THE EFFECTS OF TEMPORALLY DISTORTED SENTENTIAL STIMULI UPON PERFORMANCE OF NORMAL AND MENTALLY IMPAIRED INDIVIDUALS

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ABSTRACT

THE EFFECTS OF TEMPORALLY DISTORTED SENTENTIAL STIMULI UPON PERFORMANCE OF NORMAL AND MENTALLY IMPAIRED INDIVIDUALS

By

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The purpose of this study was to investigate the effects of temporally distorted sentential stimuli on the performance of a group of normal subjects and a group of mentally impaired stubjects.

The subject groups were composed of 30 normal hearing university students and 30 normal hearing mentally impaired individuals. The mentally impaired group showed an age range of 17-36 years and an Intelligence Quotient (I.Q.) range of 40-75 as measured by various psychological batteries.

The experimental speech stimuli consisted of ten three-word and ten five-word normal sentences, ten three-word and ten five-word second order sentential approximations, and ten three-word and ten five-word first order sentential approximations. These stimuli were time-compressed by 0%, 30%, and 60%. Each subject was presented all sentential orders of either the three-word or the five-word sequence at all three levels of time compression. All stimuli were

presented in a sound field at an intensity level of 75-80 dB SPL.

The results of this study demonstrated that an interaction of time compression, order of sentential approximation and sequence length was capable of differentiating mentally impaired subjects from normal subjects. This differentiation was accomplished by viewing the number of recall errors between groups. The normal control group showed significantly better recall than did the mentally impaired subjects. In addition, an analysis of error type showed that more than 70% of all recall errors of the mentally impaired group could be classified as reflecting memory constraints, while 25% of the recall errors of the normal group fell into these classifications. Thus, these results suggested that memory deficiencies play a role in mental impairment.

Based upon the results of this study, speculations were made about possible memory strategies employed by the mentally impaired and their possible relationships to past hypothetical findings in the area were explored. Suggestions for future research efforts that may provide additional information about the perceptual abilities of the mentally impaired were provided.

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By

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INTRODUCTION

Since the publication of Galton's "Notes on Prehension in Idiots" (1887), researchers and scholars have been interested in investigating how deficiencies in perceptual aspects of learning are related, at least in part, to behavioral inadequacies of the mentally impaired. Although such component areas as attention, experience, motivation, and memory have all been explored in relation to the mentally impaired, a dearth of information still exists. Several researchers (Calearo and Lazzaroni, 1957; Beasley, Schwimmer and Rintelmann, 1972; Calearo, 1975) have indicated the important role played by temporal aspects in speech perception. One of the most recent developments in this area of time alteration is time compression. Time compressed stimuli reduce both the redundancy and the duration of the speech signal by discarding random segments of the verbal stimuli. In addition to these effects, time compression serves to reduce both semantic and syntactic content (Beasley, Schwimmer and Rintelmann, 1972). This reduction can be further increased by the use of sentential order approximations. Previous studies in the area of time compression have obtained response data for normal young adults (Beasley, Schwimmer and Rintelmann, 1972; Beasley, Forman and Rintelmann, 1972), children

(Beasley, Maki and Orchik, 1976), geriatric populations (Konkle, Beasley and Bess, 1974), hearing impaired (Kurdziel and Noffsinger, 1973; Kurdziel, Rintelmann and Beasley, 1975), and less disabled children (Freeman, 1976). In view of these findings, an attempt to utilize time compressed stimuli with the mentally impaired seemed warranted. Therefore, the purpose of this investigation was to study, clarify, and enhance some perceptual aspects of mental impairment by means of the utilization of time compressed sentential approximations to full grammaticality.

Short Term Memory: Background

The process of short term memory has been described by several researchers within the past three decades (Hebb, 1949; Broadbent, 1958; Pollack, 1959; Aaronson, 1967; Atkinson and Shiffrin, 1971; Fisher and Zeaman, 1973). These descriptions were divided into two categories: a physiological approach and a behavioristic approach. The physiological category is primarily based upon an assumption proposed by Hebb (1949). This assumption states that memory is derived from a structural change within the organism that occurs over time. In order for this structural change to occur, however, it was necessary to theorize how memory information could be maintained prior to the structural change. Hebb postulated the presence of a memory system that was based upon past experiences. This memory basis was termed an activity trace. This trace could be interrupted by external events and thus was subject to decay. The activity trace was thought to represent a short term memory system. If the trace were not allowed to be interrupted by outside events and if it were thus stabilized over time, a structural memory trace could be established. This structural memory trace was comparable to a long term memory system in which information could be retained and brought again to the conscious level if necessary.

The behavioristic hypothesis is primarily based upon Broadbent's (1958, 1963) distinctions between temporary and long term memory stores. The information flow through the memory system was thought to begin with environmental inputs that were picked up by a sensory register (sensory receptors plus neural processes). This information was then transferred to a short term memory channel. Short term memory has been described as a working memory system wherein decisions are made, problems are solved, and information flow is continued. The important aspects of this system could, therefore, be described as the perception, retention, and retrieval of information. Following the completion of short term processing, information transfer to the long term memory system may be completed.

Aaronson (1967) reported perceptual aspects to occur in two stages for short term memory recall tasks. Stage I processing involved the presence of a large capacity perceptual storage system in which unidentified sensations or attributes of physical stimuli were subject to relative instability, rapid decay, and parallel processing. Stage II, which was thought to occur at a higher cortical level than Stage I, was characterized by slower decay and a limited storage capacity having a "series" input. Miller (1956) suggested the limits of capacity available within short term memory to be 7±2 units of information. This hypothesis suggested that whenever new material entered the short term or primary memory channel, old information had to be either transferred into a long term memory channel or forgotten. It should be noted, however, that the short term memory capacity could be enhanced by the process of "chunking." This process permitted new informational units to be coded into groups prior to entry into the primary memory channel.

According to Atkinson and Shiffrin (1971), once the information had been processed into the short term memory channel, it was acted upon by a series of control processes. These processes included rehearsal, coding, decision, and retrieval strategies. Rehearsal, an overt or covert repetition of information, increased the strength of the information in short term memory so that it could be held for a longer period of time in the primary memory channel or transferred into long term memory. Without rehearsal, information would decay quickly and thus be forgotten (Waugh and Norman, 1965). Following the rehearsal stage, the information had to be either used immediately, stored in long term memory, or forgotten (Norman, 1966). If the information were to be stored in long term memory, however, it had to be coded to go along with the information that had previously been stored there. If the information were to be used immediately, the previously coded information necessary to make a decision must first have been pulled from long term memory. Again, if the new information were not relevant to the decision, it would be forgotten (Lindsey and Norman, 1972).

The final control process proposed by Atkinson and Shiffrin concerned retrieval processes. These processes have been related to certain effects that might occur. Feigenbaum and Simon (1962) reported the presence of the recency and primacy effects within short term memory retrieval. In the recency effect, the latest information entered into the primary memory channel would be best recalled. If, on the other hand, the information needed involved earlier presented units, the recency effect would diminish and be replaced by a primacy effect. This effect involved the initially presented informational units. Brown (1958) found recall to be inversely proportional to the amount of information to be recalled.

In comparison to short term memory, the long term memory channel involves a permanent memory store of unlimited capacity (Lindsay and Norman, 1972). In order for a unit of information to be entered into long term memory, it must initially be rehearsed and coded in short term memory. Recall from long term memory involves a retrieval process that may allow thoughts to be brought to consciousness only after a sometimes laborious memory search.

Short Term Memory: Temporal Aspects

According to Broadbent (1958), the short term memory channel is affected by such temporal factors as stimulus duration, interstimulus interval, and rate of presentation. In a review of these variables that may affect information processing, Aaronson (1967) reported discrepancies within the findings of previous researchers. Fraser (1958), Conrad and Hille (1958), and Posner (1963) reported that a reduction of the presentation rate allowed more time for stimulus decay and thus resulted in lower recall accuracy. Studies by Pollack, Johnson, and Knaff (1959) and Pollack and Johnson (1963) were in disagreement with these findings. Their results showed a higher recall accuracy when a slower rate of presentation was utilized. This increased accuracy with decreased presentation rate was thought to result from increasing the time utilized for perceptual activities. Aaronson (1967) reasoned that these conflicting results probably were not due to such things as experimental procedures or type of stimulus material, rather that the discrepancy resulted from the duration of the stimuli utilized in the aforementioned research efforts. That is, experimental results were probably secondary to the stimulus durations and interstimulus intervals utilized within the experiments. Aaronson reported that stimulus duration determined the amount of information entering the short term store, whereas the interstimulus interval affected the time available for identification or encoding of the stimuli. The importance of the interstimulus interval had previously been reported by Aaronson and Sternberg (1964). These authors, in holding word duration constant and varying the interstimulus interval, found an increase in the presentation rate over time to result in a decrease in recall accuracy. This decrease was thought to be related to a reduction in the time available for information processing.

In a follow-up to the Aaronson (1967) report, a study by Aaronson, Markowitz, and Shapiro (1971) attempted further to clarify the effects on perception resulting from changes in stimulus duration and interstimulus interval. These authors varied the "speech-to-pause time" in three different experiments and compared subject response to seven digit sequences for recall, item, and order information. Results of the study indicated that when 33% of the speech signal was removed and substituted by an equal amount of silent interval, recall accuracy was significantly higher. These results suggested that cumulative perceptual delays in encoding item and order information may result when adequate pause time is not available.

Shriner and Daniloff (1970) provided additional information concerning the importance of the interstimulus interval in auditory perception. Using both meaningful and nonmealingful stimuli with first and third grade children, Shriner and Daniloff demonstrated that correct responses significantly decreased when the silent interstimulus intervals were increased. This finding became more apparent when meaningless stimuli were used. These results thus demonstrated that the more syntactical and semantic system components that were available, the more facilitated was short term memory recall. Optimum recall was found to occur when a short interstimulus interval was utilized with meaningful speech material.

The relationship between word duration and interstimulus interval was further investigated by Beasley and Shriner (1973). Using temporally manipulated first and second order sentential approximations with normal young adults, these researchers showed that the number of items correctly recalled increased as stimulus duration increased. The size of the interstimulus interval and the grammatical aspects of the stimulus materials were also judged to be important factors. The authors pointed out, however, that although stimulus duration was thought to play a more significant role in perception than interstimulus interval, a complex interaction between the two factors should discourage their being studied on an independent basis.

In view of the suggested interaction between auditory perceptual processing and short term memory, a study by Beasley and Flaherty-Rintelmann (1976) further attempted to determine the importance of the silent interstimulus interval in an auditory recall task with second and fourth grade children. Because digits and word lists were felt to be inadequate for assessing functions of short term memory (Bocca and Calearo, 1963; Pollack, 1967), semantically meaningful materials were utilized. The stimuli were ten normal sentences and ten three-word and ten five-word sentential approximations of both the first and second order. Results indicated that recall performance decreased in all sentential conditions as the interstimulus interval was increased. Grammatical approximation, sentence length, and grade level of the child were also found to be important considerations in auditory processing. These results thus served to confirm the findings of previous research efforts of Beasley and Shriner, 1973; Speaks and Jerger, 1965; Miller, 1956; Pantalos et al., 1975; and Smith, 1972.

Pantalos, Schuckers, and Hipskind (1975) studied sentence recall with preschool children. Using four- to eight-word sentences that were either of normal duration of 30% time compressed with varied interstimulus intervals (200 or 1000 msec), the suthors found recall performance decreased as the number of words in the sentence increased. Also, the limit of the preschool child's memory capacity appeared to be six or seven words. The processing of any sentential material exceeding this length was though to be related to the grammatical approximation of the material and to the child's language competence.

A study to determine the ability of children to recall unrelated items in a sequence was completed by Bisset and Koshey (1975). These authors utilized two, three, four, and five word sequences at 0% and 30% time compression in conjunction with three different (normal, compressed, expanded) interstimulus intervals. Results of the study indicated the highest scores were obtained at 30% time compression for normal and expanded interstimulus intervals. These results supported both Aaronson's suggestion that the interstimulus interval is important for perceptual activity and Kirk's (1966) contention that a child's performance in sequencing unrelated items will be enhanced by an increased stimulus presentation rate.

In summary, it is apparent from previous research that temporal factors such as stimulus duration, interstimulus interval, and rate of presentation play key roles in the processing and perception of informational units. Although these research efforts have shown some disagreement relative to the individual importance of each factor, all seem to agree that recall accuracy can be both affected and influenced by temporal alteration within the presented material. The greated the amount of temporal alteration, the greater the effect upon accuracy of response.

Short Term Memory Aspects of Mental Impairment

Deficiencies within the short term memory channel have frequently been utilized as an explanation of behavioral inadequacies within the mentally impaired. Jensen (1964) reported that the ability to hold information within short term memory appears to be a critical skill in many, if not all, learning and problem solving situations. Thus, an individual possessing an impaired primary channel may lose a large amount of incoming information prior to its processing into the long term memory channel. The result would be to greatly reduce the probability that a specific informational unit had become permanently stored. Experimental studies involving short term memory systems of the mentally impaired have primarily been based upon five theoretical interpretations relative to the nature of perceptual deficiency.

1. Broadbent (1958) proposed a model of memory in which the senses are constantly bombarded by environmental stimuli of which only a limited amount may be processed. Some of this incoming information enters a short term store known as the S system where it may be held for a matter of seconds before being passed by a selective filtering system into a limited capacity channel called the P system. The greatest factor that determines which information is passed into the P system is the individual's past experience. From the P system the filtered information can be either passed directly into long term memory, or it can be rerouted via a feedback loop into the S system in order that the amount of rehearsal necessary for retention may be completed. It has been hypothesized by Scott and Scott (1968) that any deficiency within either the S or P system would result in a general learning deficiency that could be applied to mentally impaired populations. Therefore, Broadbent's theory seems to predict that either the mentally impaired possess an impaired S system or that the capacity of the P system may be more restricted than in normals, such that mentally impaired individuals are able to attend to less incoming information than are persons of normal intelligence. Broadbent's idea was further expanded upon by Zeamon and House (1963) and Fisher and Zeamon (1973) who proposed that the mentally impaired's attention to a stimulus might well be a critical factor in determining primary memory capacity.

2. Ellis (1963) proposed a "Stimulus Trace" theory as a means of explanation of "sub-normal intelligence." Ellis described a stimulus trace as "an explanatory mechanism to account for immediate memory." His ancillary hypothesis was that the apparent learning deficiencies of the "retarded" were the result of a noncontinuity of events that were secondary to dysfunction within the short term memory channel. As the basis for his theory, Ellis primarily cited the words completed by Kohler (1929) and Hull (1952). Kohler invoked a "fading trace" theory as a means of accounting for negative time error in psychophysical judgment. He reported that if two stimuli of equal dimensions were compared one after the other, the second would be judged as greater. This effect was thought to result from a comparison of the trace of the second stimulus to the fading trace of the initial sensation. The longer the time interval between the two experiences, the greater the error. In addition, Hull felt the stimulus trace acted as a basis of learning in that behavioral acts of the present are related to the traces of preceding events. On this basis, behavioral sequences that are considered inappropriate can be eliminated because of a lack of reinforcement, whereas appropriate or reinforced behaviors are conditioned within the organism. Because of the lack of ingrained past experiences within mentally impaired populations, Ellis proposed that the strength and duration of the stimulus trace were probably diminished within this group. He further speculated that short term memory function showed a developmental trend in that the stimulus trace increased

in both strength and duration as a function of age and intelligence. Ellis was thus able to predict a difference in retention both as a function of Mental Age (MA) and Intelligence Quotient (IQ). By pointing to the probable role of memory in a number of tasks, Ellis reported the performance of the mentally impaired to be below that of normals of comparable chronological age in such areas as delayed response, reaction time, paired-associate learning, and simple retention.

3. One of the most prominent theories of forgetting in general psychology is the Interference theory (Underwood, 1957; Postman, 1963). The basic premise behind this theory is that one or more stimuli may be associated with one or more responses. When this association occurs, recall of the multiple associations may result in a response competition from which errors of recall and forgetting may arise. The theory also predicts that errors will vary as a function of the similarity of the competing material and as a function of the number of successive items to be recalled. Developmentally, it might be expected that children would become more tolerant to interference as a function of both age and intelligence.

4. A Neural theory presented by Spitz (1966) proposed that the mentally impaired are characterized by deficits within their nervous systems that include underlying brain structures and processes. The basis of the theory was presented via four postulates: (1) in the mentally impaired,

more time is required to induce both temporary and permanent changes in stimulated cortical cells; (2) once temporary changes are induced, more time is required to return to homeostasis; (3) it is more difficult to form new, or different, behavior patterns following permanent cortical cell change; and (4) in the mentally impaired there is less spread of electrochemical activity between stimulated cells and the surrounding cortical field. The implications from this theory are twofold. Since the mentally impaired are less likely than normals to organize efficiently, less total information can be permanently stored. On the other hand, because the cortical system of the mentally impaired is less resistant to change than the normal, any incoming information that has reached long term memory should be less susceptible to extinction or interference. It was therefore proposed that, relative to the amount of information processed into long term memory, the information retrieval system of the mentally impaired should be superior to that of the normal.

5. The last major theory relating to short term memory deficits in the mentally impaired is the Verbal Dysfunction theory of Luria (1963). This theory of learning disability in the mentally impaired differs in some important aspects from previously mentioned theories. In Luria's view mental retardation is thought to be the consequence of nervous system pathology, although in many instances the nature of the lesion has been admittedly difficult to specify. Luria proposed that the presence of such a lesion would produce a pathological weakness of the basic nerve processes such that

connections between nerve fibers would be acquired slowly, would respond inappropriately, and/or would be easily disrupted by extraneous stimuli or fatigue. The extent of the mental handicap was thought to be directly related to the size and location of the lesion. Luria expressed little optimism for remediation of the individual showing profound involvement. However, when the individual's verbal system remained intact, it was felt that a great deal could be done to rectify the mental defect. For those individuals, treatment consisted of attempting to compensate for the neurodynamic defects by bringing the motor reactions under the regulation of the verbal reactions. Therefore, according to Luria's thinking, the key to educating the mentally retarded lies in (1) the diagnosis of the defect, (2) enlargment of the vocabulary, and (3) the forced verbal coding of materials.

Although much has been written in regard to agreement or disagreement with the previously mentioned theories (Kellas and Butterfield, 1971; Waugh and Norman, 1965), few studies have been successful in adequately comparing the memory performance of the normal versus the mentally impaired (Butterfield, Wambold, and Belmont, 1973). Also, with the possible exception of Ellis and his associates (1968, 1968, 1969, 1969) who have attempted with great endeavor to justify the stimulus trace rationale, few practical efforts to prove or disprove the theories have been attempted.

O'Connor and Hermelin (1965) attempted to differentiate between the Broadbent and Ellis theories by presenting simultaneous or successive visual displays of digits at different rates. Both a normal and a sub-normal group were utilized. Results showed that normals performed better than the mentally impaired group for the simultaneous condition at fast rates, whereas both groups were comparable at slow simultaneous rates and for the successive condition. The authors interpreted their results as support for Broadbent's hypothesis of input restriction because of limited capacity.

Two predictions derived from Ellis' stimulus trace theory were tested by Hayes and Routh (1972). Because Ellis proposed that both the amplitude and the duration of the stimulus trace were diminished in the retarded, it was assumed that by increasing the intensity and the duration of the environmental stimulus, retardate memory should improve. Ellis (1963) had previously stated that "...any state of affairs (drugs, increase in intensity of stimuli, etc.) which increases the duration of the stimulus trace should facilitate learning." Some evidence of performance enhancement of the retarded under high intensity stimulus presentation had also previously been reported (Kouw, 1968; O'Connor and Hermelin, 1963). Hayes and Routh (1972), therefore, varied the length of recall interval (0 vs. 8 seconds) and the intensity level of the aurally presented items (55 vs. 90 dB H.L.) on a task requiring oral recall of five non-repeated 4-digit messages. Results found that the two predictions considered to be crucial to the support of the Ellis Theory were not confirmed. That is, the retardate's performance was neither more adversely affected than that of the normal's by increasing the retention interval nor differentially facilitated by an increase of the stimulus intensity. Other challenges to the Ellis Theory include Ebenholts, 1963; Jensen and Rohwer, 1965; and Butterfield, 1968.

Butterfield, Wambold, and Belmont (1973) reported that the poor short term recall of the mentally retarded could be the resultant effects of deficiencies in such areas as imperfect learning, poor retention, or incomplete retrieval. If this were the case, these short term memory deficiencies would therefore be related to difficulties in acquisition, storage, and retrieval of information. The authors conducted three different experimental tasks in order to evaluate each of these processes of short term memory in the retarded. The results indicated that although retarded individuals can competently utilize all of the individual component processes that are necessary for accurate recall of stimulus events, there is a lack of expertise in the area of correct sequencing of these processes. Unless training methods can be implemented to "teach" the retarded adequate sequencing procedures, there could be little chance of substantial improvement in short term memory performance. These findings are perhaps best related to the Neural Theory of Spitz (1966), who reported little capacity for systematic change within the memory system of the mentally impaired individual.

Spitz (1966) reported that spatial groupings of visually presented digits had been found to increase the channel capacity for information processing in retarded adolescents.

The positive effects of groupings were thought to be related to the retarded individual's failure to spontaneously organize material as efficiently as non-retarded subjects. In view of Miller's (1956) findings that subjective organization of stimuli (chunking) increases channel capacity for memory, Spitz proposed that his research evidence indicated that this organizational strategy was not efficiently employed by the retarded. However, a study by MacMillan (1972) failed to replicate Spitz's findings in that no significant improvement in recall of retarded subjects was found via the spatial grouping of digits. Despite the discrepancy of the findings in the two studies, MacMillan felt that his results only further clarified the idea of inefficient use of strategy development in the retarded.

As previously presented, Luria (1963) indicated that much emphasis must be placed upon language development and upon relating verbal behavior to motor behavior. While he did not suggest that an enlarged language system alone was sufficient to overcome the abnormality of mental function, he did imply that it appeared to be a necessary condition for cognitive development. In short, Luria felt the mentally defective's possession of a reduced capacity to use symbols could be greatly enhanced when the retarded subject could be taught to mediate his motor responses verbally. Luria's thinking was challenged on two points by O'Connor and Hermelin (1963) and Rosen, Kevits, and Rosen (1965). The former study pointed out that not only do retardates usually possess a small vocabulary but they are also somewhat reluctant to use what they do possess. Rosen et al. presented an even greater assault to the Luria hypothesis when they failed to find any substantial "dissociation" between the verbal and motor systems of a mentally impaired population.

Time Compressed Speech

Inview of the role that temporal factors play in the perception of speech, time compressed stimuli have been increasingly utilized as a means of examining aspects of auditory processing. As presently employed, the method of time compression randomly discards segments of speech stimuli in order to reduce both the redundancy and the duration of that stimuli. Jerger (1960) proposed a rationale for the presentation of time compressed stimuli based on a "Subtlety Principle." Jerger stated that "the site subtlety of the auditory manifestation increases as the site of lesion progresses from peripheral to central" and therefore that it would be necessary to increase the difficulty of the auditory task in order to evaluate adequately the higher auditory pathways. Although such procedures as filtered or interrupted speech have previously been utilized in central auditory testing, Calearo (1975) reported that time compressed speech is presently the most effective means of evaluating auditory processing at the cortical level.

Although early studies assisted in the development of new and more efficient methods of time compression and provided some insight into its uses, it was not until 1972 that adequate normative data were obtained. In that year, a study by Beasley, Schwimmer, and Rintelmann provided data about 96 normal hearing adults at six different levels of time compression (0, 30, 40, 50, 60, 70%) and four different sensation levels (8, 16, 24, and 32 dB SL). The four word lists of Form B of the Northwestern University Auditory Test #6 (N.U. #6) were utilized as the speech stimuli. These data were further expanded by Beasley, Forman, and Rintelmann (1972), who gathered additional normative information at a 40 dB sensation level. These investigations provided a basis for comparative study with adult subjects suffering from auditory pathology. Since publication of these studies, additional data on time compressed speech have been provided for children (Beasley, Maki, and Orchik, 1976; Maki, 1975; Shoup, 1975), geriatric populations (Konkle, Beasley, and Bess, 1974), organic pathologies of the peripheral and central auditory pathways (Kurdziel and Noffsinger, 1973; Kurdziel, Rintelmann, and Beasley, 1975), and learning disabled children (Manning, Johnson, and Beasley, 1975; Freeman, Beasley, and Overholt, 1975; Freeman, 1976). Also, studies by Bratt (1975) and Konkle (1976) have provided further normative data concerning the use of time compressed stimuli in sentential approximations and as a contralateral masker. A review of the results of these studies indicates support of the notion that time compressed speech stimuli are diagnostically important for delineating central auditory dysfunction.

Short Term Memory: Sentential Aspects

The relationship between language skills and memory processes seem closely linked. In this regard, several researchers have proposed that syntactic and semantic components of an utterance facilitate the recall process. Conrad (1962) and Miller and Isard (1963) were probably the first to point out that intrusion errors in the short term memory channel may be reduced when speech and languagelike inputs are utilized. Schulman (1971), on the other hand, postulated that semantic coding in short term memory, though possible, was a time consuming process and consequently employed only when the task demanded it. Schulman further pointed out, however, that "the effects of semantic and linguistic factors on immediate recall have not been extensively studied."

Despite the controversy, several authors (Savin and Perchonock, 1965; Craik and Lockhart, 1972; Baddeley, 1972; Craik, 1973; Wetherick, 1975) have supported the contention that short term memory utilizes syntactic and semantic cues. Perhaps some of the soundest and most practical findings came from an observation of Savin and Perchonock (1965) who stated that "English sentences are much easier to recall after a single hearing than are equally long strings of random English words." The authors further suggested that the use of syntax and semantics was related to the process of "chunking" and that the capacity of short term memory would thus be enhanced through their utilization.

Statement of the Problem

Evidence from the literature gives strong support to the idea that auditory perception is a temporally based phenomenon and that the utilization of temporally distorted speech material shows great potential for the measure of central auditory processing abilities. Research also shows that deficiencies associated with the mentally impaired have often been characterized as the resultant effects of inadequate utilization of the short term memory channel (Broadbent, 1958; Ellis, 1963; Spitz, 1963; Scott and Scott, 1968). In view of Smith's (1972) statement that "Behavior associated with language and perception may be developmentally bound and (that) such developmental behavior may very well be related to performance characteristics of short term memory," it can be seen that the employment of a temporally distorted stimulus is a justifiable means of measuring short term memory capacity. This is especially true if semantic, syntactic, and intonational cues remain relatively intact (Tejerian, 1968; Scholes, 1969; Carrow and Mauldin, 1973).

Because of the dearth of knowledge that is presently available concerning the processing capabilities and capacities of the mentally impaired, there exists a need for an investigation into this area. With this in mind, the purpose of this study was to determine the comparative performance between mentally impaired individuals and individuals of normal intelligence through the utilization of temporally distorted speech stimuli. Specifically, this investigation will attempt to:

(1) Determine whether time compressed sentential stimuli can be utilized to differentiate normal and mentally impaired populations.

(2) Determine whether short term recall in normal and mentally impaired populations is affected by changes in temporal aspects of speech stimuli.

(3) Determine whether short term recall of sentences in normal and mentally impaired populations is affected by semantic and syntactic aspects of speech.

(4) Determine whether differences in short term recall between normal and mentally impaired individuals are the result of discrimination errors or memory constraints.

EXPERIMENTAL PROCEDURES

Subjects

Two groups of subjects participated in this study: (1) 30 normal hearing university students enrolled at Michigan State University; and (2) 30 normal hearing mentally impaired individuals selected from E. B. I. Breakthru, Inc., a sheltered workshop for the mentally impaired located at Lake Odessa, Michigan. The mentally impaired group showed a chronological age range of 17-36 years and in Intelligence Quotient (I.Q.) range of 40-75 as measured by various psychological test batteries. Prior to participation in the study, each of the subjects was required to pass a hearing sensitivity screening via pure tone air conduction techniques. This screening was administered at the level of 20 dB H.L. (ANSI, 1969) at octave intervals of 250 through 4000 Hertz. In addition, each of the subjects within the mentally impaired population was required to pass a picture articulation test. Passing criteria were defined as no more than three articulation errors. Individuals showing more severe speech problems such as stuttering, voice disorders, etc. were categorically eliminated prior to commencement of the study.

Design and Stimuli

The experimental stimuli consisted of three experimental tapes:

1. Ten three-word and ten five-word first order sentential approximations, time compressed by 0%, 30%, and 60% (Appendix B).
2. Ten three-word and ten five-word second order sentential approximations, time compressed by 0%, 30%, and 60% (Appendix B).
3. Ten three-word and ten five-word normal sentences, time compressed by 0%, 30%, and 60% (Appendix B).

The sentential approximations to full grammatical sentences were ordered in a manner described by Beasley and Flaherty-Rintelmann (1976) and Speaks and Jerger (1965) and later modified by Freeman (1976). These sentential approximations were composed of 100 monosyllabic words selected from the Basal Vocabulary of On We Go (Teacher Eddition, Houghton Mifflin, 1966), a primary reading workbook (Appendix A). The selection of monosyllables was based upon the findings of Massaro (1972) who reported the syllable to be the most important unit for auditory processing. For the first order sentences, the words were randomly chosen for placement within three and five-word approximations. The second order sentential approximations were compiled in the following manner: (1) the first word of the approximation was chosen at random; (2) a second individual was asked to choose a word from the master list of monosyllables that could follow the first word; and (3) a third individual, having no knowledge of the initial monosyllable selected, was asked to choose a word that might follow the second word. This process was continued until all the second order sentential approximations were constructed. A similar process was used to develop the normal sentences. In this case, however, all previous individual selections were made known to those selecting the monosyllables.

Recording and Stimulus Generation Procedures

All of the stimuli used in this study were recorded onto a master magnetic tape via a tape recorder (Ampex, Model AG 440B) at a speed of 7½ inches per second following the procedure utilized by Freeman (1976). A complete description of the stimulus generation procedure is provided by Beasley and Flaherty-Rintelmann (1976).

Following completion of the master tape, a cassette copy was manufactured from the same recorder through the utilization of an Advent, Model 201, cassette tape recorder. This cassette tape was then processed through an electrical time compressor/expander (Lexicon, Model Varispeech I) at compression speeds of 0%, 30%, and 60%. This tape was processed to the desired levels of time compression through the utilization of a method proposed by Konkle, Freeman, Riggs, Riensche, and Beasley (1975). Final experimental tapes were recorded via the Ampex AG 440B tape recorder that was connected to the time compressor/expander.

Copies of the experimental tapes allowed a ten second interval between each of the three-word and five-word sentential approximations. The carrier phrase, "Number _____," preceded each of the sentential stimuli.

Presentation Procedures

Subjects were divided into the two experimental groups. Each subject was then presented either ten three-word or ten five-word sentential approximations of the first order, ten three-word or ten five-word sentential approximations of the second order, and ten three-word or ten five-word normal sentences. Each of these stimulus conditions were time compressed by 0%, 30%, and 60%. In order to avoid possible order effects, stimuli presentation was counterbalanced with regard to rate of time compression.

All subjects were tested individually in a quiet room (Ambient noise = 60 to 68 dBC using a Bruel and Kjaer Type 2203 sound level meter) via a high quality tape recorder (Ampex 600). The intensity level for the presentation of the stimuli was set at 75 to 80 dB SPL. Prior to the beginning of the study, a calibration check was carried out on all equipment in order to insure that ANSI (S 3.6 - 1969) specifications were met. These specifications were periodically monitored throughout the study in order to insure instrument stability.

Upon seating a subject within the test room, the following verbal instructions were given: "I want you to listen to what the man is saying on the tape recorder. He will say a number and then some words. When the man stops speaking, I want you to tell me exactly what you heard him say. If you can't remember everything, say as much as you can remember. Do you have any questions?" These instructions are similar to those employed by Beasley and Flaherty-Rintelmann (1976). Prior to the presentation of each time compressed condition, two practice items of either three-word or five-word first order sentential approximations were presented.

Analysis of Data

Subject response was recorded both manually and on tape during the experimental session. These responses were then evaluated with regard to accuracy of recall. Accuracy of response determination was further enhanced through the utilization of an additional judge. This judge, a Ph.D. student in Audiology with more than five years of professional experience, re-checked the tape recorded response. In cases of disagreement between the judges, the tape was replayed and a joint decision was made. Determination of error was made with regard to word discrimination, word order, additions, omissions, and distortions according to the following criteria:

1) A discrimination error occurred when a subject's response was incorrect but shared similar acoustic properties with the word stimulus.
2) An omission error occurred when one or more words within the stimulus word string was not reported by the subject.

3) An error of addition occurred when a word not present within the stimulus word string was reported by the subject.

4) A reversal error occurred when the subject reported an incorrect word order.

5) A distortion error occurred when memory constraints resulted in the subject's reporting only a portion of a word within the word string.

Discrimination errors were categorically interpreted as errors of the perceptual system, whereas omissions, additions, reversals, and distortions were thought to reflect memory constraints (Conrad, 1962). The number of items incorrectly recalled was the score for each subject. The data were then subjected to a four factor (2x3x3x2) analysis of variance with repeated measures. A Duncan Multiple Range Test was tuilized as a post hoc statistical measure.

RESULTS

The total number of incorrect items reported for each condition was determined and a computerized analysis of variance was performed. Statistically significant effects at the 0.05 level were found for the four main factors of subjects, sequence length, time compression, and sentential order. In addition, several significant interactions among these factors were demonstrated. The complete results of the analysis of variance can be found in Table 1. A Duncan Multiple Range Test was utilized to investigate further the significant main effects and interactions. The results of this study thus demonstrated that populations possessing normal intelligence and mentally impaired populations can be differentiated by imposing semantic, syntactic, and temporal constraints upon sequential stimuli.

Effect of Subjects

The analysis of variance showed a significant main effect of subjects ($F = 245.2$, $df = 1$, $p = < 0.0005$) in that the mentally impaired individuals exhibited greater difficulties in recalling sequential stimuli than did the subjects of the normal group. These difficulties were further exhibited by significant interactions between subjects and sequence length ($F = 49.8$, $df = 1$, $p = < 0.0005$), time

TABLE 1

ANALYSIS OF VARIANCE

SOURCE	MEAN SQUARE	df	F	P
Subjects	19608.4	1	245.2	< 0.0005
Sequence Length	7676.5	1	96.0	< 0.0005
Time Compression	3796.0	2	195.0	< 0.0005
Sentential Order	6381.7	2	523.1	< 0.0005
Subjects X Sequence Length	3979.9	1	49.8	< 0.0005
Subjects X Time Compression	433.8	2	22.3	< 0.0005
Subjects X Sentential Order	2668.6	2	218.7	< 0.0005
Sequence Length X Time Compression	299.4	2	15.4	< 0.0005
Sequence Length X Sentential Order	1112.6	2	91.2	< 0.0005
Time Compression X Sentential Order	335.3	4	39.3	< 0.0005
Subjects X Sequence Length X Time Compression	44.0	2	2.3	0.109
Subjects X Sequence Length X Sentential Order	610.2	2	50.0	< 0.0005
Subjects X Time Compression X Sentential Order	21.6	4	2.5	0.041
Sequence Length X Time Compression X Sentential Order	19.4	4	2.3	0.063
Subjects X Sequence Length X Time Compression X Sentential Order	7.0	4	0.8	0.514

compression ($F = 22.3$, dr = 2, $p = < 0.0005$), and sentential order ($F = 218.7$, $df = 2$, $p = 0.0005$). As can be seen from Tables 2 and 3, the subjects of the mentally impaired population showed a greater mean error response for all circumstances of presented material under both three word and five word conditions. Significant three-way interactions were found among subjects, sequence length, and sentential order ($F = 50.0$, $df = 2$, $p = < 0.0005$) and among subjects time compression, and sentential order ($F = 2.5$, $df = 4$, $P = 0.041$). These results demonstrated that 1) the subject's error response increased significantly as sentential order was decreased and temporal redundancy was reduced; and 2) recall accuracy was significantly affected by grammaticality and length of utterance.

Effect of Time Compression

There was a significant main effect associated with the rate of time compression ($F = 195.0$, $df = 2$, $p = < 0.0005$). Reference to Tables 2 and 3 show that the number of items incorrectly recalled increased as rate of time compression increased. Furthermore, time compression interacted significantly with both sequence length ($F = 15.4$, $df = 2$, $p = < 0.0005$) and sentential order ($F = 39.3$, $df = 4$, $p = < 0.0005$). These interactions indicated that recall accuracy is affected by the covariance between time compression and these two factors. Thus, as stimulus complexity was increased as a function of increasing sequence length and decreasing grammaticality, the mean error response of both subject groups was also increased.

TABLE 2

Mean error response of subjects per level of time compression (0%, 30%, 60%) and sentence order (Normal sentences, 2nd Order, 1st Order) for three-word sequence.

Order/Time Compression	Normals	Mentally Impaired
Normal/0%	0.0	1.1
Normal/30%	0.1	1.3
Normal/60%	0.6	4.9
2nd Order/0%	0.1	5.3
2nd Order/30%	2.4	7.6
2nd Order/60%	5.7	16.5
1st Order/0%	0.5	8.6
1st Order/30%	2.2	12.2
1st Order/60%	6.3	19.9

TABLE 3

Mean error response of subjects per level of time compression (0%, 30%, 60%) and sentence order (Normal sentences, 2nd Order, 1st Order) for five-word sequence.

Order/Time Compression	Normals	Mentally Impaired
Normal/0%	0.0	2.2
Normal/30%	0.6	4.1
Normal/60%	2.0	10.1
2nd Order/0%	1.7	19.1
2nd Order/30%	4.9	27.1
2nd Order/60%	11.5	44.9
1st Order/0%	1.2	22.0
1st Order/30%	2.3	30.3
1st Order/60%	12.6	41.0

Effect of Sentential Order

The significant main effect of sentential order ($F = 523.1$, $df = 2$, $p = < 0.0005$) is illustrated in Tables 2 and 3. These tables show that order of sentential approximation affected performance of both the normal and the mentally impaired groups under three and five word conditions. For all conditions the highest recall accuracy was obtained with the normal sentences, whereas the first and second order sentential approximations showed considerably lower recall accuracy. This trend is especially apparent with the mentally impaired subjects. The data thus support the contention that an increase in sentential order will provide more cues for perception, thereby aiding recall. The significant sentential order X sequence length interaction ($F = 91.2$, $df = 2$, $p = < 0.0005$) shows that the multiple cues provided by sentential material may allow a facilitated "chunking" process and thus aid in the enhancement of both storage capacity and recall performance.

Effect of Sequence Length

The main effect of sequence length ($F = 96.0$, $df = 1$, $p = < 0.0005$) as it interacts with the other variables has been discussed in the above text. These interactions closely followed the general trend for both subject groups: as length of utterable sequence increased, mean error response increased (Tables 2 and 3).

TABLE 4

Number error responses of normal subjects per type of error (discrimination, omission, addition, reversal, distortion), level of time compression (0%, 30%, 60%), and sentential order (Normal, second order, first order) for sequence length of three words. (Maximum Error = 30 per subject).

NORMAL 3-WORD

Type of Error	0%			30%			60%		
	Normal	1st	2nd	Normal	1st	2nd	Normal	1st	2nd
Discrimination	0	7	1	1	31	36	4	83	69
Omission	0	0	0	0	2	0	5	12	16
Addition	0	0	0	0	0	0	0	0	0
Reversal	0	0	0	0	0	0	0	0	0
Distortion	0	0	0	0	0	0	0	0	0
TOTAL	0	7	1	1	33	36	9	95	85

TABLE 5

Number error responses of mentally impaired subjects per type of error (discrimination, omission, addition, reversal, distortion), level of time compression (0%, 30%, 60%), and sentential order (Normal, second order, first order) for sequence length of three words. (Maximum Error = 30 per subject).

MENTALLY IMPAIRED 3-WORD

Type of Error	0%			30%			60%		
	Normal	1st	2nd	Normal	1st	2nd	Normal	1st	2nd
Discrimination	8	61	40	11	108	70	30	103	121
Omission	8	33	30	7	42	30	41	126	88
Addition	1	4	3	1	4	2	1	6	3
Reversal	0	3	5	0	5	0	0	2	3
Distortion	0	28	1	0	24	12	2	62	33
TOTAL	17	129	79	19	183	114	74	298	248

TABLE 6

Number error responses of normal subjects per type of error (discrimination, omission, addition, reversal, distortion), level of time compression (0%, 30%, 60%), and sentential order (Normal, second order, first order) for sequence length of five words. (Maximum Error = 50 per subject).

	NORMAL 5-WORD								
Type of Error	0%			30%			60%		
	Normal	1st	2nd	Normal	1st	2nd	Normal	1st	2nd
Discrimination	0	13	17	9	26	58	18	121	120
Omission	0	1	2	0	1	7	11	51	44
Addition	0	0	0	0	0	1	0	1	0
Reversal	0	4	7	0	5	7	1	16	5
Distortion	0	0	0	0	2	0	0	0	4
TOTAL	0	18	26	9	34	73	30	189	173

TABLE 7

Number error responses of mentally impaired subjects per type of error (discrimination, omission, addition, reversal, distortion), level of time compression (0%, 30%, 60%), and sentential order (Normal, second order, first order) for sequence length of five words. (Maximum Error = 50 per subject).

	MENTALLY IMPAIRED 5-WORD								
Type of Error	0%			30%			60%		
	Normal	1st	2nd	Normal	1st	2nd	Normal	1st	2nd
Discrimination	19	111	106	34	81	109	49	110	164
Omission	10	102	107	21	226	193	90	316	388
Addition	1	11	12	2	13	11	2	11	6
Reversal	3	39	16	3	11	11	3	4	21
Distortion	0	67	46	1	124	82	7	174	95
TOTAL	33	330	287	61	455	406	151	615	674

Type of Error Response

Tables 4, 5, 6, and 7 illustrate the number of each type of error response (discrimination, ommision, addition, reversal, distortion) for normal and mentally impaired subject groups under the varied conditions of time compression, sentential order, and sequential length. An overall analysis of these errors showed errors of discrimination to account for greater than 75% of all errors of the normal population, whereas the mentally impaired group showed the vast majority (68%) of error response to fall within the omission, addition, reversal, or distortion classifications thought by Conrad (1962) to reflect memory constraints. It can also be noted from tables 4-7 that as the degree of time compression increased, a greater preponderance of memory-type errors resulted. This finding was enhanced when the five-word sequences and sentential approximations were used.

DISCUSSION

The results of this study indicated that normal and mentally impaired populations can be differentiated on the basis of various semantic, syntactic, and temporal interactions of verbal stimuli. Although it was evident that, in some instances, specific variables took precedence over others in affecting recall accuracy, no variable was found to be particularly dominant.

Subject Differentiation

On the basis of the data provided by the normal subjects, it can be seen that these subjects experienced relatively little difficulty in performing the designed tasks. Although some decrease in recall performance was evident as the task difficulty increased, the results obtained from this group concurred with those of previous investigations (Freeman, 1976; Beasley and Flaherty-Rintelmann, 1976; Wingfield, 1975; Bratt, 1975). Thus, it was demonstrated that normal individuals who possessed an intact auditory perceptual system were capable of overcoming the syntactic, semantic, and intonational limitations imposed by time compressed tasks of varied sentential length and order.

The mentally impaired group showed findings that were similar to the normal group in that recall performance decreased as the task difficulty increased. However, the magnitude of performance decline among the mentally impaired was much greater than that of the normal population subjects. Only when normal sentential order was utilized at the lowest rate of time compression (0%) did the mentally impaired achieve scores that reflected adequate processing ability. These results thus seemed to substantiate the findings of earlier investigators (Savin and Perchonock, 1965; Beasley and Shriner, 1973; Craik and Lockhart, 1972; Craik, 1973; Wetherick, 1975) who suggested that syntax and semantics played a key role in auditory perception and memory. It might also be noted that the type of errors made by the mentally impaired group during normal sentence repetition seemed to lend additional support to these earlier findings. Despite the occurrence of errors, an evidence of semantic utilization was present. For example, the sentence "I was a good boy" might have become "me good boy". Furthermore, the mentally impaired often attempted to structure the first and second order sentential approximations into grammatical utterances possessing sentential meaning. The fact that peak recall accuracy was obtained with the full grammatical sentences was thought to be reflective of a multiple-cueing process which enhanced perceptual processing capabilities.

The fact that recall accuracy decreased as sequence length increased supported the findings of Aaronson (1967) and Pantalos et al. (1975). Again, the deterioration of performance in the mentally impaired group was much more readily observable than that of the normal group as sentence length was increased from three to five words. In this study, a greater error response occurred with five word than with three word sequences (Figure 1). In view of the findings of Miller (1956), who reported short term memory capacity to be seven plus or minus two units of information, the results of the present study seemed to suggest that the short term capacity described by Miller had thus been exceeded under certain experimental conditions. When this exceeding of short term capacity occurs, errors of order, omission, addition or distortion may result.

The effect of time compression was also found to play a significant role in this study. Figure 2 shows that the number of recall errors increased as the recorded material was time compressed from 0% to 60%. It can be seen from Figure 2 that the 0% condition showed the highest recall accuracy, whereas the 60% condition showed the lowest recall accuracy. The recall accuracy of the 30% time compressed condition fell between the two extremes. Results such as these seemed to be indicative of the fact that time compression affects the extrinsic redundancy of recorded sequences and thus reduces the number of intonation, stress, semantic, and syntactic cues that would be available for perception. Several investigators (Beasley et al., 1972; Freeman, 1976; Beasley and Flaherty-Rintelmann, 1976; Pantalos et al., 1975) have demonstrated that an individual possessing an intact auditory system should be able to compensate for this reduction in

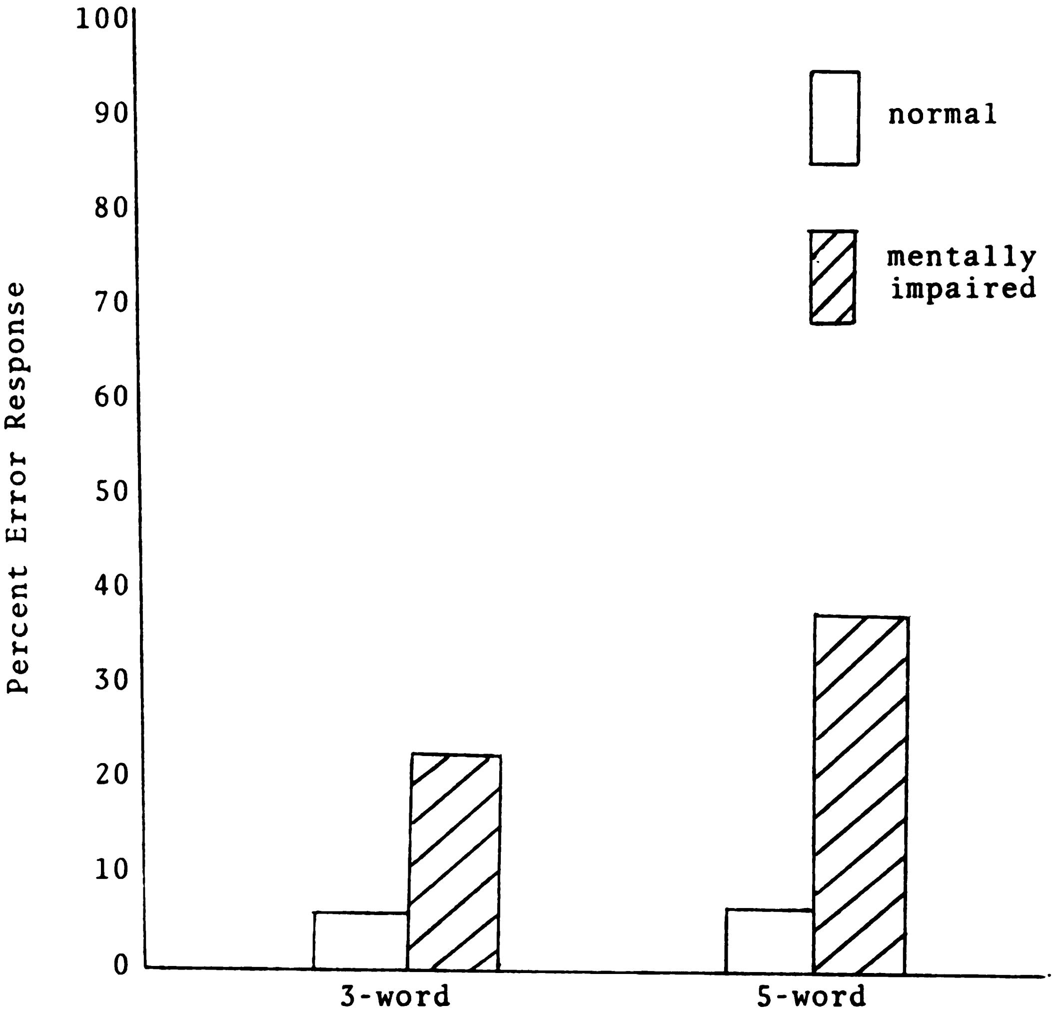

Figure 1. Mean percentage error scores of normal and mentally impaired subjects for three and five word sequences.

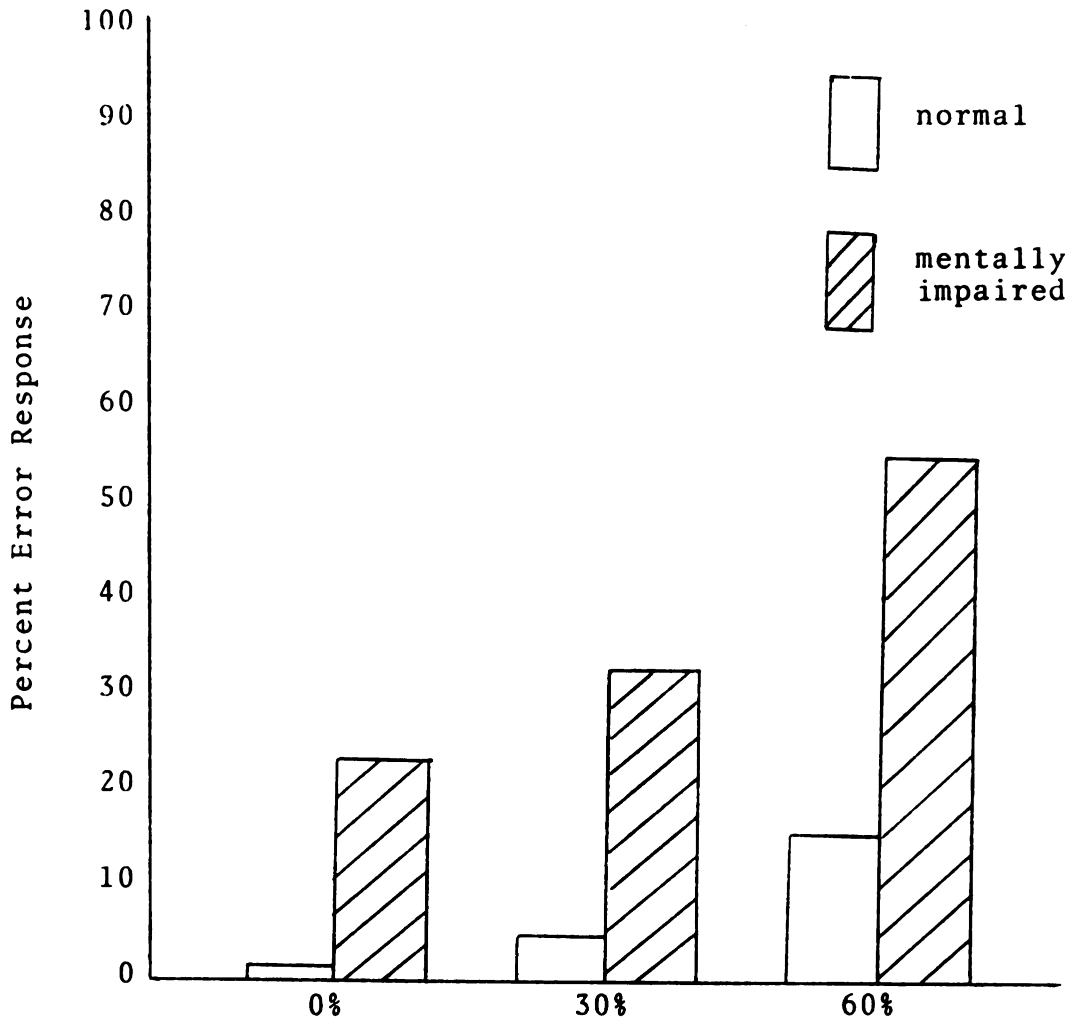

Figure 2. Mean percentage error scores of normal and mentally impaired subjects for three levels of time compression (0%, 30%, 60%).

perceptual cues and thus overcome the limitations imposed by time compression, up to a level of 60%. The results of this study were in agreement with these findings in that the normal subject group showed relatively little difficulty in recalling the recorded sequence items. This finding, however, was not true of the mentally impaired individuals with the exception of fully grammatical sentences. These subjects demonstrated significantly greater difficulty in the recall of time-compressed stimuli than did the normal group.

The finding that highest recall accuracy for both subject groups was found for normal three and five word sentences may be linked to the "chunking" process described by Miller (1956). This process permits new informational units to be coded into groups prior to their entry into the primary memory channel. When normal sentential order was utilized, it appeared that the presented material was enhanced by the multiple cueing effect and the chuncking process was thus facilitated (Figure 3). If the presented material contained a high informational content (such as that found in a normal sentence), variables such as increases in time compression or sequence length did not exert as great an effect upon the material to be recalled. Thus, recall accuracy was enhanced.

Differentiation between the subject groups was also apparent when type of recall error response was observed (Figure 4). As can be seen from the figure, some variability within categorical groupings was present. However, in

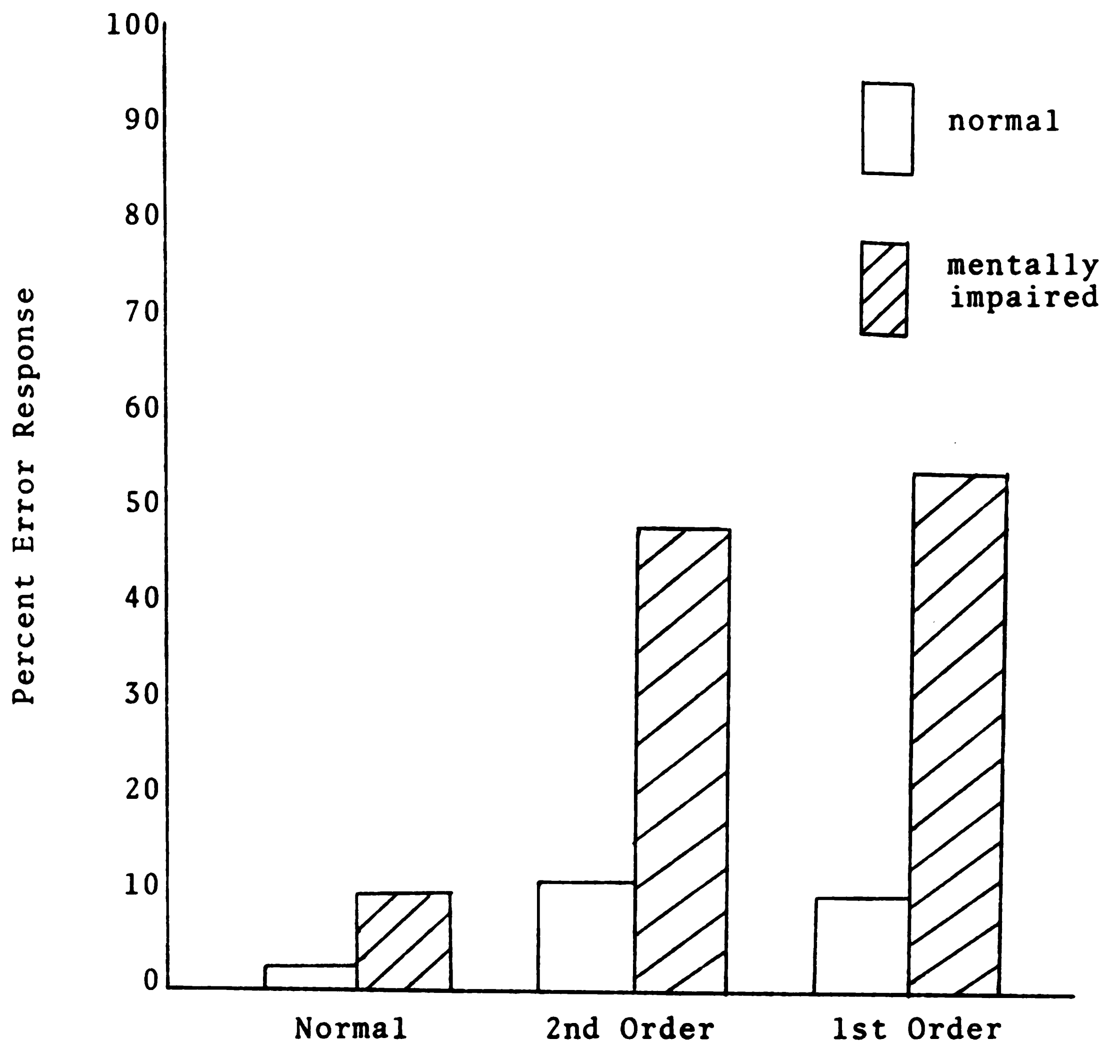

Figure 3. Mean percentage error scores of normal and mentally impaired subjects for three levels of sentential order.

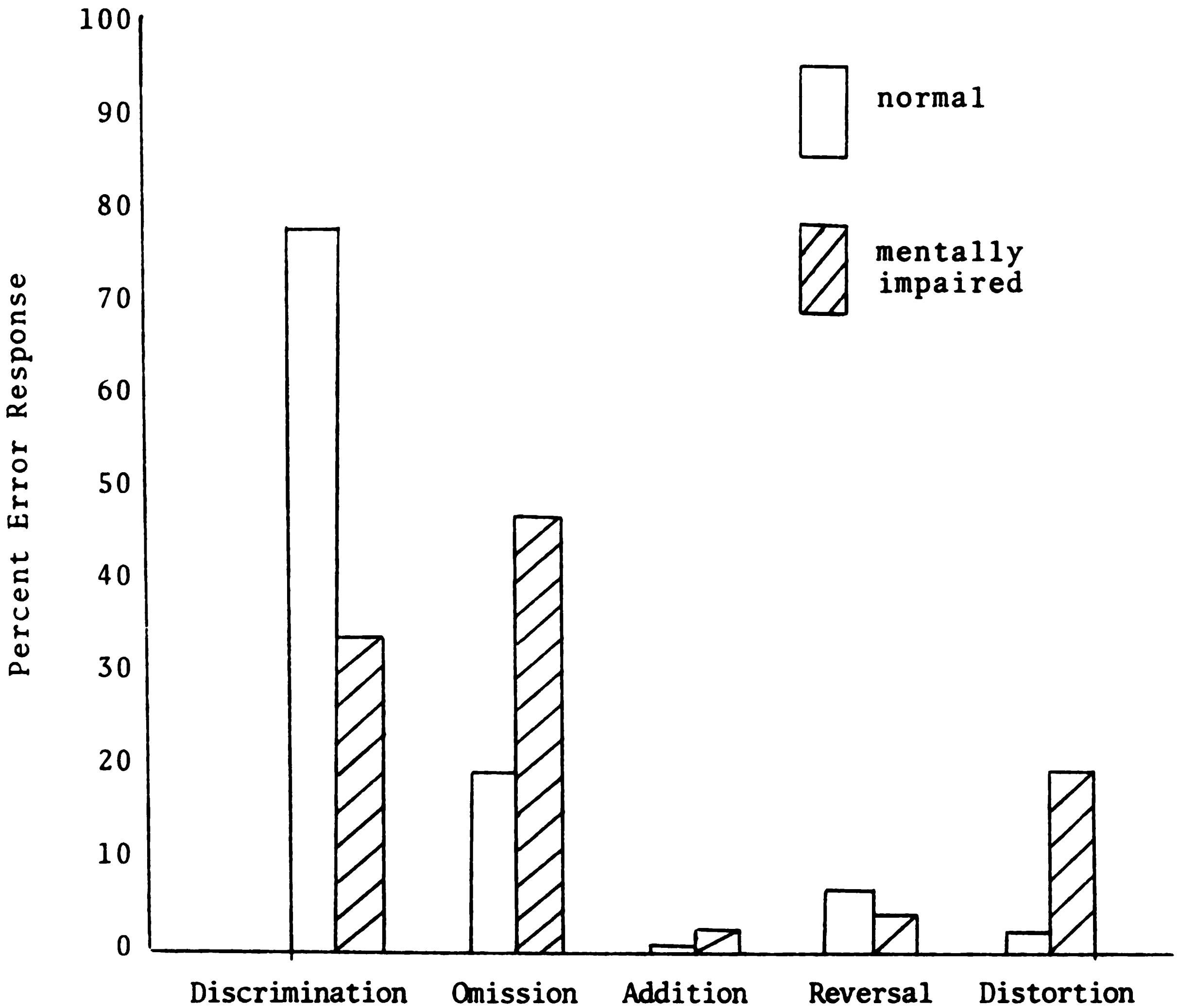

Figure 4. Mean persentage of error response of normal and mentally impaired subjects according to type of error (Discrimination, Omission, Addition, Reversal, Distortion).

the main area of differentiation, that of discrimination error versus memory-type error, results were readily observable. Errors of discrimination which were thought to represent a breakdown within the perceptual system were found to account for nearly 75% of all recall errors of the normal group. Conversely, this classification was found for only 32% of the total recall error of the mentally impaired group. Therefore, nearly 70% of all recall errors of the mentally impaired fell into the classifications (omission, addition, reversal, distortion) that have historically been thought to reflect memory constraints (Scholes, 1969; Conrad, 1962). Only 25% of the errors of the normal group seemed reflective of these memory capacity limitations. It should be noted, however, that the number of memory errors increased for both groups as task difficulty increased. However, this rate of increase of memory-type errors was significantly more dramatic with the mentally impaired than with the normal group.

Short Term Memory: Mentally Impaired

The data regarding short term memory aspects of mental impairment have not been conclusive in the past. Rather, a number of researchers have speculated, through their experimental results, about the interrelationship between behavioral inadequacies of the mentally impaired and deficiencies within the primary memory channel. Broadbent (1958) suggested that the mentally impaired may possess a short term channel capacity that is restricted to an evan greater degree than that of the normal. This capacity limitation would result in a breakdown of processing abilities if the amount of incoming information exceeded the channel capacity. Ellis (1963) proposed the "Stimulus Trace" Theory in which he reported the performance of the mentally impaired to be below that of the normal because presented informational units were usually forgotten prior to the completion of processing action. The interference theory (Postman, 1963) associated mentally impaired performance with a response competition among presented stimulus items that resulted in recall errors or forgetting of information. Luria (1963) felt mental impairment was a consequence of nervous system pathology which resulted in a description of incoming information either by the presence of simultaneous extraneous stimuli or by fatigue.

The results of the present study seemed to confirm the role that short term memory deficiencies play in relation to mental impairment. The error analysis of the sentential stimuli showed that greater than 70% of all recall errors of the mentally impaired were reflective of memory constraints. By contrast, memory type errors were evident for less than 25% of the error response of the normal group. This finding would thus seem to confirm that a short term memory deficiency is indeed present within a group of mentally impaired individuals.

In regard to why the short term memory channel may be deficient in the mentally impaired, a number of aspects must be considered. First, when the sentential stimuli were time compressed and increased in rate by 0%, 30%, and 60%, the deterioration of recall performance of the mentally impaired was significantly greater than that of the normal subjects. This result thus seemed to indicate that as the load placed upon the primary memory channel of the mentally impaired was increased, group performance deteriorated. Aaronson et al. (1971) had previously suggested that high levels of time compression can produce an overload of the perceptual system and can thus result in an increase in memory errors. While individuals possessing intact auditory pathways are often able to develop strategies to overcome this overload, the mentally impaired usually cannot. This may be due to two factors: 1) the mentally impaired may possess a short term memory of more limited capacity than the norm; and 2) the mentally impaired may not have the linguistic foundation necessary to overcome the limitations imposed by time compression. These memory limitations of the mentally impaired became even more obvious when sentential order was decreased and sequential length was increased. When these variables were added, the overload of the system was further increased to the point where additional breakdown of the short term memory channel was evident. In this case the lack of the multiple cues of a fully grammatical utterance seemed to restrict the "chunking" process and thus resulted in an increase in memory errors. It is also possible that an interference aspect, similar to that discussed by Postman (1963), may have been interacting with the limited capacity of the mentally impaired individual to result in an additional component for error response.

The significant difference in error scores between the normal and the mentally impaired seemed to be related to the assumption that the linguistic competence necessary to process distorted temporal, syntactic, and semantic cues may be deficient in the mentally impaired. This finding, when coupled with the possibility of a limitation of primary memory capacity, shows that the mentally impaired were thus required to alter the strategies employed in a short term recall task. The strategies employed by the mentally impaired subjects of this study showed a considerable amount of variation and individual difference. One might speculate that the utilization of these strategies was an attempt on the part of the mentally impaired to develop a feeling of success, to increase the linguistic structure of the utterances and thus enhance the multiple cueing effect, to gain additional time for processing, or to inhibit the forgetting process.

One of the recall strategies employed by many individuals within the mentally impaired group was to attempt to limit the amount of information to be processed. This limitation of information was seemingly accomplished by the concentration upon and isolation of one word within the presented word string. This single word was then reported by the subject during the allotted response period. The isolated word was usually found in either the initial or the final position and was thought to be related to the primacy-recency effect discussed by Feigenbaum and Simon (1962).

These authors reported that the first and last informational units of a group of stimuli would be best recalled. The utilization of this strategy by mentally impaired individuals became more evident as task difficulty was increased. Thus, this strategy implyment was most evident in five word first and second order sentential approximations at 60% time compression.

Perhaps the greatest single strategy utilized by the mentally impaired was to attempt to structure the sentential approximations into a normal sentence having sentential meaning. As discussed earlier, this strategy would increase the number of linguistic cues that could be utilized for perception and thus enhance the multiple cueing effect. It was also noted that particular difficulty was experienced when the mentally impaired were required to recall an utterance in which a verb was not present. (For example, "Tree up yes me word".) When this was the case, the mentally impaired often showed increased confusion. Also, some mentally impaired subjects attempted to add grammatical constraints to the utterance. This finding may lend additional credance to the research of Foder, Garrett, and Bever (1968) who reported the verb phrase, around which the remainder of the sentence revolved, may be the basic unit of perception. As with the strategy of single word isolation, the greater the difficulty of the recall task, the greater the employment of the strategy.

Another observable strategy utilized by a number of the mentally impaired involved their repeating of the word string with a shorter than normal latency following its presentation. This attempt at "quick" recall often resulted in a running together of words such that individual word interpretation by the tester was impossible. Results such as these were interpreted as "distortion" errors. The application of this strategy was thought to be reflexive of an attempt by the mentally impaired group to process information into the primary memory channel prior to the occurrance of informational extinction by forgetting. Thus, it was speculated that the utilization of this strategy may be related in part to the "Stimulus Trace" Theory presented by Ellis (1963). In this theory Ellis presented data that showed the mentally impaired possessed a steeper "forgetting curve" than the normal. Hence, quick repetition might be used as a means of counteracting the forgetting process. Conversely, the utilization of this strategy might also be reflective of the limited capacity theory of Broadbent (1958). Because this increase in vocal speed also seemed to be directly related to task difficulty, it is possible that this strategy was utilized when the short term memory channel was so bombarded with information that a capacity "overload" of the system occurred. An "overload" such as this might very well be reflected in an increase in vocal rate such that phonemic components of one word would overlap or interact with phonemic components of a following word. This effect would result in the garbled indistinct response that characterized this type of recall strategy.

The final observed recall strategy of the mentally impaired involved a longer-than-normal latency period between completion of the recorded utterance and the verbal response by the subject. In some instances this latency period was so long that the verbal recall of the subject was not initiated prior to the commencement of the following recorded stimulus. If the subject did not respond within the allotted interstimulus interval of ten seconds, errors of "omission" were charged. It was speculated that the use of this recall tactic may have indicated an attempt by the mentally impaired to focus greater attention or concentration upon the stimuli to be recalled. Zeamon and House (1963) and Fisher and Zeamon (1973) reported that the attention factor may be deficient within mentally impaired populations. Furthermore, this attempt by the mentally impaired to enhance attention may be in some cases a detrement to recall. This hypothesis is based on the Ellis (1963) finding of the steeper than normal "forgetting curve" within the mentally impaired. Thus, a strategy employment that involves an additional amount of processing time prior to recall may have the effect of increasing the potential for informational forgetting. If this occurs, additional memory-type errors should result.

Summary and Conclusions

The overall results of this study demonstrated that an interaction of time compression, order of sentential approximation, and sequence length was capable of differentiating mentally impaired subjects from normal subjects. The fact that a time-compressed stimulus was used provided additional support to the notion of previous research findings that time-compressed speech may be an important diagnostic tool for the delineation of central auditory dysfunction. However, the limited population and the limited past utilization of time-compressed sentential stimuli make it impossible to draw any definite conclusions as to general clinical application.

The results of this study also suggested that information processing capabilities differed between the normal and the mentally impaired groups. This differentiation of subject groups was evident when reviewing the number and type of recall errors. The normal control group showed significantly better recall than the mentally impaired subjects. In addition, an analysis of error type showed that greater than 70% of all recall errors of the mentally impaired group could be classified as reflecting memory constraints. Only 25% of the recall errors of the normal group fell into these classifications. These findings were speculated to be related to the idea that the mentally impaired may possess a short term memory capacity that is more restricted than the norm. These capacity restrictions became even more evident as task difficulty was increased.

It was also apparent from the results of this study that the grammatical structure of an utterance plays an important role in the recall of that utterance. These results support the findings of Miller and Isard (1963) and others who reported the ease with which sentences can be perceived depended to a large extent upon their degree of grammaticality. While the normal subjects showed little additional difficulty with recall of sentential approximations, this was not the case with the mentally impaired. Thus, the significant differences observed among the sentential orders implied that the mentally impaired may not have the linguistic foundation necessary to overcome the limitations imposed by less grammatical utterances.

Implications

Inview of the response of the mentally impaired subjects to the time-compressed stimuli, it might also be of interest to observe the response of this subject group to other types of temporally-altered stimuli. For example, variations in interstimulus intervals and stimulus durations may provide additional information concerning processing abilities of the mentally impaired. The use of time-expanded stimuli might also be helpful in examining these abilities. In addition, research efforts in the areas of phonemic synthesis, auditory closure, and speech-in-noise may furnish additional data about learning deficiencies within the mentally impaired and thus should also be investigated.

The results of this study may also suggest a possible implication for the educational habilitation of the mentally impaired. It was readily apparent from the results of this study that the mentally impaired achieved greatest recall accuracy under conditions in which fully grammatical sentences were utilized. This finding was speculated to be related to a multiple cueing process that was associated with normal sentence recall. Although no concrete data was obtained that could be directly related to the "education" of the mentally impaired, the evidence that grammatic structure played an important role in auditory perception cannot be denied. Therefore, it can be speculated that the educational achievement of the mentally impaired might be enhanced through the utilization of a teaching framework that stresses the presentation of grammatical utterances. However, further investigation in this area is definitely warranted.

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APPENDICES

APPENDIX A

REVISED WORD LIST BASAL VOCABULARY _ON WE GO_ HOUGHTON-MIFFLIN (1966)

REVISED WORD LIST BASAL
VOCABULARY *ON WE GO*
HOUGHTON-MIFFLIN
(1966)

a	red	pan	sand
girl	zoo	high	stop
cry	with	eye	was
all	ten	dog	late
boy	set	feet	jar
but	is	like	come
had	in	my	six
her	to	not	men
I	we	milk	ring
dot	pop	that	said
man	take	toy	they
out	will	wish	lock
on	me	sat	see
put	hot	good	snow
tell	the	it	food
see	eat	ride	dish
sun	do	play	go
two	call	wood	egg
of	cat	yes	know
here	him	no	work
box	up	name	word
big	us	end	tree
car	you	door	this
five	nest	run	time
day	store	one	would

APPENDIX B

SENTENTIAL WORD LISTS

SUBJECT__________ NORMAL SENTENCES CONDITION__________

1.	I	will	play
2.	the	cat	played
3.	I	know	you
4.	stop	the	car
5.	you	work	late
6.	I	am	big
7.	I	eat	here
8.	I	like	milk
9.	I	like	her
10.	lock	the	door

SUBJECT__________ <u>SECOND ORDER</u> CONDITION__________

1.	men	will	do
2.	that	man	of
3.	snow	time	will
4.	dog	nest	girl
5.	wish	with	her
6.	good	girl	work
7.	like	good	one
8.	up	and	to
9.	man	zoo	food
10.	do	hot	wish

SUBJECT__________ FIRST ORDER CONDITION__________

1.	go	girl	zoo
2.	take	hot	girl
3.	food	jar	wish
4.	jar	sand	man
5.	red	toy	us
6.	wish	pop	milk
7.	egg	call	ten
8.	up	jar	said
9.	nest	ring	sun
10.	name	will	jar

SUBJECT__________ NORMAL SENTENCES CONDITION__________

1.	we	went	to	the	zoo
2.	that	girl	is	not	good
3.	she	ran	to	the	store
4.	we	play	in	the	snow
5.	you	do	like	the	snow
6.	that	boy	is	with	me
7.	I	was	a	good	boy
8.	that	boy	will	play	here
9.	five	men	came	to	work
10.	you	take	that	cat	out

SUBJECT__________ SECOND ORDER CONDITION__________

1.	I	put	up	to	like
2.	here	all	of	stop	tree
3.	stop	egg	zoo	with	good
4.	feet	is	big	ten	good
5.	nest	milk	one	sun	said
6.	man	sun	eat	with	milk
7.	late	time	to	wish	you
8.	is	said	five	feet	pop
9.	I	milk	pop	come	zoo
10.	eat	egg	take	up	ten

SUBJECT__________ **FIRST ORDER** CONDITION__________

1.	men	zoo	pop	nest	is
2.	red	play	late	I	call
3.	snow	take	play	big	man
4.	name	milk	good	girl	sun
5.	time	all	sun	pop	tree
6.	snow	pop	dish	is	name
7.	pop	zoo	cry	food	milk
8.	tree	up	yes	me	word
9.	me	play	wish	milk	nest
10.	dog	cat	high	man	hot

APPENDIX C

RESULTS OF INDIVIDUAL SUBJECTS

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	1	0	0	0	0	7	0	0	0	0

Classification of Error Response Normal Subjects for Three-word Sequences at 0% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0
2	0	0	0	0	0	5	0	0	0	0	1	1	0	0	0
3	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0
6	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0
8	0	0	0	0	0	1	0	0	0	0	7	0	0	0	0
9	0	0	0	0	0	2	0	0	0	0	3	0	0	0	0
10	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0
12	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
14	1	0	0	0	0	5	0	0	0	0	3	1	0	0	0
15	0	0	0	0	0	4	0	0	0	0	3	0	0	0	0
TOTAL	1	0	0	0	0	36	0	0	0	0	31	2	0	0	0

Classification of Error Response of Individual Normal Subjects for Three-word Sequences at 30% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	5	0	0	0	0	4	1	0	0	0
2	0	0	0	0	0	4	0	0	0	0	1	1	0	0	0
3	1	0	0	0	0	10	0	0	0	0	10	1	0	0	0
4	0	0	0	0	0	2	0	0	0	0	6	0	0	0	0
5	0	0	0	0	0	5	0	0	0	0	2	0	0	0	0
6	0	0	0	0	0	2	5	0	0	0	8	2	0	0	0
7	0	3	0	0	0	0	3	0	0	0	6	0	0	0	0
8	0	0	0	0	0	6	0	0	0	0	7	0	0	0	0
9	2	0	0	0	0	3	3	0	0	0	6	0	0	0	0
10	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0
11	0	0	0	0	0	5	0	0	0	0	3	0	0	0	0
12	0	0	0	0	0	10	0	0	0	0	11	6	0	0	0
13	0	0	0	0	0	3	2	0	0	0	4	0	0	0	0
14	0	0	0	0	0	5	0	0	0	0	3	0	0	0	0
15	1	2	0	0	0	5	3	0	0	0	8	1	0	0	0
TOTAL	4	5	0	0	0	69	16	0	0	0	83	12	0	0	0

Classification of Error Responses of Individual Normal Subjects for Three-word Sequences at 60% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	1	0	0	0	3	1	0	1	0	3	1	0	0	1
2	2	3	0	0	0	3	4	2	0	0	7	1	1	0	5
3	2	1	0	0	0	3	3	0	0	0	7	3	0	0	4
4	0	1	0	0	0	4	0	0	0	0	9	0	1	0	0
5	0	1	0	0	0	2	0	0	0	0	2	7	0	0	0
6	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0
7	1	0	0	0	0	6	3	0	2	0	8	1	0	2	1
8	0	0	1	0	0	1	15	1	0	0	2	19	0	0	0
9	1	1	0	0	0	7	0	0	2	0	6	0	0	0	13
10	0	0	0	0	0	2	3	0	0	0	5	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	0	0	0	0	0	3	0	0	0	0	3	0	1	0	3
13	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	2	1	0	0	0	3	0	0	0	1
15	0	0	0	0	0	2	0	0	0	1	4	1	1	1	0
TOTAL	8	8	1	0	0	40	30	3	5	1	61	33	4	3	28

Classification of Error Responses of Individual Mentally Impaired Subjects for Three-word Sequences at 0% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	7	1	0	0	2	10	1	0	0	2
2	0	2	0	0	0	6	4	0	0	0	12	1	0	0	0
3	0	0	0	0	0	4	1	0	0	1	6	3	0	0	6
4	2	1	1	0	0	8	0	0	0	0	8	1	2	2	0
5	1	0	0	0	0	0	6	0	0	0	4	7	0	0	0
6	2	2	0	0	0	4	0	0	0	0	4	0	0	0	0
7	3	0	0	0	0	8	3	1	0	1	11	4	1	0	0
8	2	0	0	0	0	3	3	0	0	6	3	19	0	1	1
9	1	2	0	0	0	7	5	0	0	2	16	0	0	0	7
10	0	0	0	0	0	3	6	0	0	0	6	6	0	0	1
11	0	0	0	0	0	3	1	0	0	0	3	0	0	0	0
12	0	0	0	0	0	1	0	0	0	0	6	0	0	0	1
13	0	0	0	0	0	5	0	1	0	0	5	0	0	1	0
14	0	0	0	0	0	4	0	0	0	0	6	0	0	0	5
15	0	0	0	0	0	7	0	0	0	0	8	0	1	1	1
TOTAL	11	7	1	0	0	70	30	2	0	12	108	42	4	5	24

Classification of Error Responses of Individual Mentally Impaired Subjects for Three-word Sequences at 30% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	3	1	0	0	0	14	0	0	0	2	15	1	0	0	0
2	0	4	0	0	0	5	14	0	0	3	4	16	0	0	6
3	3	10	0	0	2	8	3	2	0	7	6	20	0	0	0
4	2	0	0	0	0	10	1	0	0	0	10	4	1	0	0
5	2	1	0	0	0	3	18	0	0	0	6	22	0	0	0
6	4	1	0	0	0	14	1	0	0	0	7	1	0	0	8
7	9	0	1	0	0	12	3	0	0	3	14	3	1	0	4
8	1	11	0	0	0	6	22	0	0	0	2	23	0	0	0
9	2	0	0	0	0	9	1	0	1	12	3	2	0	0	18
10	0	1	0	0	0	7	6	0	0	3	4	12	1	0	4
11	0	1	0	0	0	9	1	0	1	0	7	0	0	0	4
12	1	0	0	0	0	7	0	0	0	0	6	0	0	0	10
13	2	7	0	0	0	7	15	1	0	0	5	15	0	0	1
14	1	1	0	0	0	5	0	1	1	3	9	1	1	1	4
15	0	3	0	0	0	5	3	0	0	0	4	6	2	1	3
TOTAL	30	41	1	0	2	121	88	3	3	33	102	126	6	2	62

Classification of Error Responses of Individual Mentally Impaired Subjects for Three-word Sequences at 60% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 30.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	4	2	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
5	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
7	0	0	0	0	0	4	0	0	1	0	4	0	0	0	0
8	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0
9	0	0	0	0	0	2	0	0	1	0	2	0	0	0	0
10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
11	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
13	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0
TOTAL	0	0	0	0	0	17	2	0	7	0	13	1	0	4	0

Classification of Error Responses of Individual Normal Subjects for Five-word Sequences at 0% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	4	0	0	0	0	2	0	0	0	0
3	1	0	0	0	0	6	0	0	2	0	0	0	0	1	0
4	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	6	1	1	0	0	3	0	0	0	2
6	0	0	0	0	0	2	0	0	1	0	2	0	0	1	0
7	1	0	0	0	0	3	0	0	0	0	5	0	0	1	0
8	1	0	0	0	0	6	5	0	2	0	1	1	0	0	0
9	0	0	0	0	0	6	0	0	0	0	6	0	0	0	0
10	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
11	1	0	0	0	0	6	1	0	0	0	1	0	0	0	0
12	0	0	0	0	0	5	0	0	1	0	0	0	0	1	0
13	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0
14	1	0	0	0	0	3	0	0	0	0	2	0	0	0	0
15	1	0	0	0	0	3	0	0	0	0	3	0	0	0	0
TOTAL	9	0	0	0	0	58	7	1	7	0	26	1	0	5	2

Classification of Error Responses of Individual Normal Subjects for Five-word Sequences at 30% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	0	0	0	0	0	2	0	0	0	0	5	0	0	0	0
2	1	0	0	0	0	9	0	0	1	0	6	2	0	0	0
3	1	2	0	0	0	14	14	0	0	1	7	19	0	0	0
4	0	1	0	0	0	4	2	0	0	0	4	5	0	0	0
5	2	2	0	0	0	7	0	0	1	0	8	1	1	1	0
6	0	1	0	0	0	14	5	0	1	1	13	3	0	3	0
7	1	0	0	0	0	6	2	0	1	0	9	5	0	2	0
8	0	0	0	0	0	9	3	0	1	0	14	3	0	4	0
9	3	2	0	0	0	23	0	0	0	2	16	0	0	0	0
10	0	0	0	0	0	4	1	0	0	0	4	0	0	0	0
11	1	1	0	0	0	8	0	0	0	0	6	2	0	0	0
12	5	0	0	1	0	8	6	0	0	0	10	2	0	1	0
13	0	1	0	0	0	6	1	0	0	0	6	6	0	4	0
14	2	0	0	0	0	2	0	0	0	0	7	0	0	0	0
15	2	1	0	0	0	4	10	0	0	0	6	3	0	1	0
TOTAL	18	11	0	1	0	120	44	0	5	4	121	51	1	16	0

Classification of Error Responses of Individual Normal Subjects for Five-word Sequences at 60% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	2	2	0	0	0	1	16	0	3	0	3	21	1	2	0
2	5	3	1	0	0	4	25	0	0	10	6	13	0	2	17
3	0	0	0	0	0	6	6	1	0	1	5	4	0	3	8
4	0	0	0	1	0	7	3	0	2	0	7	0	1	3	2
5	2	0	0	1	0	7	3	2	1	6	9	7	0	4	10
6	4	0	0	0	0	9	14	0	0	0	3	19	4	3	0
7	0	0	0	0	0	7	11	1	0	1	4	7	0	1	0
8	0	0	0	0	0	5	0	0	0	0	4	0	0	0	0
9	1	0	0	0	0	11	1	0	1	2	10	0	1	0	0
10	0	0	0	0	0	12	3	0	2	0	4	5	0	3	1
11	2	0	0	0	0	7	3	1	2	14	12	3	1	1	16
12	0	2	0	0	0	6	7	0	0	3	9	7	0	0	2
13	1	2	0	0	0	9	7	3	1	3	16	7	1	11	1
14	1	1	0	1	0	10	0	4	2	6	11	2	2	2	8
15	1	0	0	0	0	5	8	0	2	0	8	7	0	4	2
TOTAL	19	10	1	3	0	106	107	12	16	46	111	102	11	39	67

Classification of Error Responses of Individual Mentally Impaired Subjects for Five-word Sequences at 0% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	2	2	0	0	1	3	15	0	1	8	4	19	0	1	8
2	6	7	1	0	0	3	31	0	0	1	4	28	0	0	5
3	0	1	0	0	0	7	4	0	2	11	3	9	0	0	17
4	1	0	0	1	0	9	6	2	0	3	14	0	0	1	5
5	3	1	0	2	0	7	16	1	1	2	7	20	1	0	9
6	5	1	1	0	0	6	26	0	0	2	4	26	0	0	3
7	1	1	0	0	0	9	12	0	3	0	7	16	0	2	0
8	1	0	0	0	0	2	32	0	0	0	1	40	0	0	0
9	3	0	0	0	0	12	6	0	0	12	10	0	0	0	9
10	0	0	0	0	0	4	10	2	0	1	2	13	0	2	1
11	5	2	0	0	0	12	8	1	1	19	3	8	0	0	26
12	1	0	0	0	0	7	8	1	0	2	7	6	0	0	10
13	1	4	0	0	0	13	6	0	3	4	9	9	3	2	8
14	4	2	0	0	0	9	1	3	0	12	2	5	7	2	18
15	1	0	0	0	0	6	12	1	0	5	4	27	2	1	5
TOTAL	34	21	2	3	1	109	193	11	11	82	81	226	13	11	124

Classification of Error Responses of Individual Mentally Impaired Subjects for Five-word Sequences at 30% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.

SUBJECT	NORMAL					SECOND ORDER					FIRST ORDER				
	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST	DISC	OMIS	ADD	REV	DIST
1	2	3	0	0	0	10	24	0	0	0	3	31	0	0	8
2	3	14	1	0	0	8	18	0	0	15	3	19	0	0	24
3	4	8	0	0	1	13	20	0	0	4	4	16	0	0	18
4	3	1	0	1	0	21	9	1	0	5	13	8	0	1	16
5	4	2	0	2	0	9	20	1	1	5	10	15	0	1	12
6	12	11	0	0	0	6	31	0	0	1	6	27	0	0	5
7	1	6	0	0	0	10	25	0	1	1	1	37	0	0	4
8	1	10	0	0	0	4	42	0	0	0	1	42	0	0	0
9	2	1	0	0	2	18	8	0	0	11	6	6	0	0	29
10	2	0	0	0	0	13	15	0	1	1	17	15	1	2	0
11	4	2	0	0	1	5	8	0	0	28	5	16	0	0	24
12	2	3	0	0	0	17	13	0	1	4	14	18	0	0	7
13	4	7	0	0	3	20	10	0	2	10	17	15	4	0	6
14	3	2	1	0	0	9	2	4	0	25	10	7	6	0	21
15	2	20	0	0	0	1	43	0	0	0	·0	44	0	0	0
TOTAL	49	90	2	3	7	164	388	6	6	110	110	316	11	4	174

Classification of Error Responses of Individual Mentally Impaired Subjects for Five-word Sequences at 60% Time Compression. (DISC = Discrimination, OMIS = Omission, ADD = Addition, REV = Reversal, DIST = Distortion) Maximum Individual Error = 50.