaning within the context of a sentence, (p. 68)."

\[e.g., \text{A ball is } \underline{\hspace{2cm}}\]
\[\text{square round thin}\]

Booth (1982) and Conrad (1979) suggested completion of the vocabulary subtest may involve use of internal speech. However, the child's preferred processing strategy may give investigators additional information necessary to understand the reading process.

The SAT-HI vocabulary subtest uses a cloze procedure. The assumption is that in order to complete the item successfully, the child would have to process print using a temporal strategy.

In the present study the scores obtained after administering the SAT and SAT-HI vocabulary subtest were converted into grade level scores. These scores were then compared to the number of words recalled temporally. Although a relationship between processing strategy and vocabulary level was not predicted for the hearing population, a highly significant difference was found between vocabulary groups and temporal processing (\(F = .0065, p. 0.01\)).
Hearing children who scored at a high grade level on the vocabulary subtest, recalled more words temporally (average recall 99.4 words). The groups having low grade equivalent scores (1.0 - 2.9) on the vocabulary subtest recalled fewer words temporally (67.23).

These results can be partially explained by examining results of Booth's (1982) study. Booth found that students who coded or processed "information temporally and had internal speech had significantly higher mean scores for syntactic ability and comprehension" (p. 57). She also stated, "the degree of internal speech, therefore, has a noticeable effect on performance" (p.57).

Logically, the variable of age could be related to both temporal processing, internal speech and therefore high vocabulary scores. As age increases, the hearing child becomes a temporal processor, usually able to use internal speech.

As stated previously, the vocabulary task may be easier for temporal processors to complete due to the test format. Booth (1982) and Conrad (1979) ascertained that internal speech had a direct relationship to syntactic and comprehension ability. The results of the present study
suggest that there is a confounding effect due to the interaction of temporal processing and internal speech with age. Some subjects do seem predisposed to high scores when instruments use a cloze format.

As predicted, a significant difference was not found between age groups and processing strategy within the hearing impaired population. There are several reasons that can be investigated, the first being that the hearing impaired subjects tested in this sample for some reason did not have a preferred strategy. This is not in agreement with the results of O'Connor and Hermelin (1973b), who stated that the deaf will process "eight times as often spatially" (p. 99). Although the group did not have a processing preference, it should be noted that various individuals within the sample did show processing preferences.

Without evidence of a preferred strategy, it is logical that differences between groups on vocabulary grade scores would not be significant.

Secondly, evidence already presented in this chapter suggests temporal processing to be a more "difficult" or higher level processing strategy. The vocabulary test used seemed to depend on the subject's ability to process temporally. If the deaf child was not capable of temporal processing it seems likely that they would do poorly on the vocabulary
subtest. In the sample of hearing children, the change from spatial to
temporal processing occurred at approximately age 8, while Sterrit et
al (1971) report it at about age 9. The same did not hold true for
the hearing impaired population. A preferred processing strategy had
not been established.

Booth (1982) tried to profile students and their processing strategies.

"The group with a high temporal-spatial ratio and high internal speech
perform consistently better on all tasks than those with a high temporal-
spatial ratio but have low internal speech. Similarly, those subjects
who have a low temporal-spatial ratio show profiles with like patterns
of responses. Those students with low temporal-spatial ratios and high
internal speech perform better on all tasks than those with a low temporal-
spatial ratio and low internal speech. Regardless of temporal or spatial
coding preference, the degree of internal speech appears to affect
performance on language related tasks, (p. 57)."

Therefore, those hearing impaired students who are spatial processors and
do not use internal speech, will not do well on language related
tasks.

**PROCESSING STRATEGY AND HEARING LOSS**

The relationship between temporal-spatial processing strategies was
first investigated by O'Connor & Hermelin (1973b). They found that
the "deaf recalled digits 8 times as often spatially as temporal " (p. 99).
They also stated that neither rate of presentation nor manner of display
affected word recognition.
Booth (1982) obtained results which contradicted O'Connor and Hermelin. Although 'the majority of the hearing impaired subjects used a spatial code (59%), the results did not correspond to the "eight times as often" figure. She also found that by altering rate and manner of presentation over 90% of the hearing impaired population whom she tested responded spatially.

Results of the present study were also found to be in opposition to those of O'Connor and Hermelin (1973b). Data enabled the investigator to reject the hypothesis that the hearing population would process using a temporal strategy and hearing impaired subjects would process spatially. Significance was not found between groups indicating that a preferred processing strategy had not been established for either group.

Results of this study are contrary to the findings of Booth (1982). She found the majority of hearing impaired subjects in her study used a spatial code. This was not the case in the present study. The hypotheses which predicted processing strategies for each group were made on the basis of pertinent results from recent research. Perhaps these findings should have been viewed with more caution.
In the present study the processing strategy was determined using a word task. O'Connor and Hermelin (1973a; 1973b) used digits in their research, and made conclusions regarding processing strategies of the deaf on the basis of their research. After examining additional research, blanket statements made regarding cognitive processing of the deaf as a group should be investigated further. The results indicated that the processing of words may be a more sophisticated task than the processing of digits. The processing of words does not necessitate predominant spatial or temporal processing in either population. Data have shown that strong relationships do exist between age and processing strategies for both populations.

Vocabulary level of the child may be another factor determining processing strategy. As was shown in the analysis of data, a relationship does exist between vocabulary level and processing strategy. The use of internal speech may play a role in the choice of a preferred processing strategy. The data gave support to this, in that a relationship did exist between internal speech and a temporal processing strategy.

Processing words could be a cognitive task very different from processing digits. The variables of age, vocabulary, and use of internal speech seem to be determinants which are more important than membership in
a hearing or hearing impaired group.

SUMMARY

Several factors seemed to link themselves to one another when investigating processing strategy and its relationship to internal speech. A schematic diagram is presented in Figure 1. Figure 1 is a generalization and has summarized the results of the current study. It is acknowledged that there are individual differences within each group.

1. Results from this study indicated that a relationship exists between temporal processing and internal speech for hearing threshold level groups.

2. There was a strong indication that age may be a determining factor for processing strategy. This holds true for both the hearing and hearing impaired populations.

3. This study also indicated that a relationship between recall of homophonous words and hearing loss exists. A significant difference was found between the hearing and profoundly deaf group.
4. A difference between processing strategy for the hearing and hearing impaired group was not evident in this study. A preferred processing strategy was not established for either group asked to complete the word task.

5. Severity of hearing loss was not found to have an effect on processing strategy. Profoundly deaf children and hearing children did not show a preferred processing strategy.
Figure 1

Possible relationship between the variables of age, internal speech and vocabulary level to processing strategy for hearing and hearing impaired children.

AGE
(determines processing strategy)

TEMPORAL PROCESSORS
(older children)

use INTERNAL SPEECH
More competent READERS

SPATIAL PROCESSORS
(younger children)

do not use INTERNAL SPEECH
Poorer READERS
LIMITATIONS OF THE STUDY

1. One limitation of the study was that processing strategy, and the use of internal speech were analyzed at the group level. It has been well documented (Booth, 1982; Conrad, 1979) that hearing impaired and hearing children are not homogenous groups. Therefore, investigations of individual performance may be beneficial.

2. Results from this study do not pertain to all deaf subjects. The sample of children was composed of subjects who were educated using a total communication methodology. Therefore, implications regarding the strategies or use of internal speech of the deaf population can not be made.

3. The Standard Achievement Test for Hearing Impaired Students was used to measure vocabulary level. As noted previously in Chapter Five, this test used a cloze procedure. The success with such a procedure may depend on the child's ability to process written information temporally. If the child, whether hearing or hearing impaired, was not able to process temporally they would not have been able to complete the task.
IMPLICATIONS FOR FUTURE RESEARCH

1. If comparative studies are to continue to investigate the similarities and differences between hearing and hearing impaired populations, an alternative means of matching the two populations must be investigated.

2. Research needs to be undertaken to investigate the relationship between internal speech and the child's vocabulary level.

3. Further investigations should be made between the role of processing strategy, internal speech and vocabulary level.

4. More information may be gained about deaf children if research took the direction of within group studies rather than between group studies. This could be achieved by testing hearing impaired children taught using an oral/aural methodology, as well as total communication methodology.

5. It may be beneficial to investigate individuals within the hearing impaired population whose preferred or dominant processing strategy
has been established. Additional variables such as age, internal speech, and vocabulary level could be investigated further for those processing temporally and spatially.
BIBLIOGRAPHY


APPENDICES
Appendix A

Temporal-Spatial Processing of Homophonous and Non-Homophonous words.

Forty-eight items with three words per item were programmed on an Apple II computer disc. Words were presented successively for 300ms. The total time per item was 900ms. Words in each item will appear randomly in the first, second or third position. The one exception will be that in no display of temporal or spatial order will the item appear in a left to right order.

Item order of presentation

Words presented.

1. 3 1 2
   have door bare

2. 3 1 2
   true who zoo

3. 1 3 2
   have bare door

4. 2 3 1
   who blue through

5. 2 3 1
   farm home lane

6. 2 3 1
   do through blue
7.  3  1  2
   door lane have
8.  2  3  1
   blue do few
9.  1  3  2
   furs bean home
10. 2  3  1
    zoo screw true
11. 2  3  1
    bare have door
12. 2  1  3
    few bare furs
13. 1  3  2
    bean bare furs
14. 2  3  1
    through few who
15. 2  1  3
    home farm bean
16. 2  1  3
    screw zoo do
17. 2  3  1
    door bare farm
18. 2  1  3
    true do screw
19. 3  1  2
    farm bean have
20. 1 3 2
   screw few zoo

21. 2 3 1
   lane home door

22. 1 3 2
   through who true

23. 2 1 3
   have furs lane

24. 2 1 3
   zoo blue through

25. 2 3 1
   farm furs bean

26. 2 3 1
   screw do through

27. 3 1 2
   door true screw

28. 1 3 2
   zoo true screw

29. 3 1 2
   bean bare have

30. 2 1 3
   who few true

31. 3 1 2
   bare bean furs

32. 1 3 2
   through screw zoo

33. 1 3 2
   have farm lane
34. 1 3 2
   few blue who

35. 2 3 1
   lane home farm

36. 2 1 3
   blue through do

37. 3 1 2
   home lane door

38. 2 1 3
   do zoo blue

39. 2 3 1
   furs door bare

40. 3 1 2
   true who few

41. 2 1 3
   home lane furs

42. 2 1 3
   blue zoo few

43. 1 3 2
   bare door home

44. 3 1 2
   who through blue

45. 3 1 2
   furs have bean

46. 2 3 1
   few screw do

47. 2 1 3
   bean farm bare

48. 3 1 2
   do true who
Appendix B

TABLE I

SUMMARIES OF STATISTICS COMPARING THE RECALL OF HOMOPHONOUS/NON-HOMOPHONOUS WORDS AND PROCESSING STRATEGY BY HEARING LOSS

a) Summary of descriptive statistics for homophonous words recalled temporally by hearing threshold level groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL I</td>
<td>36.6757</td>
<td>19.9945</td>
</tr>
<tr>
<td>HTL II</td>
<td>34.8182</td>
<td>19.5224</td>
</tr>
<tr>
<td>HTL III</td>
<td>36.8929</td>
<td>22.6737</td>
</tr>
</tbody>
</table>

b) Summary of ANOVA results, homtemp. by HTL

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>500.4900</td>
<td>1.148</td>
</tr>
<tr>
<td>Within groups</td>
<td>142</td>
<td>436.0210</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) Summary of descriptive statistics for non-homophonous words recalled temporally and hearing threshold level groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL I</td>
<td>43.4054</td>
<td>24.4870</td>
</tr>
<tr>
<td>HTL II</td>
<td>33.4545</td>
<td>25.2026</td>
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<tr>
<td>HTL III</td>
<td>36.8929</td>
<td>22.4559</td>
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</tbody>
</table>

d) Summary of ANOVA results, nonhom. temp. by HTL

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
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<tr>
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<td>1231.5542</td>
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<tr>
<td>Within groups</td>
<td>142</td>
<td>560.5474</td>
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</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
e) Summary of descriptive statistics for homophonous words recalled spatially for hearing threshold level groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL I</td>
<td>13.6892</td>
<td>15.2017</td>
</tr>
<tr>
<td>HTL II</td>
<td>18.3636</td>
<td>21.1552</td>
</tr>
<tr>
<td>HTL III</td>
<td>12.9017</td>
<td>21.0413</td>
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</table>

f) Summary of ANOVA results homspat. by HTL.

<table>
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<th>SOURCE</th>
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<th>F RATIO</th>
</tr>
</thead>
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<tr>
<td>Between groups</td>
<td>2</td>
<td>318.7290</td>
<td>0.965</td>
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<tr>
<td>Within groups</td>
<td>142</td>
<td>330.1399</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

g) Summary of descriptive statistics for non-homophonous words recalled spatially for hearing threshold level groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL I</td>
<td>13.7432</td>
<td>13.7432</td>
</tr>
<tr>
<td>HTL II</td>
<td>16.0909</td>
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<td>HTL III</td>
<td>12.4821</td>
<td>12.4821</td>
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h) Summary of ANOVA results nonhom spat. by HTL

<table>
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<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
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<td>234.3565</td>
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<td>Within groups</td>
<td>142</td>
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</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE II

SUMMARIES OF RESULTS COMPARING RECALL OF HOMOPHONOUS AND
NON-HOMOPHONOUS WORDS BY HEARING LOSS

a) Summary of descriptive statistics for recall of homophonous words
by hearing loss groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTL I</td>
<td>48.3784</td>
<td>15.1745</td>
</tr>
<tr>
<td>HTL II</td>
<td>50.7333</td>
<td>8.8355</td>
</tr>
<tr>
<td>HTL III</td>
<td>50.1964</td>
<td>13.5960</td>
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</tbody>
</table>

b) Summary of ANOVA results comparing recall of homophonous words
by hearing loss.

<table>
<thead>
<tr>
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</tr>
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<tbody>
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<td>69.3137</td>
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<tr>
<td>Within groups</td>
<td>142</td>
<td>197.6692</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* denotes significance at the 0.01 level.

-85-
### TABLE III

**SUMMARIES OF STATISTICS FOR PROCESSING STRATEGY**  
**BY GENDER**

a) Summary of descriptive statistics for temporal processing by gender.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr I (female)</td>
<td>79.1892</td>
<td>36.1834</td>
</tr>
<tr>
<td>Gr II (male)</td>
<td>73.2676</td>
<td>43.8928</td>
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</table>

b) Summary of ANOVA results, processing strategy by gender.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
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<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>1270.5830</td>
<td>0.788</td>
</tr>
<tr>
<td>Within groups</td>
<td>143</td>
<td>1611.4343</td>
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</tr>
<tr>
<td>Total</td>
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<td></td>
</tr>
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</table>

c) Summary of descriptive statistics for spatial processing by gender.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr I (female)</td>
<td>27.2838</td>
<td>31.6731</td>
</tr>
<tr>
<td>Gr II (male)</td>
<td>36.4084</td>
<td>89.2823</td>
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</table>

d) Summary of ANOVA results, processing strategy by gender.

<table>
<thead>
<tr>
<th>Source</th>
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<th>F Ratio</th>
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</table>
### TABLE IV

**SUMMARIES OF PROCESSING STRATEGY BY POPULATION**

a) Summary of descriptive statistics for temporal recall by population.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TempR Hearing</td>
<td>72.1667</td>
<td>40.9082</td>
</tr>
<tr>
<td>TempR Hearing Impaired</td>
<td>80.8182</td>
<td>39.1551</td>
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</tbody>
</table>

b) Summary of results, temporal recall by population.

<table>
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<tr>
<th>SOURCE</th>
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<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>2675.7732</td>
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<tr>
<td>Within groups</td>
<td>142</td>
<td>1609.2319</td>
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<tr>
<td>Total</td>
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<td></td>
</tr>
</tbody>
</table>

c) Summary of descriptive statistics for spatial recall by population.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpatR Hearing</td>
<td>30.1410</td>
<td>37.0722</td>
</tr>
<tr>
<td>SpatR Hearing Impaired</td>
<td>34.0454</td>
<td>90.0603</td>
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</table>

d) Summary of ANOVA results, spatial recall by population.

<table>
<thead>
<tr>
<th>SOURCE</th>
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<tr>
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<td>0.122</td>
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<tr>
<td>Within groups</td>
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<tr>
<td>Total</td>
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</table>
TABLE V
SUMMARIES OF RESULTS FOR PROCESSING STRATEGY
BY HEARING LOSS

a) Summary of descriptive statistics for temporal recall by hearing loss groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TempR, HTL I</td>
<td>79.1892</td>
<td>36.1834</td>
</tr>
<tr>
<td>TempR, HTL II</td>
<td>63.7273</td>
<td>46.4846</td>
</tr>
<tr>
<td>TempR, HTL III</td>
<td>72.4464</td>
<td>43.8317</td>
</tr>
</tbody>
</table>

b) Summary of ANOVA results, temporal recall by hearing loss.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>2668.1753</td>
<td>1.682</td>
</tr>
<tr>
<td>Within groups</td>
<td>142</td>
<td>1586.5356</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Summary of descriptive statistics for spatial recall by hearing loss groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpatR, HTL I</td>
<td>27.2838</td>
<td>31.6731</td>
</tr>
<tr>
<td>SpatR, HTL II</td>
<td>34.4545</td>
<td>44.5878</td>
</tr>
<tr>
<td>SpatR, HTL III</td>
<td>39.2679</td>
<td>98.4214</td>
</tr>
</tbody>
</table>

d) Summary of ANOVA results, spatial recall by hearing loss.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>2773.8733</td>
<td>0.625</td>
</tr>
<tr>
<td>Within groups</td>
<td>142</td>
<td>4439.1641</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE VI
SUMMARIES OF RESULTS FOR PROCESSING STRATEGY BY
CHRONOLOGICAL AGE

a) Summary of descriptive statistics for spatial recall of homophonous words for hearing subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA I</td>
<td>42.4483</td>
<td>35.7617</td>
</tr>
<tr>
<td>CA II</td>
<td>16.3143</td>
<td>19.0769</td>
</tr>
<tr>
<td>CA III</td>
<td>22.000</td>
<td>46.1432</td>
</tr>
</tbody>
</table>

b) Summary of ANOVA results, spatial recall by chronological age for hearing subjects.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>5519.8125</td>
<td>6.287*</td>
</tr>
<tr>
<td>Within groups</td>
<td>67</td>
<td>878.0393</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Summary of descriptive statistics for temporal recall by chronological age for hearing subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA I</td>
<td>59.7586</td>
<td>31.7943</td>
</tr>
<tr>
<td>CA II</td>
<td>91.2857</td>
<td>43.7934</td>
</tr>
<tr>
<td>CA III</td>
<td>94.333</td>
<td>57.6031</td>
</tr>
</tbody>
</table>

d) Summary of ANOVA results, temporal recall by chronological age for hearing subjects.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>8705.8516</td>
<td>7.969*</td>
</tr>
<tr>
<td>Within groups</td>
<td>62</td>
<td>1092.4133</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
e) Summary of descriptive statistics for spatial recall by chronological age for hearing impaired subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA II</td>
<td>15.861</td>
<td>18.998</td>
</tr>
<tr>
<td>CA III</td>
<td>24.722</td>
<td>38.671</td>
</tr>
<tr>
<td>CA IV</td>
<td>71.400</td>
<td>153.113</td>
</tr>
<tr>
<td>CA V</td>
<td>22.210</td>
<td>41.297</td>
</tr>
</tbody>
</table>

f) Summary of ANOVA, spatial recall by chronological age for hearing impaired subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>11584.3711</td>
<td>1.483</td>
</tr>
<tr>
<td>Within groups</td>
<td>67</td>
<td>7809.542</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


g) Summary of descriptive statistics for temporal recall by chronological age for hearing impaired subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA II</td>
<td>116.000</td>
<td></td>
</tr>
<tr>
<td>CA III</td>
<td>72.500</td>
<td>42.1696</td>
</tr>
<tr>
<td>CA IV</td>
<td>53.800</td>
<td>39.9006</td>
</tr>
<tr>
<td>CA V</td>
<td>82.631</td>
<td>44.2067</td>
</tr>
</tbody>
</table>

h) Summary of ANOVA, temporal recall by chronological age for hearing impaired subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>3</td>
<td>4248.3047</td>
<td>2.331*</td>
</tr>
<tr>
<td>Within groups</td>
<td>67</td>
<td>1822.6384</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE VII
SUMMARIES OF RESULTS COMPARING VOCABULARY LEVEL TO PROCESSING STRATEGY FOR HEARING SUBJECTS

a) Summary of descriptive statistics comparing vocabulary level to temporal recall for hearing subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC I</td>
<td>67.2258</td>
<td>36.1881</td>
</tr>
<tr>
<td>VOC II</td>
<td>77.7391</td>
<td>33.0663</td>
</tr>
<tr>
<td>VOC III</td>
<td>99.4000</td>
<td>32.1008</td>
</tr>
</tbody>
</table>

b) Summary of ANOVA results comparing vocabulary level to temporal recall for hearing subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>6327.3555</td>
<td>5.418</td>
</tr>
<tr>
<td>Within groups</td>
<td>71</td>
<td>1167.8950</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Summary of descriptive statistics for spatial recall by vocabulary level for hearing subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC I</td>
<td>32.5484</td>
<td>33.4971</td>
</tr>
<tr>
<td>VOC II</td>
<td>30.2609</td>
<td>30.2538</td>
</tr>
<tr>
<td>VOC III</td>
<td>15.7000</td>
<td>28.7349</td>
</tr>
</tbody>
</table>

d) Summary of ANOVA results, spatial recall by vocabulary level for hearing subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>1873.3623</td>
<td>1.914</td>
</tr>
<tr>
<td>Within groups</td>
<td>71</td>
<td>978.6790</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE VIII
SUMMARIES OF RESULTS COMPARING VOCABULARY LEVEL TO PROCESSING STRATEGY FOR HEARING IMPAIRED SUBJECTS

a) Summary of descriptive statistics comparing vocabulary level to temporal recall for hearing impaired subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC I</td>
<td>70.2758</td>
<td>43.7304</td>
</tr>
<tr>
<td>VOC II</td>
<td>81.1364</td>
<td>44.4000</td>
</tr>
<tr>
<td>VOC III</td>
<td>71.7500</td>
<td>47.3172</td>
</tr>
</tbody>
</table>

b) Summary of ANOVA results, temporal recall by vocabulary level for hearing impaired subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>765.8806</td>
<td>0.6809*</td>
</tr>
<tr>
<td>Within groups</td>
<td>52</td>
<td>1955.098</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Summary of descriptive statistics for spatial recall by vocabulary level for hearing impaired subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC I</td>
<td>52.4828</td>
<td>131.0096</td>
</tr>
<tr>
<td>VOC II</td>
<td>27.1364</td>
<td>43.1953</td>
</tr>
<tr>
<td>VOC III</td>
<td>25.000</td>
<td>40.3237</td>
</tr>
</tbody>
</table>

d) Summary of ANOVA, spatial recall by vocabulary level for hearing impaired subjects.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DF</th>
<th>MEAN SQUARE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>2</td>
<td>4526.3086</td>
<td>0.4486</td>
</tr>
<tr>
<td>Within groups</td>
<td>52</td>
<td>10089.2148</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>