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ATTENTION ALLOCATION AND CAPACITY IN RETARDED AND NONRETARDED INDIVIDUALS

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Attention Allocation and Processing Capacity in Retarded and Nonretarded Individuals", submitted by Patricia M. Nugent in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Eighteen retarded (MR), twenty children (MA) and twenty adult (CA) subjects were given three conditions of an auditory detection task. In the Location Condition, subjects were presented with a random sequential presentation of alphabetic letters to both ears and were required to they verbally repeat letters presented to one preassigned ear. In the Meaning Condition, a monaural sequence of rapidly presented backward letters containing infrequent forward target letters was presented. Subjects were required to repeat all forward letters. In the Both Condition a binaural presentation of the Meaning Condition was presented and subjects were to repeat forward letters in the preassigned ear.

It was found that MR and MA subjects had consistently slower reaction times (RTs) than CA subjects but RTs remained consistent across the three conditions. MR and MA subjects reported significantly fewer letters during the Meaning and Both Conditions. This was attributed to a limited attentional capacity. Both MR and MA subjects reported a significantly greater number of distracting letters showing an

inefficient allocation of attention.

It was concluded that developmentally immature populations showed deficits in attentional allocation and a limited attentional capacity relative to more mature populations

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Attention Allocation and Capacity in Retarded and Nonretarded Individuals

The study of attention has been a central part of cognitive research since the late 1950's. It is generally agreed that it is an important component of human learning in that attention is necessary for the accurate encoding and efficient processing of information (Borkowski, Peck, & Damberg, 1983). The present study concentrates specifically on selective or focused attention which requires not only the ability to focus on, encode and process relevant information but also the ability to omit the processing of irrelevant, distracting information. It is the ability to successfully omit the processing of irrelevant material that is of particular interest in that it greatly enhances the processing efficiency of relevant information.

Attention has been studied at various levels and with a variety of paradigms (Posner, 1982). While much of this research can be linked together it is not yet reducible to a single comprehensive theory. The one aspect of attention on which there is unanimous agreement is that it is of limited capacity. Only a limited amount of information from the environment is perceived, responded to and remembered. What has not been agreed upon is where in the information processing system these limits occur, how we control selected vs rejected information and the costs and benefits of such selections.

Among the earliest work which investigated attention was that of Broadbent (1958). He generated one of the first theories of attention commonly referred to as the Filter Theory or Early Selection Theory. This theory stemmed mainly from information gathered from two sources.

In a study by Broadbent (1958) subjects were dichotically presented with two sets of three digits, one set to each ear. On average subjects recalled only four to five digits which is considerably less than the average of seven to ten digits which can be recalled with serial presentations. It was also found that subjects organized the input by ears, recalling one ear first then the second ear. Errors were greatest during recall of material presented to the second ear.

Another study by Cherry (1953) used a dichotic listening technique in which subjects received simultaneous imput to both ears and were asked to repeat or "shadow" the message presented to one predesignated ear. Cherry (1953) reported that subjects did not seem to be aware of the content of the message presented to the unshadowed ear. Not only were the subjects unable to remember the nonattended information but they were often unaware of the language in which the message was spoken.

Based on these and similar findings, Broadbent maintained that the translation of this sensory information to memory or further processing is limited, requiring passage through a limited channel or filter. Information is selected for further processing on the basis of physical characteristics such as intensity, pitch or spatial location. The information remaining in the sensory storage system is subject to rapid decay and is therefore not processed. Any shift in the selection process from one information source to another requires additional time.

There were several problems with the Broadbent model. Primarily it was evident that ignored information also gained access to memory (Corteen & Wood, 1972; Duncan, 1980; Lewis, 1970; Treisman, 1964a,b,c; Triesman, Squire & Green 1974). Furthermore, information was not selected solely on the basis of physical characteristics but could be selected on the basis of semantic meaning (Grey & Wedderburn, 1960). Both of these factors suggest that a certain amount of processing occurs prior to the filtering mechanism.

These findings contributed to a modified Late Selection Theory (Treisman, 1969) which proposed the existence of a limited channel between the sensory and memory processes but suggested that information was merely attenuated rather than perfectly filtered. The proposed attenuation mechanism is flexible and can be brought into operation in response to physical features or after various degrees of semantic processing. Other theories went as far as to propose that all information gained unimpaired parallel access to memory and that selection occurred after access to memory (Deutsch & Deutsch 1963; Norman 1968).

As it became evident that more than one sensory stimulus was capable of obtaining further processing and gaining access to memory, research shifted to observations of the interference which these simultaneously active stimuli produced. It was recognized that under certain circumstances some information processing does not appear to require attention: eg., stimulus access to memory (Forster & Govier, 1978; Treisman, 1964) and word recognition (Corteen & Wood, 1972; Duncan, 1980; Lewis, 1970). Thus it was suggested that certain processing is automatic and can occur with little or no cost to the simultaneous processing of other material (Shiffrin & Schneider, 1977). With this information, the concept of attention began to shift from one of a pre-memory filter to that of an active control system operating later in the processing system (Duncan, 1980; Treisman & Gelade, 1980; Keele & Neill, 1978; LaBerge, 1975; Shiffrin & Schneider, 1977).

A model proposed by Keele & Neill (1978), suggests that attention should be viewed as a control process influencing the flow of information. This process can be preset for early or late selection of information. If two sources of information which are being simultaneously processed interfere with each other, attention can be used to attenuate one source of the information prior to memory. The attenuated input receives only the residual processing which remains after the primary input is fully processed. On the other hand, when two or more sources of information require very little processing capacity (ie. they are automatic), they do not appear to produce interference. The inputs can therefore be effectively processed in parallel through to the memory stage.

Shiffrin & Schneider (1977) expanded on the idea of parallel processing. They used a visual detection paradigm where subjects were presented with four items (called a memory set) which they were later required to detect from a series of rapidly presented frames; each frame containing four simultaneously presented items. A trial consisted of 20 frames presented at a constant rate. Subjects were asked to respond when a memory set item was detected in a frame. Frame time, memory set size, frame size and content of frames were varied across conditions (see Shiffrin & Schneider, 1977). From these experiments they describe two types of attentional processes; automatic and controlled.

Controlled search is described as highly demanding of attention. It is a serial search (therefore dependent on load) and is easily established and altered. In contrast, automatic detection often occurs with a well learned detection task and is demanding of attention only in the presence of a target. It occurs in parallel and is unaffected by load. It is difficult to alter, suppress or ignore and it does not utilize the limited attentional capacity of short term storage. Automatic detection can develop as a result of consistent, long term training (Shiffrin & Schneider, 1984; Underwood, 1974). A mental process is considered to be automatic if it occurs without voluntary control and is not affected by the allocation of attention

(Kahneman & Chajczyk, 1983).

The attention theory proposed by Shiffrin & Schneider suggests that performance depends on a complex mixture of automatic detection and controlled search (Shiffrin & Schneider, 1984). In this theory attention is viewed as active and exhibits some control over which elements gain access to further processing. This is more powerful than simply attenuating or filtering various elements on the basis of physical characteristics (Broadbent, 1958). The Shiffrin & Schneider (1977) model proposes that there is some degree of automatic processing for all items and that controlled processing can be directed sequentially to examine and respond first to the specific information actively selected for further processing. Short Term Storage (STS) is seen as a continuum of all automatic encodings plus inputs from Long Term Storage (LTS). It contains information from a variety of processing levels and attention selectivity can therefore appear at any level, either in response to physical cues or semantic processing (Posner, Snyder & Davidson, 1980; Shiffrin & Schneider, 1977).

Neural Evidence

The above theories have been developed on the basis of behavioral data. Some recent research has focused on the neural components of attention. Much work has been done on the study of attention through the use of auditory Event Related Potentials (ERPs) (Donald, 1983; Hillyard, Hink, Schwent & Picton, 1973; Naatanen & Michie, 1979; Sutton, 1977). ERPs are obtained by averaging cortical and subcortical activity which occurs in response to external stimuli during the performance of an information-processing task. ERPs provide a special insight into the study of attention, in that they reflect direct, simultaneous, on-line neural responses to both attended and nonattended stimuli (Donald, 1983).

The ERP research provides evidence for the neural attenuation of nonattended channels relative to attended channels. Two of the most documented ERP components are the N1 and P3 components. It has been consistently found that a negative neural component (N1) occurs approximately 100 ms after stimulus presentation. The amplitude of this component becomes significantly decreased in the nonattended channel, 30 - 40 seconds after onset of an auditory detection task

(Donald & Young, 1982). A second positive component occurring approximately 300 ms after a target stimulus presentation (P3), is virtually nonexistent in nonattended channels but occurs only to attended targets (Donald & Little, 1981; Sutton, 1977).

The N1 component is preset and occurs to every sensory stimulus including distractors, attended nontargets and targets (ie., a parallel processing mechanism). Over a period of 30-40 seconds the amplitude of the N1 component obtained from nonattended stimuli becomes significantly smaller than the N1 amplitude simultaneously obtained from attended stimuli. This gradual decrease in amplitude of the N1 component to nonattended stimuli is strong evidence of a neural attenuation mechanism. The P3 component appears selectively to preassigned target stimuli, being considerably smaller for nontarget stimuli. Most interestingly it is influenced by instructional set as it is virtually absent to targets and nontargets in the nonattended channel (Donald, 1983).

These data provide strong support for an attenuation mechanism, as well as an instructionally controlled, all or none gating mechanism which operates during signal detection tasks. It is suggested here that the N1 component is similar to and may reflect the automatic parallel processing system referred to in many attention theories (Keele & Neill, 1978). The P3 component appears to reflect a preset, instructionally controlled detection process, possibly similar to a controlled search process suggested by Shiffrin & Schneider (1977). While the exact source and nature of these components are still being debated, they are consistent with the theories based on behavioral data. Furthermore, they are generally well accepted as reflecting internal information processing and can be seen as a useful research and diagnostic tool (Lindsley, 1976).

Attention and Mental Retardation

Current theories suggest that attention operates to facilitate information flow and reduce the attentional capacity needed for well learned tasks or skills, therefore allowing larger amounts of this capacity to be devoted to novel or relevant information. The ability of this controlling system to operate effectively will obviously have a great impact on the efficiency and speed with which complex tasks can be performed. An inefficient system will not only slow down the rate of processing, but if we consider that much processing operates in parallel, then processing inefficiencies at an early level could result in incomplete or inaccurate data being available for subsequent processing. Thus, the cumulative effect of these inefficiencies may become quite robust (Sperber & McCauley, 1984). In light of the large impact attention can have on cognitive processing, it becomes increasingly important to understand the degree to which attention is related to intelligence or subject to individual differences.

The present study is interested specifically in the attention ability of mentally retarded individuals as indexed by an auditory selective attention task. Mental retardation is defined by the American Association on Mental Deficiency as a "significant subaverage general intellectual functioning existing concurrently with deficits in adaptive behavior, and manifested during the developmental period" (Robinson & Robinson, 1976). Mental retardation may have a variety of causes, some of which remain unknown. Distinctions are often made between mentally retarded individuals who are simply assumed to represent the lower ranges of the normal distribution of intelligence and those whose intellectual development has been interfered with by a pathological condition such as disease, injury or a chromosome abnormality (Mulick, 1983; Robinson & Robinson, 1976; Zigler & Balla, 1982). The first condition is often referred to as functional retardation and it is this category which is dealt with in the present study.

In studying the mentally retarded it is obvious that they display weaknesses in almost all aspects of cognitive functioning. Much research is therefore aimed at specifying the precise structures or processes which, if absent or inefficient, produce the observed deficits in cognitive performance (Campione & Brown, 1978). Recent theories view attention as a flexible executive process which affects all aspects of the information processing system (Shiffrin & Schneider, 1984). Consequently research with mentally retarded individuals has begun to look for deficits in an all-encompassing dynamic control process such as attention, rather that static structural deficits in the memory system (eg., sensory registors, short term and long term memory (Borkowski, Peck, & Damberg, 1983). Furthermore, there seems little evidence that the structural aspects of the information processing system in mentally retarded subjects differs qualitatively (Sperber & McCauley, 1984). There is however, considerable evidence of quantitative differences such as speed of encoding and amount of information that can be dealt with at one time (Nettelbeck & Brewer, 1981; Stanovich, 1978).

Some early and important cognitive research done with the mentally retarded focused specifically on attention. Zeaman and House (1963) used a chained discrimination learning paradigm where subjects were directed to attend to one relevant dimension of a stimulus (ie., shape or colour). The results showed that mentally retarded subjects took a greater number of trials to learn a discrimination. However, the intelligence related difference appeared only in the initial phase, once the subjects began to perform above chance they improved at the same rate as nonretarded subjects. Overall performance deficits were therefore attributed specifically to the initial, imprecise direction of attention towards the relevant stimulus dimensions. They concluded that the major determinant of poor performance with mentally retarded subjects was a deficit in the initial direction of attention (Zeaman & House, 1963; Zeaman & House, 1979).

Subsequent evidence (Okada, 1978) found that the early Zeaman and House (1963) design was more sensitive to the initial direction of attention than to learning rate and was therefore unfairly biased. When this bias was accounted for learning rate differences were found. The theory was subsequently modified (Fisher & Zeaman, 1973) and combined with the Atkinson & Shiffrin (1968) model of memory. The revised model proposed that intelligence was related to the probability of initial attention being directed to the relevant dimension, as well as the ability to attend to more than one dimension and memory capacity.

These early theories were derived from paradigms employing discrimination learning. These paradigms usually require memory storage and were influenced by prior knowledge. It is therefore difficult to attribute any observed deficits in performance directly to inefficiencies in attention. Current studies of intelligence related attention deficits have therefore been challenged to observe attention processes which are independent of memory, prior knowledge and learning rate.

Current theories conceive of attention as a control process mediating information flow, of which only a limited amount can be adequately processed at one time. Consequently, it appears that there are two areas where mentally retarded subjects may show deficits in attention. According to Carr (1984), mentally retarded subjects can be described as deficient with respect to available attentional capacity and in their ability to allocate this capacity to the most relevant information. Research aimed at the separation of these two aspects of attention has proved to be quite challenging. Not only are these two components difficult to distinguish, but they are also closely interrelated and often confounded with other mental processes, such as memory and response initiation.

Attentional Capacity and Automaticity

It has been widely held that mentally retarded subjects have less available attentional capacity than intellectually average subjects (Carr, 1984; Ford & Keating, 1981; Golberg, Schwartz, & Stewart, 1977; Sperber & McCauley, 1984). A major problem with this idea is the fact that practice, experience and prior knowledge greatly affect the attentional capacity which is required by a particular task. Tasks which initially require much effort and therefore a greater portion of the limited processing capacity can, with practice, become increasingly automatic so that they require only minimal amounts of attention (Shiffrin & Schneider, 1977).

Even complex tasks can become automatic with continued long term practice. Underwood (1974) found that dichotic listening tasks could be performed with no interference from the distracting messages. Spelke, Hirst & Neisser (1976) report that even the dual task of reading and writing could be practiced sufficiently so that the two tasks produced no interference. These studies provide evidence that extended practice can indeed facilitate the performance of tasks to the point where little attention is required. When multiple tasks can be performed without voluntary control and without causing interference with one another, they are considered to be automatic processes which can be carried out without attention (Kahneman & Chajczyk, 1983).

However, regardless of the influence of practice, any control or voluntary function involved in the task requires some attention and attentional capacity (Shallice, 1972). Also, tasks which cannot be automatically processed in parallel do require attention and a certain degree of attentional capacity. The poor performance of mentally retarded subjects which appears initially to be related to a more limited attentional capacity, could be due to unequal familiarity between the tasks they are performing therefore requiring more attention, or because the control processes involved requires more of the mentally retarded subjects total attentional capacity. A specific task may therefore require a greater proportion of the mentally retarded subjects limited attentional capacity than it would for an intellectually average subject due to the task being less familiar or less automatic.

It is difficult to distinguish between automaticity and available capacity due largely to the difficulty of determining whether tasks are indeed automatic. Most methodologies do not account for the automaticity of a task and therefore do not allow for a distinction to be made between automaticity and available attentional capacity. While many studies report intelligence related deficits in tasks such as memory scanning (Dugas & Kellas, 1974; Harris & Fleer; 1974), perceptual comparisons (Silverman, 1974), and response selections (Baumeister & Kellas, 1967), these may be due to decreased automaticity of performance for mentally retarded subjects. This idea is further supported by studies which find no intelligence related deficits in more automatic operations or when extremely unfamiliar stimuli are used. For instance no deficits have been found for sensory encoding (Berkson, 1960, Likbuman & Freidrick, 1972; Pennington & Luszcz, 1975), perceptual encoding (Das, 1971; Thor, 1970; Spitz & Thor, 1968) and simple response initiation (Freidrich, Likbuman, & Hawkins, 1974).

It is therefore extremely important to consider the degree of automaticity or familiarity of the task when studying mental processes in mentally retarded subjects. Two studies, one by Sperber, Ragain & McCauley (1976) and another by Cody & Barkowski (1977) have been designed to determine whether knowledge differences or subject familiarity with stimuli, was equal for mentally retarded subjects. Such information is valuable so that studies of attention can be designed without the bias of unequal task difficulty.

Cody & Borkowski (1977) used a paradigm from Wickens, Borm, & Allen (1963) where subjects were asked to recall triplets of words all obtained from a similar category. Results showed that performance decreased over trials due to a spontaneous build-up of proactive interference. When the category from which the words were chosen was changed, the proactive interference disappeared. The magnitude of proactive interference was similar for both mentally retarded and nonretarded groups. The fact that interference was obtained in the absence of instructions, suggests that there was no passive encoding deficit in the mentally retarded group and that prior knowledge or familiarity concerning category information was relatively equal between subject groups. Thus, it appears that simple encoding and basic category knowledge for simple words is equally familiar to and processed automatically by both groups.

Sperber et al., (1976) used a semantic priming task where subjects were presented with a priming picture followed by a target picture. Subjects were simply asked to identify the target pictures. Typical results showed that target pictures from the primed category were responded to faster (Sperber, McCauley, Ragan, & Weil, 1979). The magnitude of this priming effect was equal for mentally retarded and nonretarded subjects. Since the priming effect operated passively and without awareness it is argued that this provides a direct index of stored category knowledge (Davis, Sperber, & McCauley, 1981). The equality of the priming effect between the two groups suggests that the encoding process for category information is equally automatic for the two intelligence groups.

However, in a second part of the study, subjects were asked to actively categorize targets. In this case the mentally retarded subjects responded more slowly than nonretarded subjects. They concluded that active category evaluation was not an automatic process therefore requiring more attentional capacity for mentally retarded subjects. This is similar to other studies using active retrieval and evaluation of stored category information which find intelligence related deficits (Ford & Keating, 1981; Goldberg et al., 1977; Sperber et al., 1976).

Both of these studies report that passively activated priming effects showed no magnitude differences between the mentally retarded and nonretarded groups. Both studies concluded that encoding of simple category information was automatic and equally efficient for both groups (Sperber & McCauley, 1984). These studies provide evidence that simple word encoding and some simple category knowledge is equally familiar and therefore automatic for mentally retarded subjects. Other studies also reported that sensory encoding (Berkson, 19760; Likbuman & Friedrich, 1972), pattern recognition (Das, 1971; Ryan & Jones, 1975; Spitz & Webreck, 1971), memory retreival (Logan, 1978, 1979) and response initiation (Freidrich et al., 1974) do not show intelligence related deficits.

The research indicates that in order to

distinguish between those processes influenced by intelligence and those which are not one must consider the degree to which active control as opposed to automaticity is involved in the task. For instance, differences in memory scanning are obtained only with alphanumeric stimuli (Dugas & Kellas, 1974; Harris & Fleer, 1974) which may be more familiar to nonretarded subjects. With equally familiar stimuli to which processing becomes automatic, or with equally unfamiliar stimuli, no intelligence related differences are found (Hornstein & Mosley, 1979; Stanovick, 1978).

Research suggests that tasks which meet the criterion of equal familiarity consist of such processes as sensory encoding, or pattern recognition of either simple and equally familiar objects or equally unfamiliar objects. By using tasks which allow automatic processing to occur and/or do not confound knowledge differences, any subsequent observations of attentional deficits can be attributed to a more limited attentional capacity rather than a decreased automaticity of task performance.

Few paradigms look at attentional capacity without confounding automaticity or prior knowledge. Sperber, McCauley, Davies, & Wagor (in press), purport to have studied attentional capacity after successful elimination of the effects of familiarity. The paradigm which they used is a modification of a paradigm used by Posner (1978), where subjects were sequentially shown paired pictures of simple objects. The subjects were asked to judge whether the pictures were the same or different, based on whether the two objects could be referred to by the same name (basic level), or the same category (superordinate level). The interstimulus interval (ISI) between the first picture and the second was varied (0 to 1000 ms) so that a measure of the time to encode the first picture could be obtained from the overall processing time as a function of the length of the ISI. The point at which reaction times no longer decreased are assumed to reflect the time required to encode the first item. Note that no decision is required to encode the first picture, therefore, the reaction time (RT) recorded reflects simple word encoding which should be automatic for both mentally retarded and nonretarded subjects. The results showed that mentally retarded subjects took approximately 500 ms to encode the first picture (ie. automatic encoding). This time was consistently 100 ms slower than for nonretarded subjects. This study reveals the first evidence of an absolute semantic processing difference that is not confounded by decision processes or unequal automaticity of stimuli (Sperber & McCauley, 1984).

Merrel (1982) used a modified Sternberg (1969) task where subjects were given an auditory presentation of one to four words (memory set), followed by a probe word. This is one of the few studies using auditory stimuli rather than visual pictorial stimuli. Subjects were asked to detect whether the probe word was a match with any of the memory set words. There were three possible conditions: a)Basic level, where memory set and probe words were simple object names b)Superordinate level, where the probe and memory words were category names and c)Basic-Superordinate level, where a positive response was required if the probe word was a member of the category presented as the memory set. As the first two conditions did not require a decision but simply a match of two stimuli, it was assumed these processes would be processed automatically. Only the last condition required controlled processing and might therefore be affected by unequal stimulus familiarity or automaticity. The slope of the RT function in the first two conditions was assumed to reflect the time required to search short term memory (STM) for a set of words. The RT slope in the Basic-Superordinate Condition was assumed to reflect STM search (similar to conditions one and two), PLUS the decision time required to determine whether or not the probe stimulus was a category example.

The results support the earlier findings of Sperber et al., (in press) in that mentally retarded subjects required more time for active category processing (Condition c), than for either the Basic or Superordinate conditions which only involved simple semantic encoding. Due to the similarity of the tasks this study allows direct comparison of semantic processing speed for visual and auditory information. Comparisons between mentally retarded and nonretarded subjects, for episodic processing of superordinate categories (conditions a and b) show the mentally retarded were 2.1 times slower. For semantic processing (condition c) mentally retarded subjects were 1.8 times slower. This is reasonably similar to findings of 1.7 times slower for episodic processing, and the 1.9 times slower for semantic processing, obtained with pictorial stimuli (Davies et al., 1981). Thus, in general, mentally retarded subjects proved to be approximately two times slower on episodic and semantic processing tasks.

These studies are unique in that they provide a direct measure of encoding time without confounding unequal automatic decision processes (ie. the basic category in both studies is a measure of simple automatic encoding). Both studies found a deficit in simple encoding processes independent of prior knowledge or category decisions. This is therefore compelling evidence that mentally retarded subjects show a deficit in attentional capacity in that even simple automatic encoding requires more time regardless of the stimulus modality employed.

Attentional Capacity vs Allocation

There is a second issue concerning whether attentional capacity "per se" or simply the allocation of this capacity produces deficits in information processing performance (Carr, 1984). The previously mentioned studies do not allow for the determination of whether the performance deficit was due to a decreased capacity or a decreased ability to allocate this capacity to the appropriate dimensions of the task. The ability to separate these two dimensions has been extremely difficult. However there are a few methodologies presently being used to assess the role of attention allocation.

Studies which look at the regulation of selected attention report intelligence related differences but often in different directions depending on the paradigms involved (Carr, 1984). Hagen & Huntsman (1971) required that subjects determine themselves what was to be attended. Their results showed that mentally retarded subjects were less selective in the information to which they responded. Carr & Bacharach (1976) on the other hand, specified which information was relevant, and found that mentally retarded subjects showed a greater selectivity. The fact that both studies found that overall performance was slower for mentally retarded subjects suggests an attentional capacity deficit. The different effects of the two paradigms also suggests that mentally retarded subjects are less efficient at directing their attention appropriately, although further testing is required to determine more specifically the exact nature of this deficit.

Attention and Development

A paradigm which has been used to assess attentional allocation is the primary - secondary task used by Posner (Posner, 1978; Posner & Bois, 1971; Posner & Klein, 1973). This paradigm requires subjects to perform a visual matching task (primary task) while a concurrent auditory probe is presented to which the subjects must respond (secondary task). The response times to the auditory probe are assumed to be a measure of the amount of attention allocated to the matching task. While this paradigm has not been applied to mentally retarded subjects, it has been applied to children.

Manis, Keating, & Morison, (1978) applied this primary-secondary task to second and sixth grade children and an adult population. A letter matching task was used for the primary task and an auditory pure tone probe for the secondary task. The performance of the dual task was compared to the performance of the auditory detection task alone. Any relative decrease in performance in the dual task condition was assumed to reflect the amount of attentional capacity required for the primary task. It was found that the adults allocated less attention to all stages of primary task (alerting, early encoding, late encoding and responding) whereas younger children allocated relatively more attention to the primary task during the late encoding and reponding stages. It was concluded that there are developmental changes in the allocation of attention. It appears that late encoding and responding require relatively more attentional capacity for younger subjects.

While it must be kept in mind that there may be group differences in automaticity of the two tasks, this would seem unlikely in that both tasks involved simple word encoding without requiring active decision processes. The younger children seemed more prone to interference by the auditory probe as it occured closer to the response stage. This may reflect a decrease in the efficiency of switching attention between tasks. A deficit in the allocation of attention would cause more interference in RT measures as this switching of attention is required closer in time to the subjects response. Evidence from this study suggests that children are slower in their ability to rapidly reallocate attention between two tasks. This provides convincing evidence for developmentally related differences in attention allocation.

Further support for the idea of developmental deficits in attention allocation is obtained from research employing ERPs. A doctorial thesis by Brooker (1980), found that the attenuation of the N1 component to nonattended stimuli during an auditory detection task was not developed fully until approximately the age of twelve. Until this age, no significant difference was detected in the amplitude of the N1 component between the attended and nonattended channels. Subsequent to the age of 12, a significantly greater N1 amplitude is seen in response to stimuli in the attended channel. Thus, it is suggested that a deficit in the attenuation mechanism for nonattended stimuli would result in proportionally less attention being allocated to relevant information. This may be an influential factor in the observed processing deficits that are found in developmentally immature populations (Brooker, 1980; Donald, 1983).

There is a large body of evidence indicating that immature developmental populations show deficits in attentional allocation. It is well documented that children have pronounced deficits, relative to adults, in cognitve processing and specifically attention related processing (Elliot, 1964; Hagen, 1972; Wickens 1974). Several studies using incidental learning tasks as a measure of the allocation of attention have found that with increasing age there is an increase in attention to relevant stimulus dimensions as opposed to irrelevant dimensions (Crane & Ross, 1967; Hagen, 1967; MacCoby & Hagen, 1965; Siegal & Stevenson, 1966). This increase is attributed to an increase in selective attention or, in other words an improvement in the efficiency of attention allocation.

Baker (1970), suggests that this increase in selective attention is influenced by learning. Children are not entering a task with a predisposed ability to attend to relevant information but improve this skill during the performance of the task. The ability to attend to relevant information is increased with practice. This is especially important if it can be applied to mentally retarded populations, as it suggests the possibility that attention allocation training may improve the cognitive perfomance of mentally retarded individuals.

Other studies have found that children are also slower in other cognitive processes such as percepual encoding (Gummerman & Roberts, 1972; Liss & Haith, 1970; Welsandt, Zupnick & Meyers, 1973) and visual search (Forsman, 1967; Gibson, 1969; Gibson & Yonas, 1966). While these processes are often confounded by nonspecific factors such as incentive, practice and differential experience or knowledge, they reflect deficits very similar to those found with mentally retarded populations.

Deficit vs Development Controversy

A comparison of immature populations and mentally retarded populations is frequent in many areas of research involving mentally retarded subjects. Various researchers claim that the poor performance of mentally retarded subjects is due mainly to the fact that they develop at a slower rate and reach a lower level of final development. Some researchers argue that the cognitive system of the mentally retarded individuals is normal in that it falls within the normal variations dictated by the gene pool, but remains at an immature or underdeveloped level (Zigler & Balla, 1982). They predict little cognitive difference between the mentally retarded and a population of equal mental age, unless external factors are influential. They further suggest that because of their underdeveloped cognitive system mentally retarded subjects are faced with constant failures and expectations of failure (Cromwell, 1963). This in turn may produce poor motivation which cyclically leads to poorer performance resembling the "learned helplessness" phenomenon proposed by Seligman (Weisz, 1982). This view is often referred to as the Developmental Delay Theory of mental retardation.

The Developmental position is frequently concerned with the effects of motivation and personality factors and the influence of the environment on performance. Mentally retarded children are found to be more dependent on support and social reinforcement (Balla & Zigler, 1975). Yet, there is evidence suggesting that mentally retarded children are less responsive to intangeable reinforcement as opposed to tangeable reinforcement, than MA matched, middle socioeconomic children (Zigler & deLaby, 1962). Mentally retarded subjects are therefore in the position of requiring more social reinforcement yet benefitting less from intangeable reinforcements which are most common in real world situtations. Also, there is considerable evidence that differences between mentally retarded and Mental-age-matched subjects may stem from the socially deprived environment in which mentally retarded subjects are raised particularly if raised in an institution (Balla & Zigler, 1983).

Other researchers continue to hold a conflicting opinion that mentally retarded populations show deficits over and above developmental differences and are qualitatively different. Evidence supporting this idea comes mainly from research where mentally retarded subjects have consistently shown greater cognitive deficits than populations of equal chronological age (Ellis, 1982; Cascione, 1982; Luria, 1982; Stanovich, 1978; Zeaman & House, 1979). In those cases where neurological research and autopsy reports have been conducted, some degree of brain damage has been found in as many as 90% of those autopsied subjects (Baumeister & MacLean, 1979; Ellis, 1982; Jellinger, 1972). These structrual changes will inevitably impair behavior. In turn, observed behavioral deficits are often assumed to reflect underlying pathology of the Central Nervous System. These views are referred to as the Deficit Theory of mental retardation.

The Deficit theorists presume low IQ is evidence of a central nervous system pathology. Therefore, their research efforts are consentrated on determining the number of areas affected, the particular areas affected and the type of insult responsible. They feel the initial key to understanding mental retardation is to identify those processes which appear deficient as well as those which are normal.

Both theoretical views pose problems for researchers. It is difficult to assume developmental differences or similarities between mentally retarded and equal mental-age groups when both IQ and mental-age tests are considerable less than perfect. Also, even normal children develop at different rates, therefore, homogeneity of groups matched on mental-age and chronological-age proves difficult. Furthermore, the finding of a difference in developmental level does not contribute to the understanding of the reasons behind a slower rate of development. Further difficulties are encountered in that even functionally retarded individuals cannont be considered a homogeneous group. It is difficult to separate organic vs functionally retarded individuals due to poor records and often unknown etiologies. There is a lack of sophisticated non-invasive techniques to detect minor brain damage. Even if a homogeneous functionally retarded group is obtained, the study of behavior can rarely be traced to underlying central nervous system deficits.

Despite practical limits in research, the debate between these two views remains at the centre of much research concerning mental retardation. Thus, mentally retarded subjects are generally compared to groups of equivalent mental age. Typically, differences between these groups provides evidence for the Deficit position, whereas no difference supports the Developmental Delay position. However, regardless of the lack of homogeneity of functionally retarded individuals, the inadequacy of MA and IQ tests, and the influence of motivation, personality and the environment must be taken into consideration before attributing any differences or similarities in performance to either the deficit or developmental position.

The Present Study

The present study is designed to look at possible deficits which may exist in the control process of attention in mentally retarded individuals. It will be of special interest to note whether any observed performance deficits in the mentally retarded population are similar to or greater than the deficits observed in a population of similar intellectual maturity. The relationship between observed differences in performance for two groups may provide support for either the Developmental Delay or the Deficit Theory. A greater understanding of the degree and type of attention deficit may provide valuable information for possible training or remedial work for mentally retarded individuals.

A review of the research on attention and mental retardation, indicates two issues which must be addressed. The first issue is whether or not mentally retarded subjects have less total attentional capacity resulting in poorer performance. The second issue concerns whether or not they are effectively allocating attention to appropriate relevant sources of information.

A major confound plaguing the earlier attentional research is that of establishing equal automaticity or familiarity of stimuli. The present study has attempted to eliminate the effects of automaticity and familiarity by using a task where minimal processing of either very familiar or equally unfamiliar stimuli is required. The subjects were instructed either to verbally repeat an alphabetic letter stimulus or detect a familiar alphabetic letter from among meaningless speech sounds which will be equally unfamiliar to both mentally retarded and nonretarded subjects.

The experiment will examine the interference of distracting auditory stimuli during an ongoing auditory detection task. There will be a total of three conditions. The verbal response reaction time and the number of correctly identified target stimuli will be the dependent measures.

In the first condition (Location Condition) subjects will hear alphabetic stimuli presented at an average rate of one target every four seconds. These stimuli are presented randomly to both ears but not simultaneously. The subjects will be asked to repeat verbally the letters heard in a preassigned ear. The first condition is a simple RT task where little or no processing is involved. The task should be able to be completed automatically and should reflect a base rate measure of the automatic encoding speed.

The second condition (Meaning Condition) will consist of a monaural presentation of meaningless nonletter stimuli in which infrequent, target letter stimuli have been randomly inserted (average of one target every four seconds). Subjects will be asked to verbally repeat the randomly inserted target stimuli. This condition involves the discrimination of alphabetic letters from meaningless speech sounds. This task will therefore be a simple category/noncategory decision followed by a verbal response. As the target stimuli are familar, it is assumed that they will be equally familiar to both groups of subjects and should therefore be able to be encoded relatively automatically without requiring a large amount of attentional capacity. This condition will provide a baseline measure of the category encoding speed of subjects.

In the third condition (Both Condition) the subjects will receive two separate, non-simultaneous, stereophonic channels of meaningless rapid, random, nonletter stimuli (overall rate of presentation is 2.5 stimuli per second), in which infrequent target letter stimuli are inserted. The subject will be instructed to verbally repeat the infrequent meaningful letter targets in a preassigned ear (the attended channel) while ignoring all stimuli in the other channel (the distraction channel). Having attempted to eliminate the effects of unequal automaticity, the Both Condition is designed to assess the efficiency with which subjects can allocate their attention. During this condition the subjects will be required to conduct the letter detection task of the Meaning Condition in the presence of distracting stimuli. If subjects are able to allocate 100% of their attention to the detection task then there should be no observed deficit in the Both Conditions relative to the Meaning Condition. If attention is missallocated to distracting stimuli or targets in the nonattended channel then the degree of the missallocation should be reflected by load induced performance deficits.

The stimuli used in this task have several features which are important to the design. First, letters of the English alphabet were chosen as stimuli so as to be very familiar to all subjects and therefore should be processed automatically. The other source of stimuli are meaningless, backward letters which should be equally unfamiliar to all subjects.

Second, the stimuli will be presented as rapidly as possible. This is done to push subjects towards the limits of their attentional capacity in the Meaning Condition. The more frequent presentation of stimuli will require a greater attentional capactity in order to detect all the target letters. Thus, if mentally retarded subjects or children show a deficit in the Meaning Condition, it can be taken as a index of their attentional capacity. Rapid presentation will also produce relatively fast RTs which should lead to a minimal amount of interference from subsequently presented stimuli and finally, rapid presentation should facilitate the ability to maintain attention to one channel (Harvey & Treisman, 1973; Hillyard, Hink, Schwent, & Picton, 1973; Treisman, 1971). The more rapidly presented the stimuli, the easier it becomes to maintain constant attention to them and to attenuate or ignore the distracting stimuli (Harvey & Treisman, 1973; Hillyard, Hink, Schwent, & Picton, 1973). Therefore, pronounced deficits in attention allocation would be necessary in order to create a difference between the Meaning and Both Conditions.

A third feature of this design is that target or letter stimuli which are to be detected are relatively infrequent (10% probable). This is based on evidence which claims that unexpected stimuli are more difficult to ignore (Hillyard, Hinck, Schwent, & Picton, 1973).

Based on past research it is hypothesised that the Location Condition should provide little difficulty to either mentally retarded or nonretarded groups. This condition should produce a baseline measure of the speed and accuracy for which subjects can respond to an auditory input. The Meaning Condition should produce a baseline measure of the speed and accuracy for which subjects can detect a letter from nonletter speech sounds. This will reflect the efficiency of stimulus encoding plus response time and give an indication of the subjects' total attentional capacity. The Both Condition should provide a measure of the degree to which subjects can appropriately allocate attention. Any observed deficits in this condition relative to the Meaning Condition can be assumed to reflect of the degree to which subjects were unable to maintain attention to the appropriate relevant information.

The present study provides an estimate of both the attentional capacity and the efficiency with which this capacity can be allocated. It is assumed that any confounding effects of stimulus familiarity have been reduced by using stimuli which are either equally unfamiliar or familiar enough so as to be equally automatic between mentally retarded and nonretarded groups. The results of this study should provide relevant information as to the nature of the attentional deficit demonstrated by functionally mentally retarded individuals. Such information may also be useful for remedial purposes with the mentally retarded.

Method

Subjects

Eighteen mentally retarded volunteers (MR group), were selected from the Vocational and Rehabilitation Research Institute (VRRI) in Calgary. The subjects were screened on the basis of intelligence tests, cause of retardation and degree of medication. The final 18 subjects selected were high functioning, retarded individual (mildly retarded). Three subjects were on minimal medication (Appendix A). The subject's mean Chronological Age (CA) was 25.75 years (SD = 5.90). Their mental age (MA) was assessed with the Peabody Picture Vocabulary Test (PPVT) and revealed a mean MA of 7.08 years (SD = 1.75). Seven of the females and seven of the males were right handed. Written consent was received from all subjects as well as from a Parent/Guardian where required.

A second group of 20 volunteer Elementary School Children (MA group), was selected randomly from grades one, two and three of St. Margarets Catholic School in Calgary. The mean CA of subjects was 8.77 years (SD = .789). Based on PPVT scores the subjects had a mean MA score of 9.0 years (SD =1.49). This was significantly greater than the MA scores of the MR group ($t(36) = 4.335$, $p<.01$) so that the groups could not be considered matched for MA. All of the subjects in this group were right handed. Written consent from Parents/Guardians and the subjects themselves was received prior to testing.

The final group of subjects consisted of 20, volunteer adults from Calgary (CA groups). Their mean CA was 24.6 years (SD =5.06) which was not significantly different from the CA of the MR group ($t(36) = .5474$, $p>.05$). Seven of the ten males and nine of the ten females were right handed. Written consent was received from all subjects.

Each subject in the MR and MA groups was required to acheive a 75% correct criterion on a prestest designed to demonstrate the subjects' ability to distinguish right from left ear and letters from nonletter speech sounds (see Appendix B). All three subject groups contained an equal number of male and female subjects. Each subject was given an audiometric test showing normal hearing ability and no more than 5.0 dB hearing difference between thier right and left ear. All subjects spoke English as their first and only language.

Apparatus

Stimuli

The stimuli consist of 18 humanly spoken letter sounds. To construct these 18 stimuli, each letter of the alphabet was repeated five times by a male volunteer. These letters were recorded, in a soundproof room, on to a SONY FeCr 90 cassette with a SONY ReVOX B 710 MK 11 cassette recorder and a TURNER SE14 microphone. Each recorded letter was then accurately measured by a High Resolution Signal analyser (Type 2033). Those letters (18) which were exactly 200 ms ($\pm$ 5 ms) in length were then selected for computer digitization.

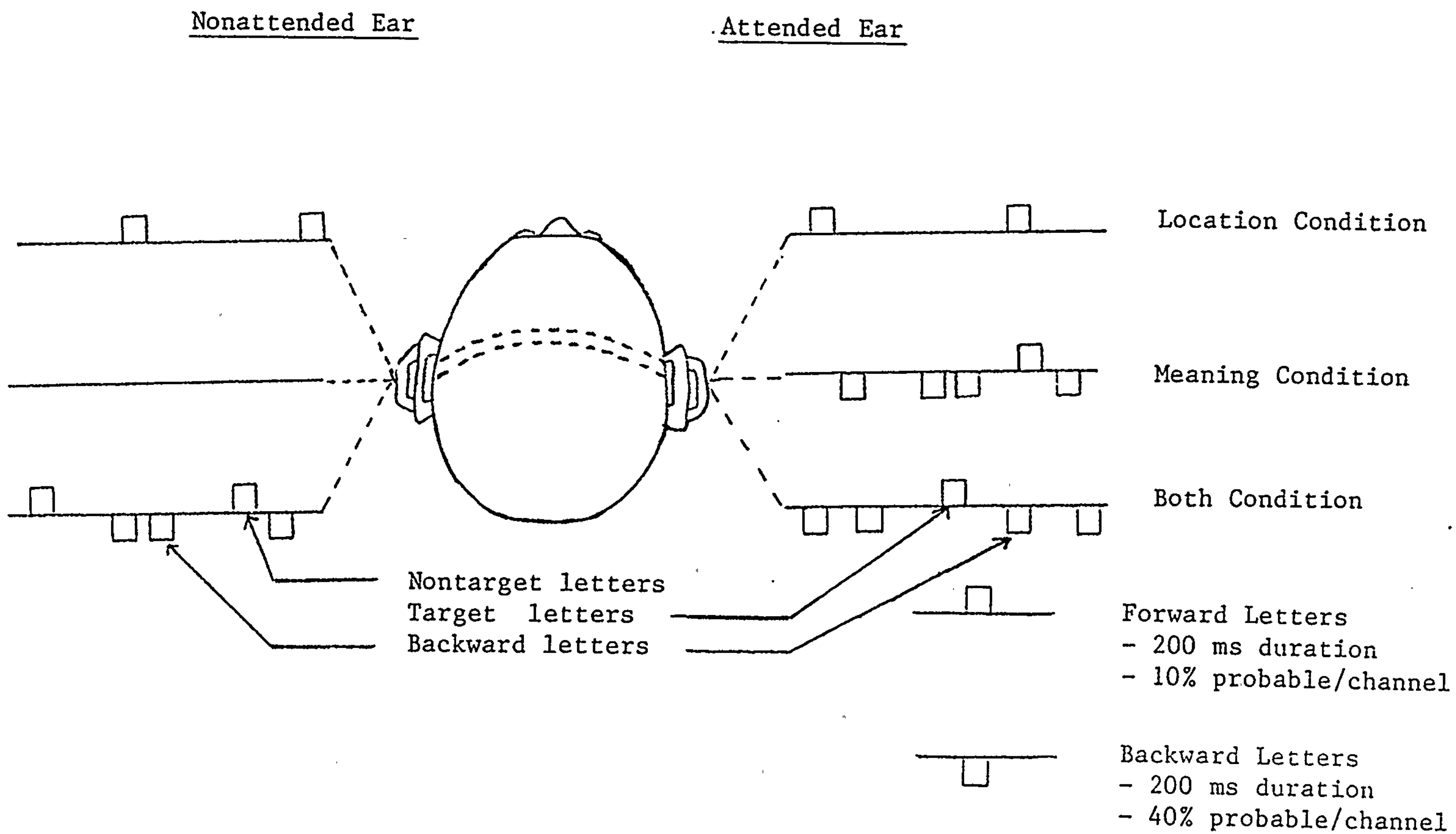
A VAX 11/730 computer, digitized each of the selected letters. The letter stimuli were then equalized for amplitude so as to be in the range of about 65 dB. A reversed replication of each letter was produced by the computer to create 18 additional "backward" letters. The 18 backward letter stimuli, were judged by 5 independent listeners. Fifteen of the backward letters which sounded distincly different from any alphabetical letters were selected. The stimuli used for the study consisted of 18 forward letters and 15 backward letters (see Appendix C). These were then sequenced by a PDP 11/23 computer, under the following constraints.

Each stimulus sequence contained 450 randomly selected stimuli of which 20% were forward letters and 80% were backward letters. The interstimulus interval (ISI) between any two stimuli was randomly chosen from seven possible ISIs (70, 120, 170, 220, 270, 320 and 370 ms). A random 50% of the stimuli were generated on the right channel and 50% on the left channel of a stereophonic playback system. The resulting stimulus sequence lasted approximately 180 sec ($\pm$15 sec) and contained 45 forward letters in each of the two stereophonic channels. This basic stimulus sequence was then modified to produce three distinct conditions (see Figure 1).

Figure 1

The Location, Meaning and Both Conditions

Stimulus Parameters For Each Condition



For the LOCATION condition, only the forward letters of the original stimulus sequence were generated. At positions where backward letters would have occurred, 200 ms of silence was inserted. Thus, the final LOCATION sequence consisted of 45 forward letters, randomly produced in each channel. The average overall rate of presentation was one stimulus every two seconds for both ears, or one stimulus every four seconds in one ear.

In the MEANING condition, only one channel of the original sequence was generated. This monaural sequence contained 10% forward and 40% backward letters occurring at an average rate of 1.25 stimuli per second. The average rate of presentation for forward letters remained at one every four seconds.

In the BOTH condition, the original stimulus sequence containing a random generation of both forward and backward letters was employed. The average rate of stereophonic presentation was therefore 2.5 stimuli per second, while the average rate for a single channel remained at 1.25 stimuli per second and the average rate of forward letters presented to one ear was one every four seconds.

It is important to note that the average rate of forward letters in one channel remained constant for all three conditions; ie. one forward letter every four seconds in one ear. Under each of the three conditions, four different randomly generated stimulus sequences were created. These sequences are referred to as sequences one to four.

Testing Equipment

Once the stimulus sequences and parameters were set, the stimuli were then rerecorded on to SONY HFX 90 cassetts by an audiometric station containing a ReVox B7 10 MK 11 cassette recorder. A SONY TC-HFX44 cassette recorder played the recorded stimulus sequences to subjects through SUPERIOR SM 40 headphones. The prerecorded stimulus sequence plus the subjects verbal responses were then simultaneously recorded onto two tracks of SONY HFX90 cassetts by a SONY TC 158SD cassette recorder. A SONY ECM-16 Electret microphone was used to pick up the subjects' verbal repetitions of targets.

For analysis the two track recordings were played back by either a SONY TC-HFX44 or a TASKAN 122 cassette recorder through a GRASS Model 7D polygraph machine onto 1 X 5 mm grid graph paper. Each recording produced two polygraph traces. One needle of the polyograph machine reproduced a trace of the stimulus sequence which subjects were listening to, while the second needle reproduced a trace of the subjects verbal responses. Reaction time measures were taken as the difference between the onset of a target stimulus to the onset of the subjects' verbal response to that stimulus.

The relative equality of subjects' hearing ability between both ears was tested with a Maico Advanced Diagnostic Audiometer (Model MA 22). MR and MA subjects were tested with the Peabody Picture Vocabulary Test - Revised, Form L (Dunn & Dunn, 1981).

Procedure

Pretest.

To qualify for inclusion in the experiment, each MA and MR subject was required to undergo a pretest. A criterion of 75% correct responses was required before the subjects were accepted.

The pretest contained three sections. The first section contained a random presentation of the 18 forward letters. The letters were presented at a rate of one letter every two seconds. Fifty percent of the letters were randomly presented to the right ear and the remaining 50% to the left ear. The subjects were required to indicate the ear to which the letters were presented, by pointing to the appropriate ear or verbally naming the ear to which stimuli were presented. Two sequences were presented resulting in a total of 36 stimuli. The first section was designed to ensure that subjects were able to distinguish their right and left ears.

The same 18 forward letter sequence was presented in the second section of the pretest, but the subject was instructed only to repeat the letters they heard disregarding the ear in which they heard the letters. Two randomly ordered sequences containing 36 stimuli were presented. This was to ensure that the subjects were familiar with the alphabetic letters used in this study.

The final section of the pretest consisted of the 18 forward letters and the 15 backward letters, presented monaurally at a rate of one stimulus every two seconds. The subject was instructed to repeat only those letters which they recognized from the alphabet. Any omission of a forward letter or attempted repetition of a backward letter was recorded as an error. Two randomly ordered sequences were presented, one to each ear. Satisfactory performance on this section indicated that subjects were able to distinguish meaningful from nonmeaningful stimuli.

During pretesting, MA and MR subjects were also assessed for mental age, hearing and handedness. Mental age was assessed with the PPVT using standard recommended procedures (Dunn & Dunn, 1981). Handedness was assesed as the hand with which subjects signed the written consent forms.

Hearing assessment was acomplished by playing the pretest tape throught a MAICO Advanced

Diagnostic Audiometer (Model MA 22). Volume level was set at zero, then gradually increased until the subject verbally indicated that they could detect a signal. This procedure was repeated four times alternating between the right and left ears. The average dB level at which the subject detected a signal in each ear was calculated, and the difference between the two ears was not to exceed 5.0 dB.

The CA subjects were not administered the pretest as there was no doubt as to the their ability to perform the task, nor were they required to complete the PPVT. They were all assessed for handedness and required to undergo the hearing test. Hearing and handedness were assessed in the same manner as for the MA and MR groups. However, these tests were not administered in a separate pretest session but at the beginning of the first testing session.

Experimental Session

There were three experimental sessions, one for each of the three conditions. Each experimental session lasted approximately 20 - 30 minutes and was scheduled two weeks apart. The MA and MR groups underwent four sessions (one pretest and three experimental sessions) while the CA group underwent only the three experimental sessions.

For the experimental sessions subjects were seated facing the experimenter and instructions were given. The experimenter briefly explained which type of stimuli were on the tape, the ear/ears to which they would be presented and their approximate rate of presentation (see Appendix D). The subjects were told which ear they were to attend and which stimuli they were expected to repeat. When the subject indicated that they understood the required task, headphones were comfortably placed over the subjects ears.

The MR and MA groups were given practice sequences (generally lasting one to three minutes), prior to each experimental session, to ensure that they were responding correctly to the instructions. During this time feedback concerning the subjects performance was given. Practice sessions were terminated as soon as the subject was responding correctly.

The CA group received little or no practice prior to the LOCATION or BOTH conditions. They were permitted to listen to the MEANING condition for approximately one minute prior to testing, in order to familiarize themselves with the "backward" letters sounds.

Each subject listened to four stimulus sequences, each being three minutes duration. Subjects were given a short break (about one to two minutes) after sequences one and three. During this time they were given instructions for the following sequence. After sequence two, they were given a longer break (about two to five minutes) at which time they were given instructions and asked to reverse the headphones.

For each sequence subjects were asked to respond to only one ear, preassigned by the experimenter. The ear to which they were to attend was alternated for each of the four sequences. The first ear to which a subject attended was counterbalanced between subjects. The headphones were always switched halfway through the test session and the order of headphone placement was alternated between subjects in order to counterbalance for possible equipment influence.

The MR group was tested in a small 8' X 11' soundproof audiometric testing room at the VRRI. The CA group was tested in a 9' X 11' sound attenuated room at the University of Calgary where outside noise was minimal. For the testing of the MA group a small 15' X 23' classroom at St. Margarets school was used. The room was not soundproof and outside noises could be heard. However, once the headphones were placed over the subjects ears, any noise was considerably attenuated and it is unlikely to have interferred with subjects performance.

Results

Three dependent measures were used in the present study. They consisted of the number of correct responses (ie., the verbal repetition of targets); the reaction times (RTs) of the correct responses ie., the time from the onset of a target stimulus to the onset of the subject's verbal response; and the number of errors. Four different types of errors were analysed. The classification of these errors will be discussed later.

The reaction times were obtained from the grid paper of the GRASS polygraph machine. The first stimulus presented was taken as point zero. For each sequence a key sequence was obtained by measuring the onset of each stimulus relative to this zero point. This key sequence therefore represents the actual time at which the stimulus was presented. The subjects' verbal responses were then measured in cm relative to the original referenced zero point. The RTs of subjects were then obtained by subtracting the onset for each of the subjects' verbal response from the onset of each stimulus on the key sequence. These measurements were then converted to ms by multiplying them by the speed at which the graph paper was moving (2.5 cm/sec).

It was necessary to compensate for variations in the length of polygraph traces which were most probably caused by variations in the speed of the tape recorder at the time of recording (average variances were less than 1 cm per stimuli). This was accomplished by subtracting the difference between the overall length of the polygraph trace for the response sequence from the overall length of the key stimulus sequence. Each verbal response was then multiplied by this difference in proportion to its position along the sequence. A verbal response occurring at one third of the polygraph trace would be multiplied by one third of the difference between the response sequence and the key sequence. This procedure compensates for any constant change in the polygraph traces due either to motor speed of the tape recorder or motor speed of the polygraph machine.

Analyses were completed using the Biomedical Computer Programs P series (BMDP) software (1959).

An alpha level of $p<.01$ was used for all analyses of variance. Not all analyses met the sphericity assumption therefore the Greenhouse-Geisser ratio with adjusted degrees of freedom was employed (see Frame, 1980). None of the significant findings were associated with epsilon values less than 0.5. Post Hoc tests for main effects were completed using the Spj0tvoll and Stoline's Modification of Tukey's HSD test which used the minumum n value to account for unequal n's (see Kirk 1982).

Correct Resposes

The number of correct responses was subjected to a Group (3) X Gender (2) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance with Condition, Sequence and Block being repeated measures. A Sequence consisted of the 45 target stimuli played over a three minute period. Each Sequence was divided into three Blocks A, B and C, each consisting of one third of the target stimuli ie., 15 targets per block.

The results showed a significant main effect of Group, $F(2,48)$, = 31.07, $p<.001$, with the mean number of correct reponses for the MR, MA and cA groups being 11.89, 12.47, and 14.86 respectively. A Post Hoc analysis revealed a significant difference between the MR and CA groups, $p<.01$ and the MA and CA groups, $p<.01$, but no difference between the MR and MA groups.

There was a significant main effect of Gender, $F(1,48)$, $=9.15$, $p<.001$, with the average number of Correct responses for males being 13.61 and 12.60 for females.

The Condition main effect was also significant, $F(2,96)$, $= 63.87$, $p<.001$. The mean number of correct Responses for the Location, Meaning and Both conditions were 14.07, 13.43 and 11.88 respectively. The Post Hoc analysis revealed a significant, $p<.01$ difference between all three conditions.

There was a main effect of Block, $F(2,96)$, $=$ 5.60, $p<.0071$, where the means for Block A, B, and C were 13.27 , 13.01, and 13.10 respectively. Further analysis revealed a significant difference between Blocks A and C and A and B, $p<.01$, but no difference between Blocks B and C.

The Condition X Group interaction was significant, $F(4,96) = 15.14$, $p<.001$ (see Figure

2). Analysis of the simple main effects revealed a significant, $p<.001$ difference between groups at all three conditions. Further analysis revealed that the MR and MA groups demonstrated a significant, $p<.001$ decrease in the number of correctly reported responses over the three Conditions. The MR group reported 86.9% correct for the Location condition and then decreased to 82.7% and 66.1% for the Meaning and Both conditions respectively. Likewise the MA group reported 92.3% correct on the Location condition but only 86.7% and 67.8% on the Meaning and Both conditions respectively. The CA group on the other hand remained constant, reporting 99.7%, 99.1% and 98.6% correct over the three conditions.

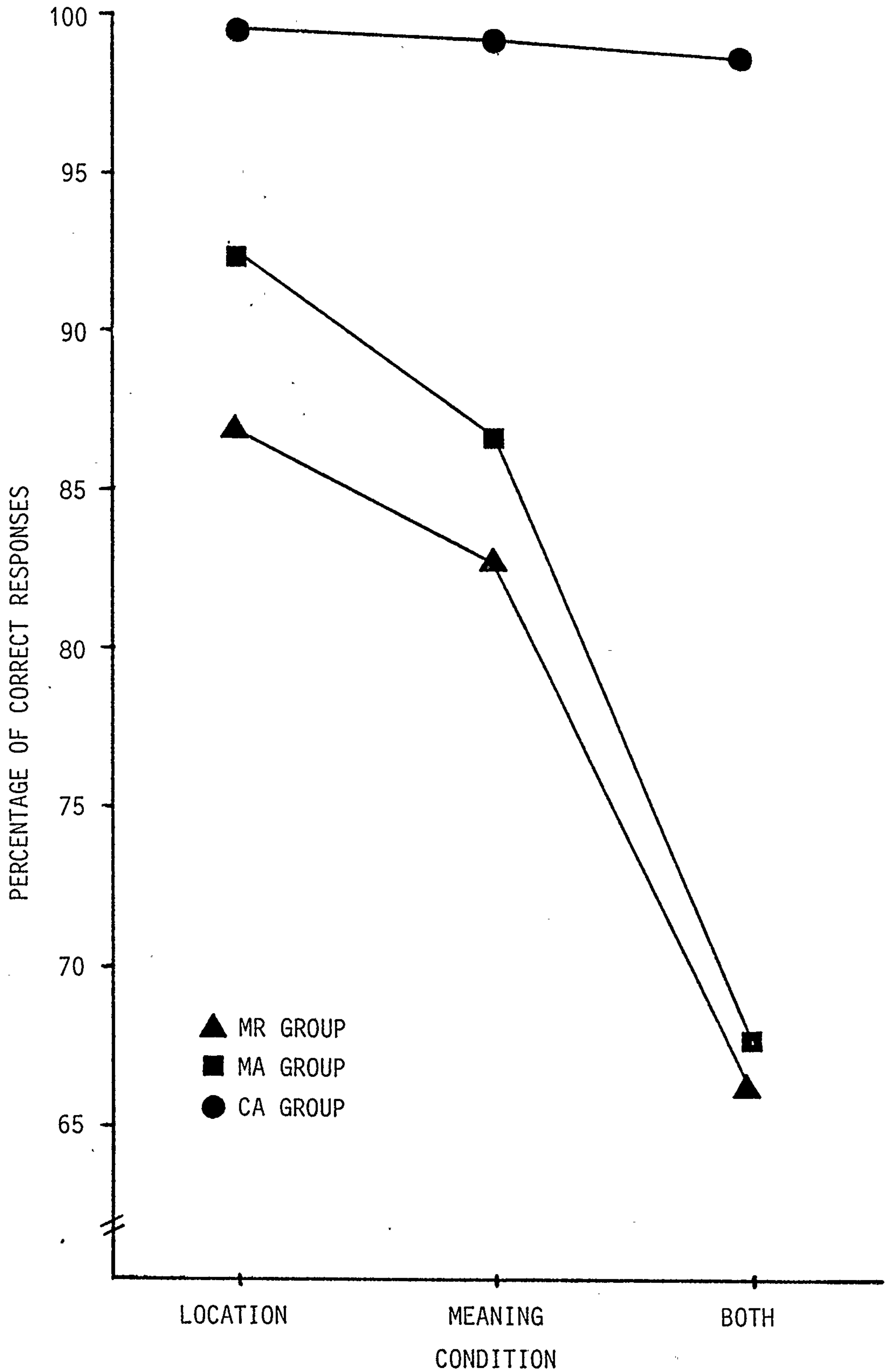
Reaction Times of Correct Responses

The Reaction Times for correct responses were subjected to a Group (3) X Gender (2) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance with Condition, Sequence and Block being

Figure 2

The Condition X Group Interaction for the

Number of Correct Responses


100
95
90
85
80
75
70
65
PERCENTAGE OF CORRECT RESPONSES
MR GROUP
MA GROUP
CA GROUP
LOCATION
MEANING
BOTH
CONDITION

repeated measures. This analysis did not reveal a significant main effect of Gender, nor any interactions of Gender with other variables. Thus, to increase the degrees of freedom and the power of the test, the Gender variable was collapsed and the data were reanalysed employing a Group (3) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance, with Condition, Sequence and Block being repeated measures.

This analysis revealed a signficant main effect of Group, $F(2,38) = 11.88$, $p<.0001$, with the mean RTs being 943.12, 974.73 and 708.27 ms for the MR, MA and CA Groups respectively. Post Hoc analysis of the main effects revealed signficant differences between the CA group and both the MR and MA groups, $p<.01$. However no difference was found between the MA and MR groups.

A main effect of Sequence was signficant, $F(3,114)$, = 5.16, $p<.0055$. The mean RTs for Sequences one through four are 909.2, 897.4, 926.3 and 856.5 ms respectively. Main effect analysis revealed significant, $p<.01$ differences between Sequences One and Four; Sequences Two and Four; and Sequences Three and Four.

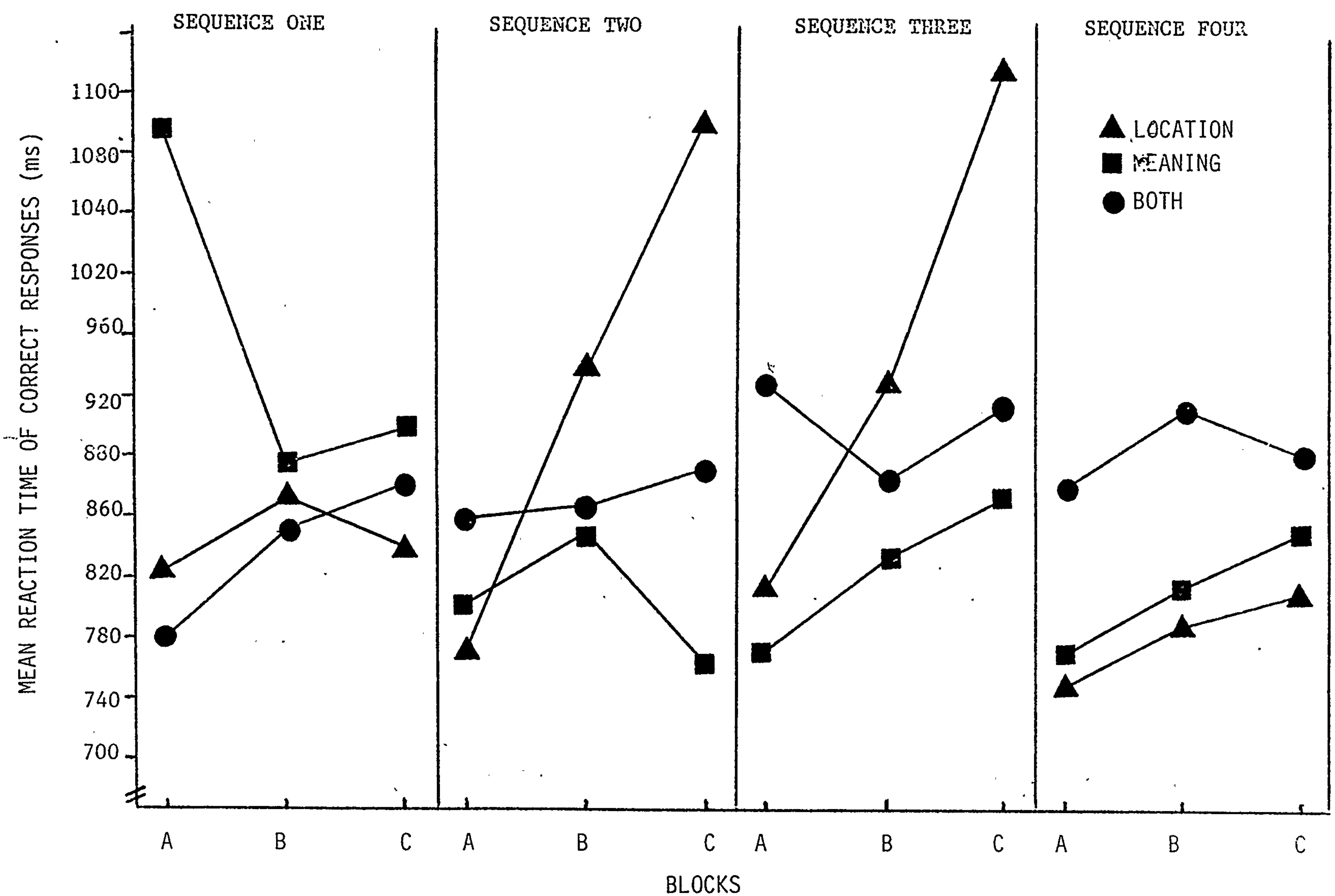
A main effect of Block was also significant,

$F(2,76) = 18.16$, $p<.001$. The mean RT for the first block was 806.0 ms with the second and third blocks having mean RTs of 836.2 and 865.3 ms respectively. Significant, $p<.01$ differences were found between all three blocks.

There were three significant first order interactions; Condition X Sequence, $F(6,228) = 9.09$, $p<.0022$; Condition X Block, $F(6,228) = 12.48$, $p<.001$; and Block X Sequence, $F(6,228) = 4.36$, $p<.0044$. (Graphs of these interaction are displayed in Appendix E). The nature of these signficant interactions is clairified in the significant Condition X Sequence X Block interaction, $F(12,152)$, $= 4.53$, $p<.001$ (see Figure 3) . A significant simple interaction of Condition X Block was found at Sequence One, $p<.0016$; Sequence Two $p<.0001$ and Sequence Three, $p<.001$. Analysis of these interactions further revealed a simple simple main effect of Condition at Block A of Sequence One, $p<.001$; where Block A of the Meaning condition was significantly greater than any of the blocks at the other two Conditions. Also at Block C of Sequence Two the Location condition showed a of Sequence Three

Figure 3

The Condition X Sequence X Block Interaction for the Reaction Times to Correct Responses



SEQUENCE ONE
SEQUENCE TWO
SEQUENCE THREE
SEQUENCE FOUR
LOCATION
MEANING
BOTH
MEAN REACTION TIME OF CORRECT RESPONSES (ms)
1100
1080
1040
1020
960
920
880
860
820
780
740
700
A
B
C
BLOCKS

significantly greater RT score, $p<.001$. At block A of Sequence Three there was a signficiantly greater RT score for the Both condition, $p<.001$, and at Block C of Sequence Three there was a signficantly greater RT score for the Location condition, $p<.0006$).

Error Analyses

Errors were divided into four types. The number of occurrences of each type of error was subjected to a Group (3) X Gender (2) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance with Condition, Sequence and Block being repeated measures. If the Gender main effect was not significant and there were no interactions involving Gender, this variable was collapsed. The data were therefore analysed by a Group (3) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance. This resulted in increased degrees of freedom and a consequent increase in the power of the analyses.

Insertion Errors.

Insertion errors occurring when a subject responds to a nonletter ie. responded to a backward letter sound or meaningless stimulus.

As there was no significant Gender main or interaction effects the data were analysed with a Group (3) X Condition (3) X Sequence (4) X Block (3) analysis of variance. The analysis yeild a Group main effect $F(2,50) = 5.61$, $p<.0063$. The CA group made the least number of errors ($M = .08$) compared to the MA ($M = 0.58$) and the MR ($M = 0.63$) groups. Main effect analysis revealed a significant difference between the MR and CA groups, $p<.01$ and between MA and CA groups, $p<.01$. No significant difference was found between the MR and MA groups.

The Condition main effect was also significant, $F(2,100)$, $= 19.25$, $p<.001$ with the means for the Location, Meaning and Both condition being .04, .94 and .29 respectively. Further analysis revealed significant, $p<.01$ differences between Meaning and Location Conditions, and between the Meaning and Both Conditions.

Exchange Errors.

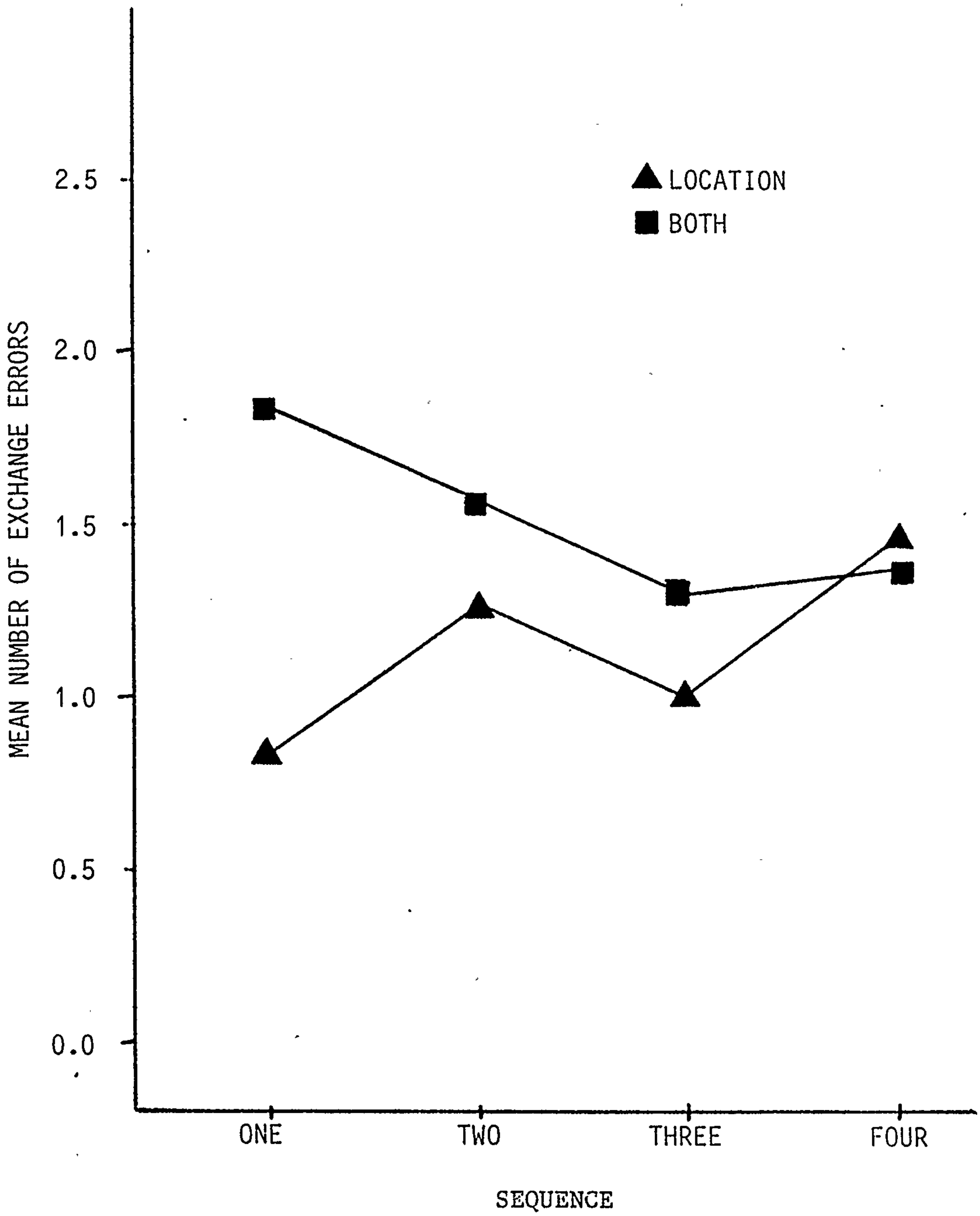
Exchange errors occur when a subject correctly identifies a forward letter in the nonattended ear. As the Meaning Condition is monaural there are no stimuli in the nonattended channel. Thus, exchange errors only occur in the Location and Both Conditions.

In the absence of Gender effect the exchange errors were subjected to a Group (3) X Condition (2) X Sequence (4) X Block(3) which revealed a significant Group main effect, $F(2,51, = 13.24$, $p<.001$. The mean number of exchange errors for the MR, MA, and CA groups were 1.83, 2.22 and .07 respectively. Main effect analysis again showed significant, $p<.01$ difference between the CA group and both the MR and MA groups, but no difference between the MR and MA groups.

The Condition X Sequence interaction was significant, $F(3,153)$, $= 4.94$, $p<.0074$ (see Figure 4). Further analysis showed a significant main effect of Condition at Sequence One, $p<.0002$) where the Both condition at Sequence One showed signficantly more errors than at the Location condition in Sequence One.

Figure 4

The Condition X Sequence Interaction for Exchange Errors


LOCATION
BOTH
2.5
2.0
1.5
1.0
0.5
0.0
MEAN NUMBER OF EXCHANGE ERRORS
ONE
TWO
THREE
FOUR
SEQUENCE

The Condition X Block interaction was also significant, $F(2,102)$, = 6.17 $p<.0065$ (see Figure 5). The simple main effect analysis revealed a significant, $p<.001$ difference between Conditions at Block A, where the Both condition resulted in signficantly more errors.

The Sequence X Block interaction was significant, $F(6,306)$, = 3.62, $p<.0070$ (see Figure 6). Simple main effects show that there was a significant, $p<.01$ Block main effect at Sequence one, where Block A showed a greater number of errors than Blocks B and C, and also at Sequence Four, where errors in Block C was signficantly higher than errors in Blocks A or B.

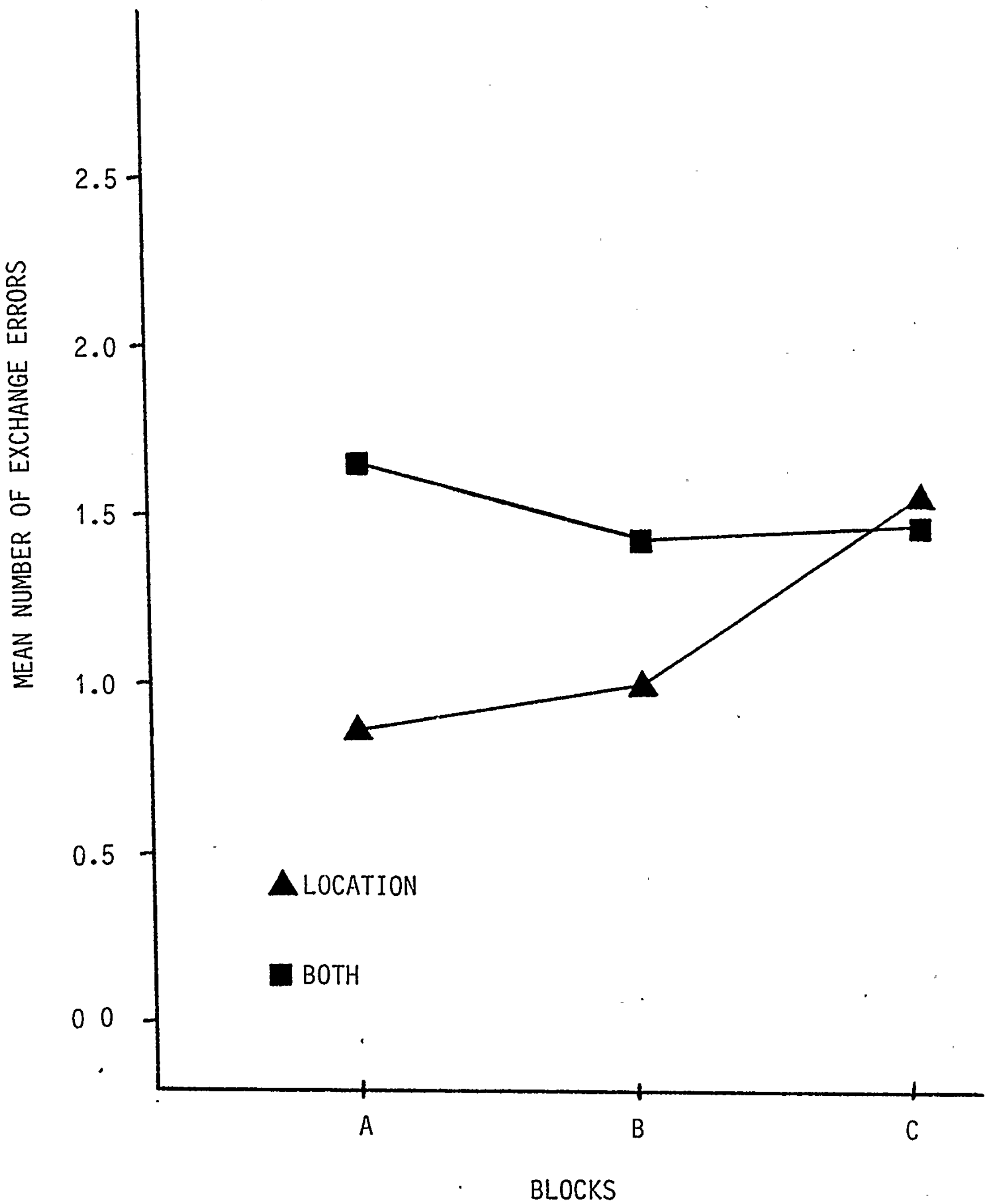
Omission Errors.

Omission errors consist of the omission of any stimulus to which the subjects were to have responded ie., forward letters in the "attended" channel.

The error data were subjected to a Group (3) X Gender (2) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance with Condition, Sequence and Block being repeated

Figure 5

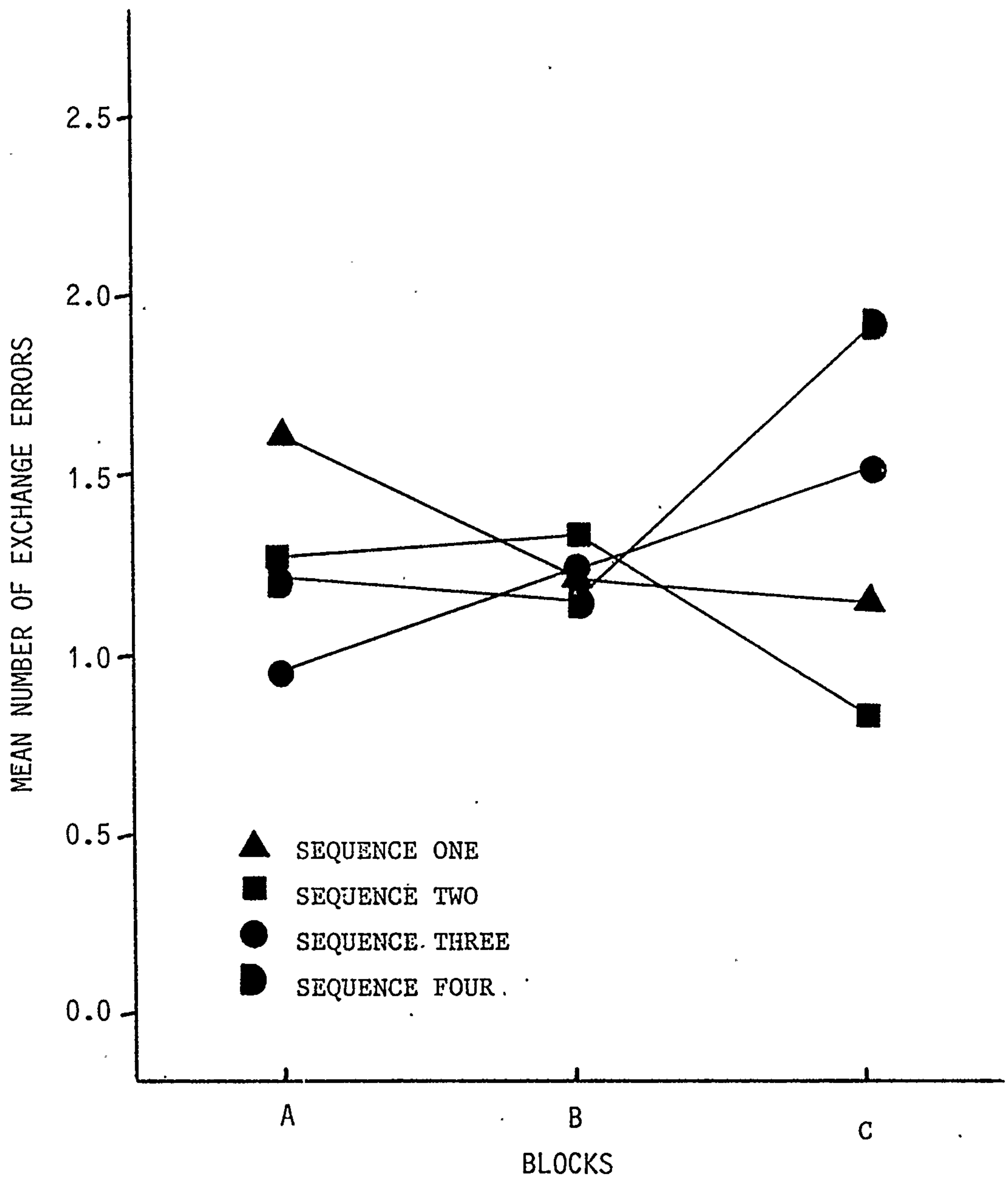
The Condition X Block Interaction for Exchange Errors



2.5
2.0
1.5
1.0
0.5
0 0
MEAN NUMBER OF EXCHANGE ERRORS
LOCATION
BOTH
A
B
C
BLOCKS

Figure 6

The Sequence X Block Interaction for Exchange Errors


MEAN NUMBER OF EXCHANGE ERRORS
2.5
2.0
1.5
1.0
0.5
0.0
SEQUENCE ONE
SEQUENCE TWO
SEQUENCE THREE
SEQUENCE FOUR
A
B
C
BLOCKS

measures. The results revealed a Group main effect, $F(2,48) = 31.07$, $p<.001$, where the mean number of errors for the MR, MA and CA groups were 3.11, 2.53 and .14 respectively. Further analysis showed significant, $p<.01$ differences between the CA group and the other two groups, but no difference between the MR and MA groups.

The main effect of Gender was significant, $F(2,48)$, $= 9.15$, $p<.0040$). Females made considerably more omission errors ($M = 2.40$) than the males ($M= 1.39$).

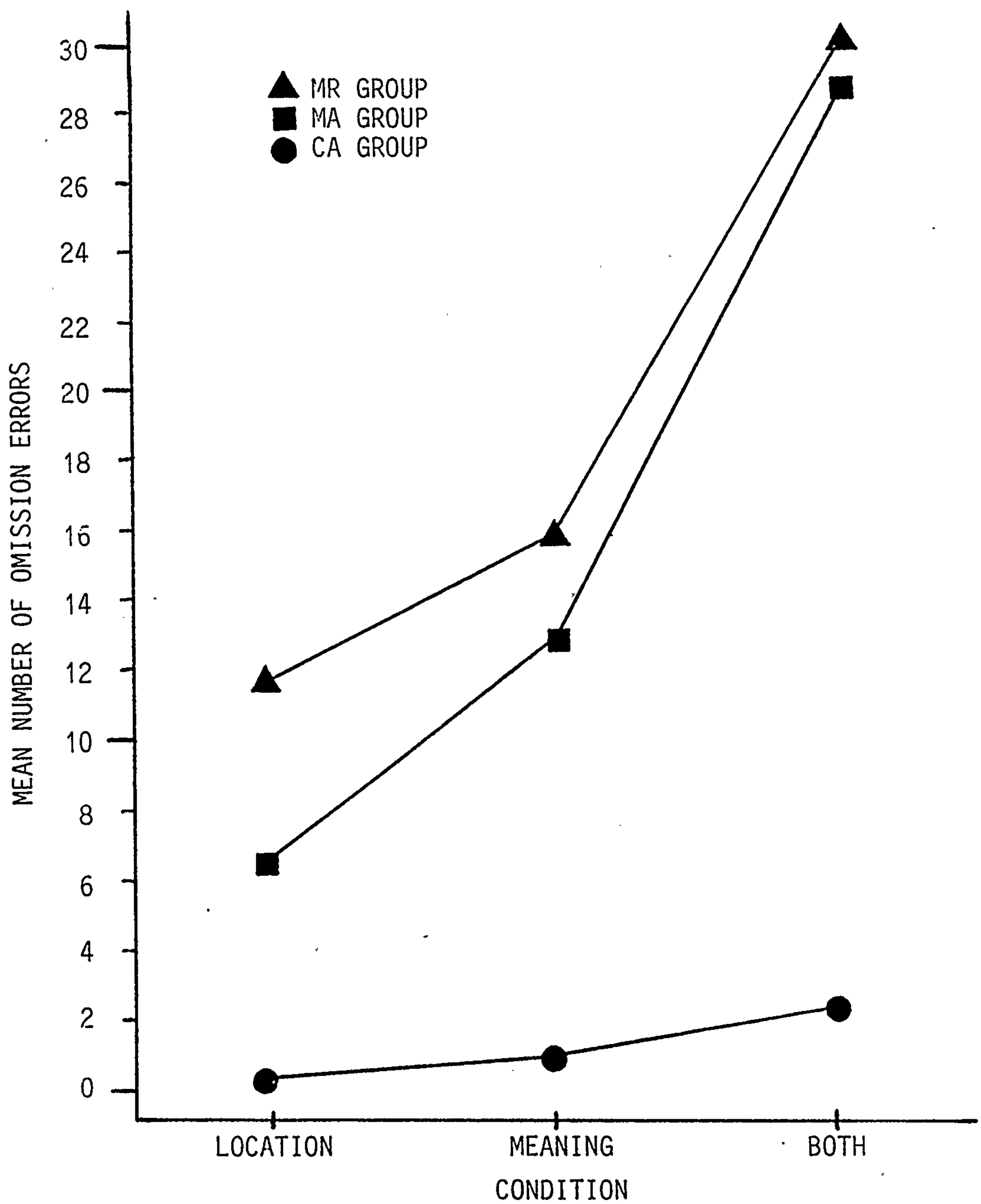
There was also a significant Condition main effect, $F(2,96)$, $= 63.87$, $p<.001$. The mean number of errors increased for the Location ($M = 0.93$), Meaning ($M = 1.57$), and Both ($M = 3.21$) condition. Main effect analysis showed significant, $p<.01$ differences between all three groups.

A significant main effect for Block was also obtained, $F(2,96) = 5.6$, $p<. 0071$. The mean error rates for Block A, B, and C were 1.73, 1.99 and 1.89 respectively. Main effect analysis revealed a significant, $p<.01$, difference between Blocks A and B.

Finally, there was a Condition X Group interaction, $F(4,96)$, $= 15.14$, $p<.001$ (see Figure

Figure 7

The Condition X Group Interaction for Omission Errors


MR GROUP
MA GROUP
CA GROUP
MEAN NUMBER OF OMISSION ERRORS
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
LOCATION
MEANING
BOTH
CONDITION

7). Further analysis shows MR and MA groups demonstrated a significant, $p<.001$ increase in errors at each of the three Conditions. Figure 7 reveals that the MR and MA groups had significantly greater errors for all three conditions. These errors increased for the Meaning and Both conditions, while the low rate of errors remained constant for the CA group.

<u>Substitution Errors.</u>

Substitution errors are classified as cases where two independent observers detected a subjects response close in time to a target stimulus but in which the letter appeared to be mispronounced. For instance if the target letter was B and the subject responded D. Note these errors were only made to a limited number of stimuli those being B-D-E-G-T, Q-U, I-R, and M-N-L.

The Gender variable was not signficant and was therefore collapsed so that the data were subjected to a Group (3) X Condition (3) X Sequence (4) X Block (3) mixed analysis of variance. The analysis revealed a significant

Group effect, $F(2,50)$, = 14.60, $p<.0001$ with the means being 0.48, 0.59 and 0.06 for the MR, MA and CA groups respectively. Post Hoc analysis of the main effects revealed a significant, $p<.01$ difference between the MA and CA groups. The MR group did not differ signficantly from the other two groups.

A Condition X Sequence interaction was obtained, $F(6,300) = 4.90$, $p<.0003$ (see Figure 8). The simple main effect showed a signficant, $p<.001$ difference in Condition at Sequence One, where the Location condition had a greater number of errors that the other two conditions.

The Condition X Sequence X Block was significant, $F(12,600)$, = 2.59, $p<.0092$ (see Figure 9). Further analysis reveals a simple main effect of Condition at Sequence One, Block A $p<.01$ and at Block B, $p<.001$ where the Location condition showed a greater number of errors than the other two conditions.

Figure 8

The Condition X Sequence Interaction for Substitution Errors

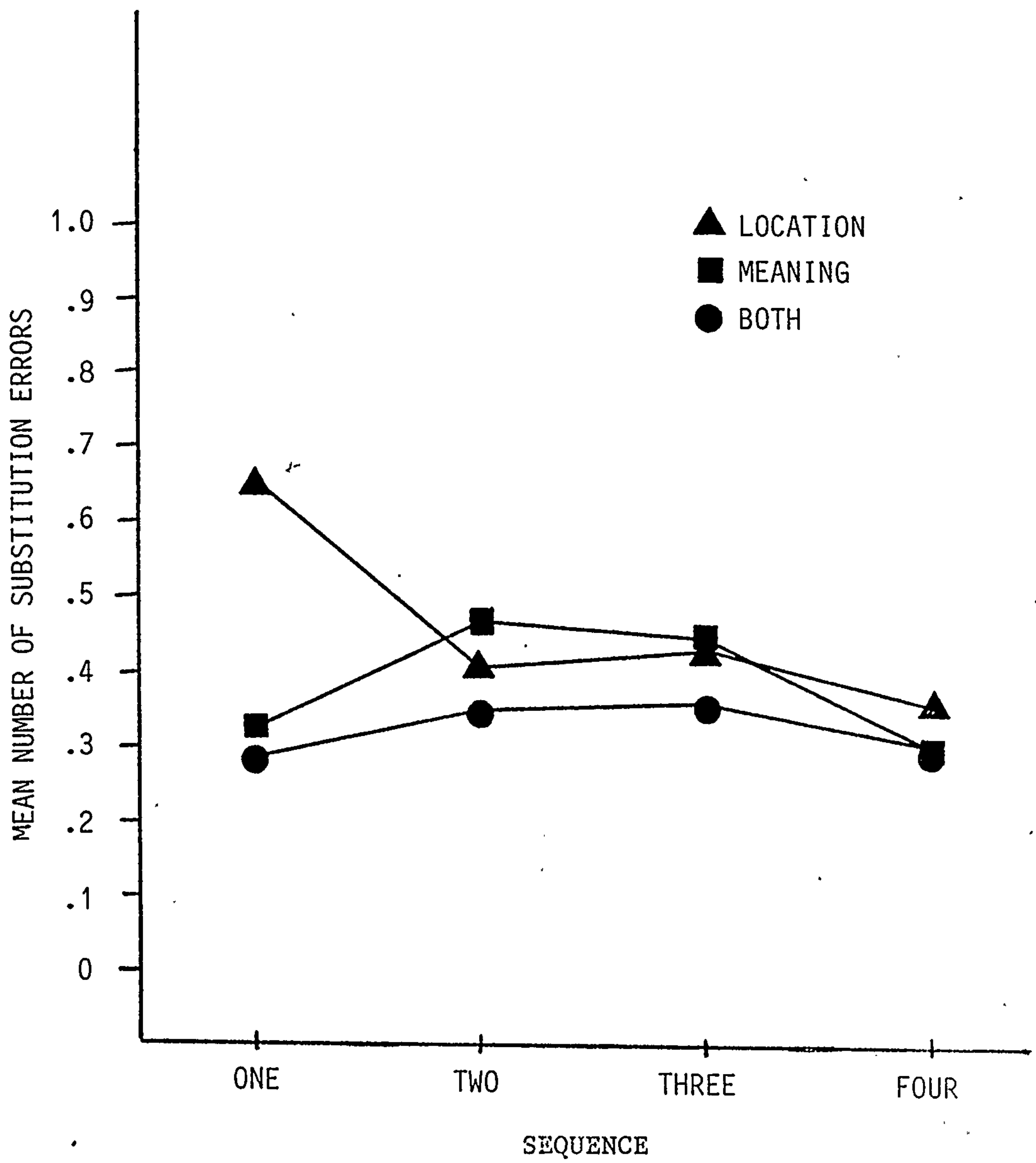
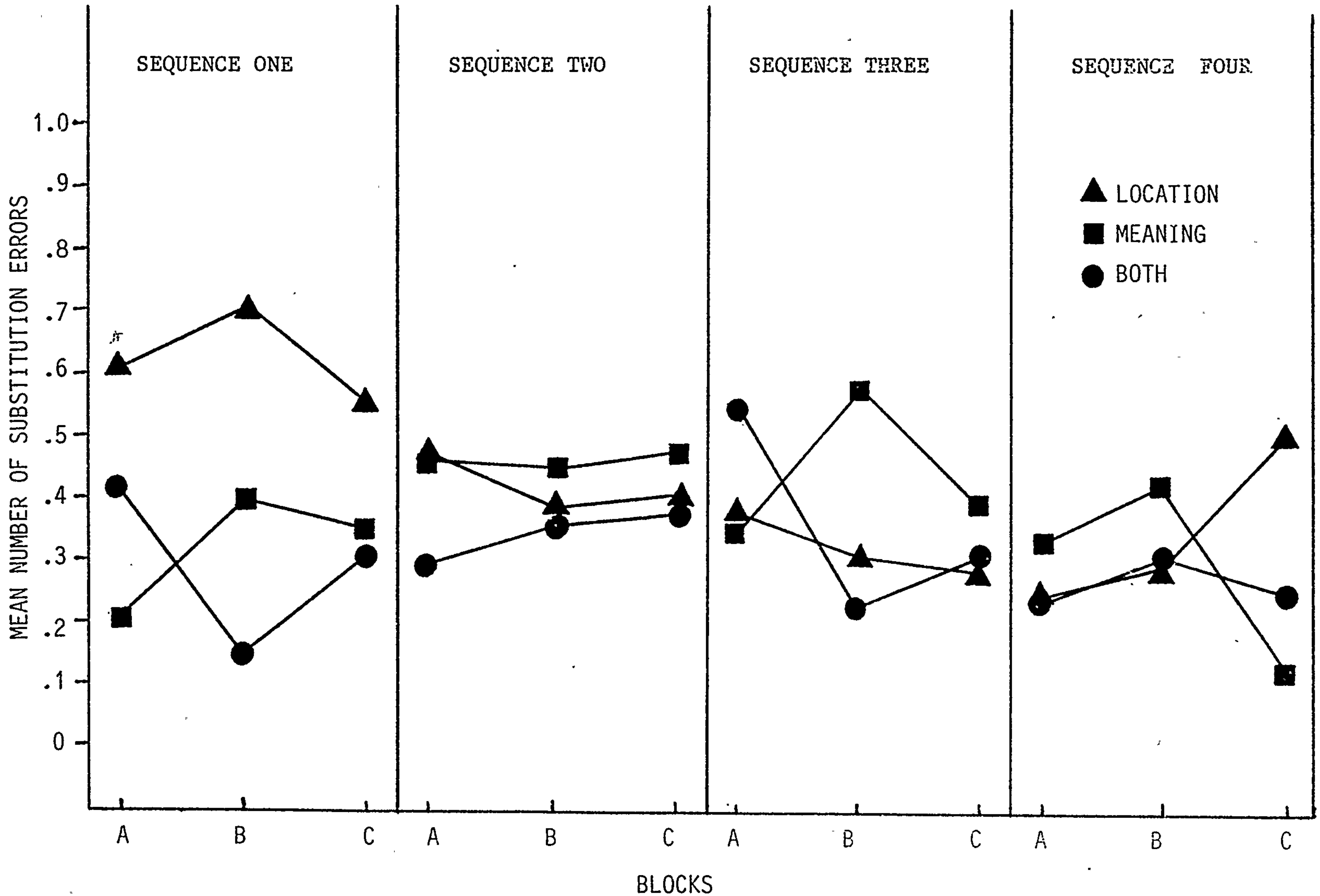

LOCATION
MEANING
BOTH
MEAN NUMBER OF SUBSTITUTION ERRORS
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
ONE
TWO
THREE
FOUR
SEQUENCE

Figure 9

The Condition X Sequence X Block Interaction for Substitution Errors



SEQUENCE ONE
SEQUENCE TWO
SEQUENCE THREE
SEQUENCE FOUR
LOCATION
MEANING
BOTH
MEAN NUMBER OF SUBSTITUTION ERRORS
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
A
B
C
BLOCKS

Summary of Error Analyses.

All four types of errors consistently showed a significant main effect of group with the CA group making significantly fewer errors than the MR and MA groups. No difference was found between the MR and MA groups for any of the error types. For insertion errors there was a main effect of Condition where a significantly greater number of errors were made during the Meaning Condition. For exchange errors there were three first order interactions, Condition X Sequence; Condition X Block; and Sequence X Block. Omission errors showed significant main effects of Gender, Condition and Block as well as a Condition X Group interaction. Substitution errors produced a significant Condition X Sequence and Condition X Sequence X Block interaction.

Discussion

The Group main effect for the number of correct responses revealed a significant difference between the CA group and the other two groups where the CA group performed significantly better. This group performed at ceiling with an average of 99.07% correct. It can therefore be concluded that the CA group did not find any of the conditions difficult and were able to complete all conditions with almost no omission errors. Another important finding was that the MR and MA groups were not significantly different. Although the MA group scored significantly higher on the PPVT, their performance did not differ from that of the MR group. This finding was consistent throughout all of the analyses.

As expected, there was a main effect for Group on the reaction time measure. MR and MA subjects showed significantly slower RTs relative to CA subjects, which is consistent with earlier research (Baumester & Kellas, 1960; Berkson, 1960; Jones & Benton, 1977; Kirby, Nettlebeck & Tiggeman, 1977; Lally & Nettelbeck, 1977;

Nettlebeck & Brewer, 1977; Silverman & Haris, 1982).

The magnitude of reaction times is in the order of 700-1000 ms which is consistent with earlier findings for auditory stimuli (Baumeister & Kellas, 1960; Lally & Nettlebeck, 1977). Overall, the RTs are quite fast due partially to the nature of the stimulus presentation. The stimulus sequence contains rapid and randomly presented stimuli. Both these factors have been found to contribute to faster reaction times (Hillyard, Hink, Schwent, & Picton, 1973). Also due to the rapid presentation of stimuli it is necessary for the subjects to maintain a rapid response rate in order to be able to hear subsequent presentations of stimuli.

The fact that no RT differences were found between conditions and that there was no Condition X Group interaction is quite important. It indicates that the detection of letters from nonletters (Meaning and Both Conditions) seemed to be no more difficult than the simple recognition of letter sounds (Location Condition) and furthermore this held for all three subject groups.

It was hypothesized that the Location Conditon would provide a baseline measure of the speed and accuracy of subjects' performance. Furthermore, that relatively poorer performance during the Meaning Condition would reflect a limit in subjects' total attentional capacity and poor performance during the Both Conditon would reflect a deficit in attentional allocation.

<u>Attentional Allocation</u>

The analysis of correct responses revealed a significant Group X Condition interaction (Figure 2). The Location Condition appeared to place little pressure on the generation of responses as the overall accuracy rate for all groups was 93.8%. Even the MR and MA groups were able to obtain accuracy rates as high as 86.9% and 92.3% respectively. However, the MR and MA subjects were still significantly poorer than the CA subjects (99.7%). This decreased performance can best be explained as a function of increased load. These subjects were unable to allocate their attention as reflected by a signficantly higher number of exchange errors (ie. processing targets in the nonattended channel). Thus, the deficient allocation of attention for MR and MA subjects resulted in increases in processing load and response rate which in turn may be responsible for the decreased performance.

The drop in accuracy between the Meaning and Both Conditions can also be accounted for on the basis of stimulus presentation rate, but, only if there is a deficit in the subjects' ability to allocate attention. If attention is maintained only to the attended ear, then no additional time constraints are placed on processing because the stimulus presentation rate in one channel of the Both Condition is identical to the presentation rate in the Meaning Condition. If the allocation of attention is complete, there should be no change in accuracy scores or RTs. However, if subjects are unable to allocate their attention completely to the "attended" channel and, instead, attend to both channels, the overall stimulus presentation rate increases to 2.5 stimuli per second. If subjects were attempting to process all stimuli, this would further tax attention, requiring a category/noncategory decision every

0.4 seconds. Therefore, if and only if, subjects are unable to ignore the nonattended channel, additional time demands are encountered in the Both Condition and would account for the decreased accuracy.

The CA group seemed able to maintain their attention appropriately as directed by the experimenter. They made an average of 0.07 exchange errors which converts to 0.4%. The MR and MA subjects made an average of 1.83 (12.2%) and 2.22 (14.8%) exchange errors respectively. It therefore appears that the MR and MA groups have an allocation deficit of approximately 13% relative to the CA group.

The consistent performance of the CA subjects in the Both Condition may be due to several factors. It is suggested that these subjects were able to successfully allocate attention to the proper channel as supported by the low number of exchange errors. It is also possible that these subjects had sufficient attentional capacity to process both relevant and irrelevant channels without affecting the speed or accuracy of their response or that they found the task easier and therefore required less attentional capacity to be devoted to the task. Any one or combination of these factors would lead to higher accuracy for the CA group.

However MR and MA sujects did not show consistent performance. It is therefore suggested that the drop in accuracy between the Meaning and Both Conditions reflects a difficulty in allocating their attention which in turn increases the load which these subjects were required to process. This is supported by the significantly greater incidence of exchange errors made by MR and MA subjects relative to the CA subjects.

Attentional Capacity

In the Meaning Condition the overall rate of stimulus presentation was increased to 1.25 stimuli per second. While the rate of correct target presentations per ear remained the same, the number of nontargets was greatly increased. Therefore subjects were required to make, on average, a category/noncategory distinction every 0.8 seconds although the actual rate of responding should not change. At this stimulus presentation rate, the overall accuracy of target detection dropped significantly to 89.5% from 93.8% in the Location Conditon.

It should also be noted that in the Meaning Condition the task changed from localizing a letter, to making a discrimination between a letter and a nonletter sound. It could be argued that the letter/nonletter discrimination was more difficult than a right/left ear discrimination (Location Condition) resulting in the decreased accuracy of response. However, in light of the finding that there was no Condition main effect with the RT measures, it can be argued that the letter/nonletter classification was not more difficult in that it did not require any more time to process than the right/left ear discrimination.

A plausible explanation for the decreased accuracy rate is the increased time demands of the stimulus sequences. It appears that the subjects were forced to maintain a consistently fast reaction time to detect targets in order to be able to hear the subsequent stimuli. The increasing time demands of the task therefore resulted in decreased accuracy. This reflects the well documented speed vs acuracy tradeoff (Carr, 1984; Sternberg, 1974) where subjects sacrificed accuracy to maintain their speed of response.

The decreased accuracy of the MR and MA subjects may reflect a smaller amount of available attentional capacity. Since RTs remain similar between the Location and Meaning Conditions, the decrease in accuracy does not appear to be due to increased difficulty in making a letter/nonletter discrimination as opposed to a right/left ear discrimination. Rather, it is suggested that the increased stimulus presentation rate requires more decisions to be made in the same amount of time. Thus, as stimulus presentation rate increases, some decision processing must be carried out concurrently with responses to previous decisions. If we consider that subjects have only a limited amount of attentional capacity it is possible that the concurrent overlapping decision/response processing may exceed this given capacity. Once the attentional capacity has been exceeded subsequent stimuli entering the system may not have access to this capacity and may therefore result in erorrs of omission as exemplified by the Condition X Group interaction for omission errors.

Because the CA group showed a ceiling effect it is not possible to determine whether they were effectively allocating attention or whether they had sufficient capacity to process both channels of information. Also, it is possible that CA subjects adopted a strategy whereby they reduced the amount of attention necessary to perform the task (ie., required less attention to detect letters from nonletters). The inability to determine if task were equally difficult for all groups disallows the conclusion that performance by MR and MA subjects is due to less attentional capacity relative to CA subjects. While the CA group appears to possess the ability to respond rapidly and accurately at this speed, the MR and MA groups do not.

However, since the RTs to target stimuli remained equal for both the Location and Meaning Conditions, it is concluded that increased time demands of the stimulus presentation rate placed an increased demand on the subjects attentional capacity. The MR and MA groups were unable to maintain both their speed and accuracy when the time demands of the task were increased. Given that the MR and MA groups maintained constant motivation over both conditions, it can be suggested that the decreased accuracy observed for

MR and MA subjects may reflect a decrease in available attentional capacity for these groups.

In addition, considering that MR and MA subjects are not effectively allocating attention, these subjects are exposed to an increased number of target letters. If the number of correct responses and the number of exchange errors for the Both Condition are added together, a measure of the total number of correct target detections can be obtained. It was found that the MR, MA and CA subjects made an average of 12.48, 12.75 and 14.51 target detections, respectively. A t-test analysis reveals that, despite the fact that MR and MA groups were also attending to irrelevant targets, they were still reponding to significantly fewer targets relative to the CA subjects, $t(36)=2.23$, $p,.05$; $t(38)=2.42$, $p,.05$. This provides additional support for the conclusion that MR and MA subjects posses a more limited attentional capacity relative to the CA subjects. By not effectively allocating attention, they are placed in a position of further sacrificing accuracy to maintain their constant reaction times.

Peripheral Findings

The main effect of Gender for the number of correct responses revealed that females made significantly more errors than males. Based on past research there is little reason to expect unequal performances between males and females on an auditory detection task (Harvey & Treisman, 1973; Hillyard, Hink Schwent & Picton, 1973; Treisman, 1964). Therefore this finding may be spurious. The Gender variable did not interact with any of the other variables and therefore did not influence the interpretation of subsequent results.

The main effect of Block revealed that the accuracy rate was significantly greater in the first minute of a Sequence (Block A), than the two subsequent minutes (Blocks B and C). This suggests that the concentration level of subjects may have dropped over the course of a Sequence. This conclusion is further supported by the decrease in reaction times during the latter part of a Sequence as demonstrated by the main effect of Block in the reaction time analysis. Thus, it appears that subjects are more alert (as reflected by faster RTs) and more accurate during the first minute of the sequence and that both their accuracy and speed of response decreased over the latter two minutes. As there is no Group X Block interaction, the Block effect seem to reflect a characteristic of attention in general in that it is present even with a fully developed attention mechanism (ie., the CA group) (Baumester & Kellas, 1968; Joubert & Baumeister, 1970).

The remainder of the significant RT effects (Condition X Sequence; Condition X Block; Block X Sequence and Condition X Sequence X Block), did not include the Group variable. All groups reacted in the same manner to Conditions, Sequences and Blocks. Due to the random generation of the stimulus sequence, not all sections would produce equal time demands on the subjects decisions and responses. Also, since the order of letter presentations were randomly generated as well, it is possible that they occurred both in sequences facilitating detection and sequences interfering with detection.

It is therefore possible that reaction times would mimic the rate or sequence of stimulus presentations. In some sections of the sequence subjects would have more time to make the response without being distracted by other stimuli. Conversely, where stimulus presentation was more rapid the subject would be forced to respond more quickly. A similar effect for RTs may occur in reponse to the ordering of alphabetic stimuli. It is possible that certain sequences of letter presentations may produce priming effects whereas other combinations may produce interference effects.

If changes in RT are due to the parameters of the stimulus sequence, consistent changes in RT would be found for all groups. The lack of a Group interaction supports the idea that the patterns observed in Condition X Sequence X Block interaction and the three first order interactions, reflect the underlying randomness of stimuli presentations.

<u>Omission Errors.</u>

Omission errors are defined as attended target letters which failed to elicit a subjects response. A main effect of Condition showed that as conditions became increasingly difficult the accuracy decreased, producing an increase in omission errors. Past research finds that MR subjects tend to respond on the basis of less information than nonretarded subjects (Nettlebeck et al., 1980). It is therefore unlikely that these subjects made more omission errors due to a difference in response strategy such that they required more certainty before responding. Rather it is suggested that the Condition X Group interaction is better explained by a decrease in attentional capacity and selective allocation of attention this capacity.

Insertion Errors.

Insertion errors occur when subjects respond to a backward letter or make a response which does not appear to be related to a target letter presentation. There was a significant difference in the incidence of insertion errors between groups. The MR and MA groups both made significantly more insertion errors than the CA group. It is suggested that these errors reflect a lack of selectivity with respect to the criterion used to the categorize stimuli as letters. Some of the backward letter sounds did resemble phonetic sounds of letters. Examples on some phonetic sounds which were present on the stimulus tapes were eh, ah and ees. These were often interpreted by MR and MA subjects as E, A, and S respectively.

It is argued that the high incidence of insertion errors is due to less selective criterion as opposed to decreased familiarity or automaticity in detecting the letters. This argument is made in light of the evidence that target letters were detected at the same rate for a simple recognition (ie. Location Condition) as when detected from among backward letters (ie. Meaning and Both Conditions). The fact that the speed of detection did not change when the letters were to be distinguished from backward stimuli indicates that this detection occurred with an automaticity equal to that of simple letter recognition.

Instead, the MR and MA subjects appear to have a more general or varied letter acceptance criterion. Several studies support the idea that MR subjects are more willing to make a discrimination response based on less information that higher IQ subjects (Lally & Nettlebeck, 1977; Nettlebeck & Lally, 1976; Nettlebeck & Lally, 1979; Nettlebeck, Kirby, Hames & Bills, 1980).

There were significantly more insertion errors in the Meaning Condition than either the Location or Both Conditions. There were very few errors in the Location Condition which would be expected as there were no nonletter stimuli presented.

The greatest number of insertion errors occurred in the Meaning Condition. It is here that subjects were specifically asked to detect letter sounds from nonletter speech sounds. Since the subjects expectations were geared toward "letter" detection it appears that the criterion which subjects set was lower, making them prone to false positive identifications.

When time demands were increased under the Both Conditions further taxing the subjects response system, these errors decreased. It appears that time demands raised the criterion of a positive identification, decreasing the number of false positive identifications. This is consistent with past evidence of decreased selectivity of response for MR and MA groups

(Nettlebeck, et al., 1980). It therefore appears that when time demands increased the subjects could no longer afford the broad criterion and were forced to respond only to those stimuli of which they were most certain.

Substitution Errors.

These errors occur when a subject correctly responds to a letter target but misresponds to it as another similar sounding or accoustically similar letter. Before a response was classified as a substitution error, two independent observers agreed that it was the subject who misperceived the stimulus and not the researcher misperceiving the subject's verbal response. If only one observer found the response to be incorrect judgement was made in favour of the subject and the response was considered correct.

A Group main effect showed MR and MA subjects produced more substitution errors than CA subjects. This group difference is most likey related either to immature perception or production of alphabetic stimuli. There was no significant difference between the MR and MA groups.

Two interactions were found for the substitution error analysis (Conditions X Sequence and the Condition X Sequence X Block). Block A of Sequence One in the Location Condition showed a greater number of errors that combinations of remaining Blocks and Sequences in the remaining Conditions.

In Sequence One of the Location Condition, it does not appear that targets in Block A are any closer together in time, nor are they potentially more confusable. Therefore it is concluded that the high incidence of substitution errors is due to unfamiliarity with the stimuli. Block A of Sequence One of the Location Condition is the first minute of tape to which the subjects are exposed. Previous exposure of MR and MA subjects to the stimuli was limited to the short practice trials held one week previously. The CA subjects had no prior exposure. These errors may therefore reflect the subjects unfamiliarity with the sound of the letters. As they were presented with more stimuli and became familiar with the sounds of each sequence, the incidence of substitution errors for all groups decreased.

Exchange Errors.

Exchange errors appear to be the category of errors that most reflect the subjects' ability to efficiently allocate attention. These errors occur when a subject identifies a nonattended target. They are a clear indication that the subject was processing and therefore paying attention to a stimulus they were instructed to ignore.

There were three first order interactions: Condition X Sequence; Condition X Block and Sequence X Block. In the Condition X Sequence and the Condition X Block interactions more errors were made in the Both Condition than the Location Condition. The greater occurrence of exchange errors for the Both Condition was supported by the the Condition main effect which approached significance (p,.053).

Interestingly it appears that significantly fewer errors were made at the beginning of a session (Sequence One) and at the beginning of a Sequence (Block A), in the Location Condition, while the opposite appeared to hold for the Both Condition. This could be interpreted as evidence that attention wanders during a relatively easy task (Location Condition) where a more difficult task (Both Condition) appears to remain constant or to improve. This hypothesis is supported by evidence that it is easier to maintain attention to one spatial location when the overall stimulus presentation rate is greatest (Harvey & Treisman, 1973; Hillyard, Hink, Schwent & Picton, 1973; Treisman, 1964).

The large effect of increased exchange errors with MR and MA groups taken with the increase in omission errors between the Meaning and Both Conditions are strong evidence that the developmentally delayed groups show deficits in the allocation of attention.

Conclusion

The most robust finding of this study was a significant difference between the CA group and the MR and MA groups. No significant difference was found between MR and MA groups. This supports the idea that attention deficits are closely tied to developmental level, supporting the Developmental Delay orientation to mental retardation. Present evidence does not suggest that MR subjects show a greater deficit in attentional allocation and capacity over and above deficits due to developmental immaturity.

Given that CA groups reached a ceiling effect it is not possilbe to determine if their performance was the result of more capacity, better allocation or a more efficient strategy. However, within the MR and MA groups it is possible to bake some observations based on their performance over the three conditions. The MR and MA groups consistently showed a significantly greater number of omission errors, and also decreasing accuracy over the Location, Meaning and Both Conditions respectively. No differences in RTs were found across these conditions. It is therefore concluded that it is the increasing time demands across the Location, Meaning and Both Conditions respectively which appear to produce the deficit in subjects accuracy.

Based on this evidence and given that motivation factors remained constant across conditions, it is suggested that performance deficit in MR and MA subjects are due to a more limited attentional capacity. Thus, as time demands are increased (Meaning Condition) and the processing of information is forced to occur concurrently, the subjects' limited capacity is exceeded and consequently the processing of some stimuli is omitted. Also, even when the total number of target detections are accounted for (number of correct targets plus number of exchange errors), the MR and MA subjects are still processing significantly less than the CA subjects. It is therefore concluded that the decreased accuracy of MR and MA subjects stems from a more limited attentional capacity.

Finally, the significant reduction in accuracy between the Meaning and Both Conditions and the greater number of exchange errors for MR and MA groups provide strong evidence for an inefficient ability to allocate attention. Developmentally immature subjects were influenced by the increased time constraints in the Both Condition indicating that the nonattended information was gaining access to their limited attentional capacity. Furthermore, stimuli in the nonattended channel were actually being processed to a stage where they evoked a response. These exchange errors occur with (Both Condition) and without (Location Condition) time constraints indicating that developmentally immature populations exhibit clear deficits in allocating attention.

The similarity of perfomance between MR and MA subjects was quite striking, suggesting that the attention deficits observed in this study are related to the developmental level of subjects. This finding suggests that while MA subjects will improve performance with maturation alone, MR subjects will not. Additional training would appear necessary to improve the performance of MR subjects. In light of the evidence provided in this study, it would be recommended that remedial work aimed at improving attention in MR subjects should concentrate on strategies designed to improve attentional allocation.

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APPENDIX A

Medication

DRUG	CLASSIFICATION	SIDE EFFECTS
Depakene	Anticonvulsant	Nausia, Vomiting, Indigestion, Diarrhea, Anorexia, Ataxia, Headaches, Nystagmus, Tremour dysarthria, Dizzyness.
Dilantin	Anticonvulsant	Nystagmus, Ataxia, Lethargy, Slurred speech, Confustion, Dizzyness, Twitching, Headaches.
Stelazine	Antianxiety	Motor disorders, Agitation, Oversedation, Parkinsonism.
Tegratol	Antianxiety	Drowsyness, Dizzyness, Decreased coordination, Slurred Speech, Nausia, Depression, Agitation, Blurred vision, headaches, Talkitiveness.
Trifluorazine	Antianxiety	Motor disorders, Agitation, Oversedation, Parkinsonism.

APPENDIX B

Pretest Scores for the MR and MA Groups

Table 1

Pretest Scores for the MA Subjects

GROUP	GENDER	SUBJECT	PRETEST CRITERIA		
			EAR	LETTERS	MEANING
		01	0	4	4
		02	0	4	4
		03	0	4	4
	M	04	0	4	4
MA	A	05	0	5	5
	L	06	0	3	0
	E	07	0	6	7
		08	0	3	0
		09	0	2	5
		10	0	4	3
		11	0	3	4
		12	0	5	9
	F	13	0	5	4
	E	14	0	1	1
MA	M	15	0	0	4
	A	16	0	4	3
	L	17	0	6	5
	E	18	0	5	4
		19	0	3	3
		20	0	2	0

Table 2

Pretest Scores for MR subjects

GROUP	GENDER	SUBJECT	PRETEST CRITERIA		
			EAR	LETTERS	MEANING
		01	1	3	1
		02	0	2	10
		03	2	0	3
	M	04	0	4	5
MR	A	05	0	1	2
	L	06	0	1	2
	E	07	0	4	3
		08	2	3	6
		09	0	2	4
		11	0	4	3
		12	0	5	8
	F	13	6	3	0
	E	34	0	3	3
MR	M	15	0	0	3
	A	16	0	4	6
	L	17	0	3	6
	E	18	3	6	8
		19	0	4	5

APPENDIX C

Forward and Backward Letters

Forward Letters	Backward Letters
A	A
B	B
D	D
E	-
G	G
I	I
J	J
K	K
L	L
M	M
N	N
O	O
Q	Q
R	R
T	T
U	U
Y	-
Z	-

APPENDIX D

Instructions to Subjects

Note: For the MR and MA subjects the ear to which they were assigned to listen to was said verbally and also pointed to, in order to ensure that the subjects were listening to the correct ear.

Instructions to Subjects

LOCATION CONDITION:

You will now hear a series of letters. You will hear some of the letters in your right ear and some in your left ear. I would like you to repeat any letters which you hear in your [right/left] ear. Say the letter as soon as you hear it.

MEANING CONDITION:

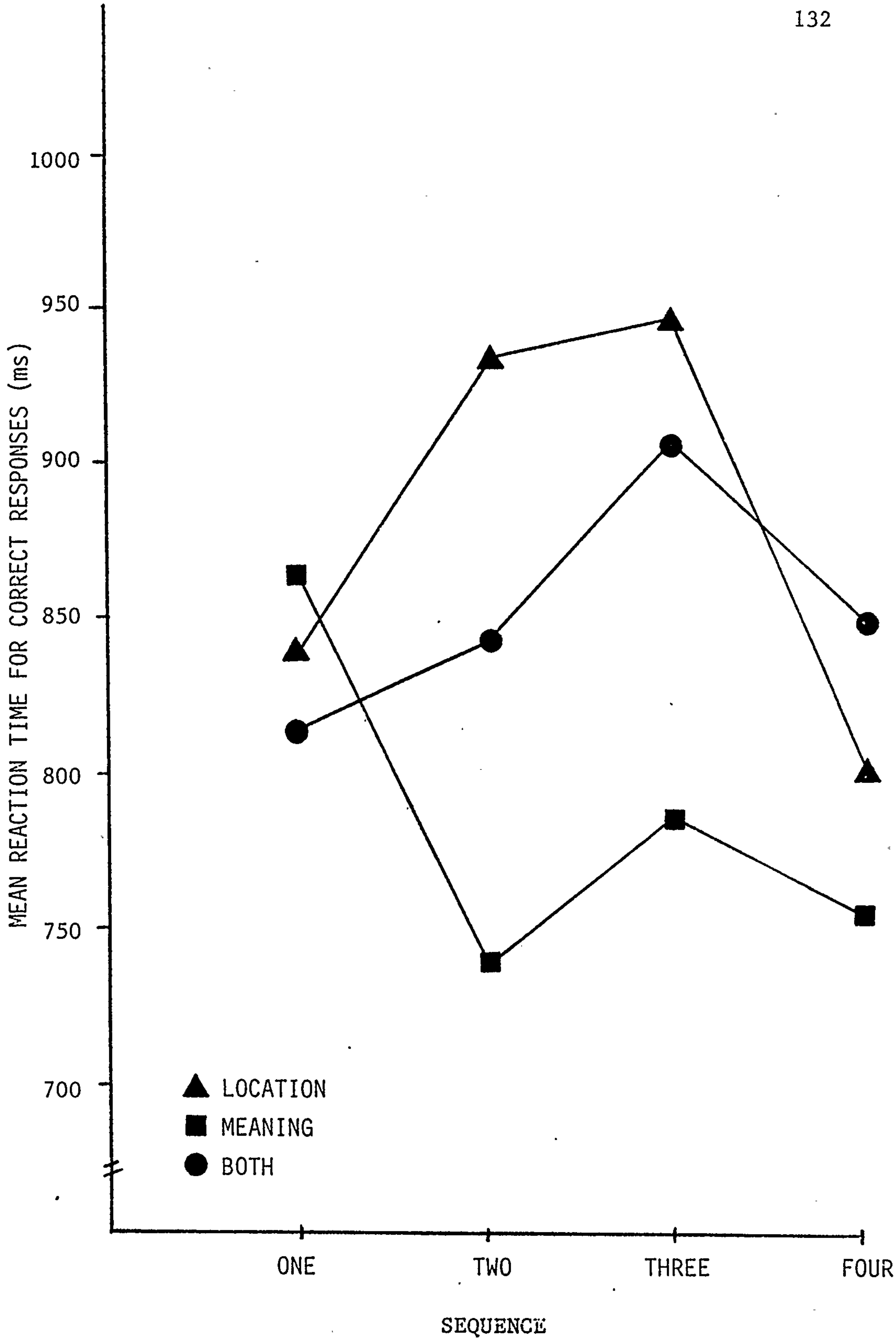
You will now hear a series of sounds. Some of the sounds will be letters from the alphabet, for instance A-B-C-D. Some of the letters will be said backwards. They will be strange sounds which you have probably not heard before. I would like you to repeat the sounds which are letters from the alphabet. Do not repeat any of the backward letters. Say the alphabet letters as soon as you hear them. All of the sounds will be played to your [right/left] ear.

BOTH CONDITION:

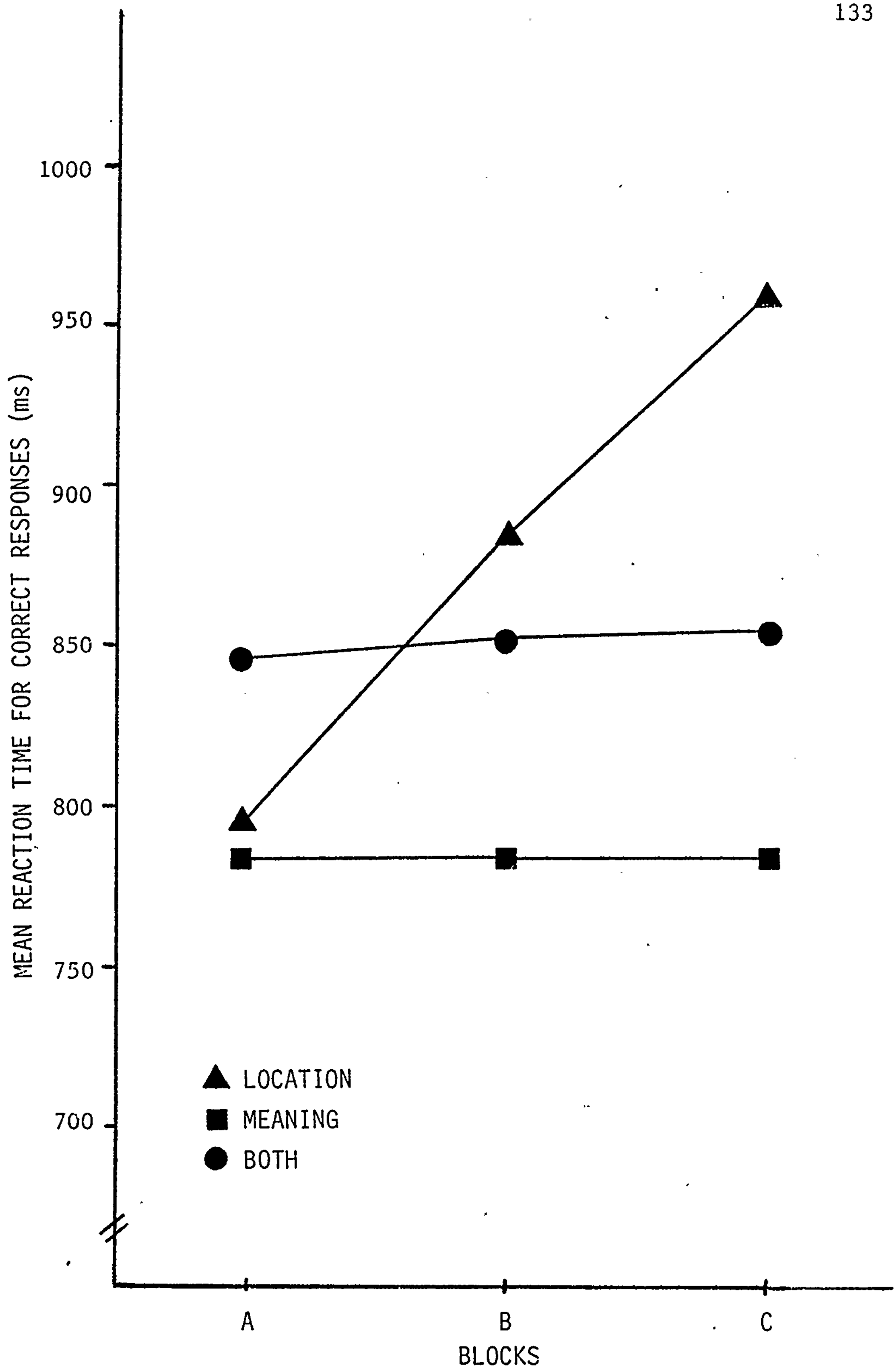
Do you remember the tape from last time? Today you will be listening to the same sounds, but this time you will hear the sounds in both ears. Some of the sounds will be letters from the alphabet. Some of the letters will be said backwards. They will be strange sounds which you have probably not heard before. I would like you to repeat the sounds which are letters of the alphabet. But, only repeat the letters which you hear in your [right/left] ear. Do not repeat any of the backward letters. Say the alphabet letters as soon as you hear them. Remember only say the letters which you hear in your [right/left] ear.

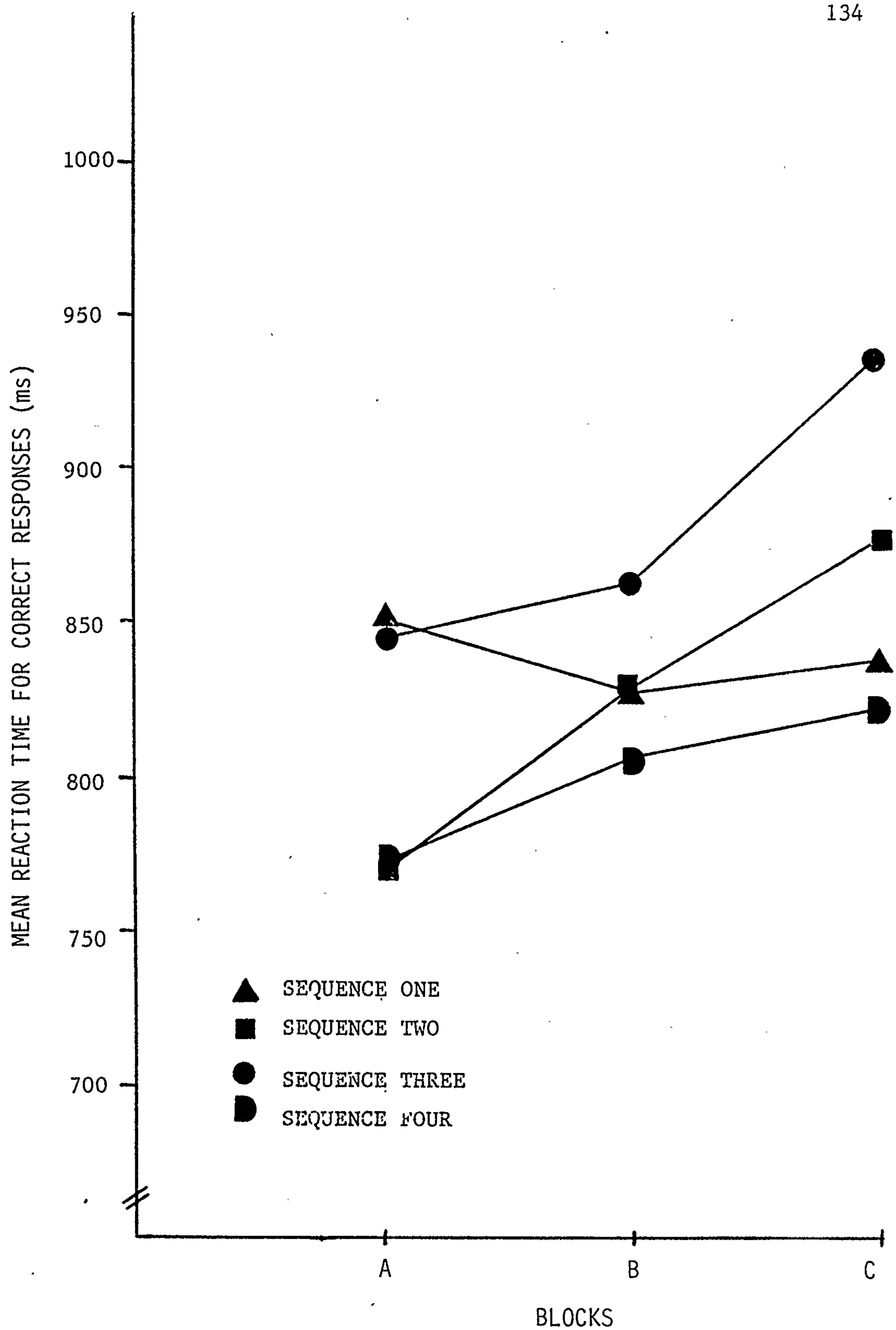
APPENDIX E

First Order Interactions for Reaction Times to Correct Responses



1000
950
900
850
800
750
700
MEAN REACTION TIME FOR CORRECT RESPONSES (ms)
LOCATION
MEANING
BOTH
ONE
TWO
THREE
FOUR
SEQUENCE


MEAN REACTION TIME FOR CORRECT RESPONSES (ms)
1000
950
900
850
800
750
700
LOCATION
MEANING
BOTH
A
B
C
BLOCKS



MEAN REACTION TIME FOR CORRECT RESPONSES (ms)
1000
950
900
850
800
750
700
SEQUENCE ONE
SEQUENCE TWO
SEQUENCE THREE
SEQUENCE FOUR
A
B
C
BLOCKS

APPFNDIX F

Analysis of Variance Source Tables

Table I

Analysis of Variance Source Table for the Number of Correct Responses

SOURCE	SS	DF	F	P
GROUP	3201.93	2	31.07	0.0001
SEX	471.48	1	9.15	0.0004
G X S	188.89	2	3.67	0.0330
ERROR	2473.33	48		
CONDITION	1664.77	2	63.87	0.0001
C X G	789.35	4	15.14	0.0001
C X S	11.17	2	0.43	0.6394
C X G X S	91.27	4	1.75	0.1499
ERROR	1251.12	96		
SEQUENCE	27.03	3	3.25	0.0256
Sq X G	49.61	6	2.98	0.0101
Sq X S	13.98	3	1.68	0.1765
Sq X G X S	34.91	6	2.10	0.0602
ERROR	399.77	144		
C X Sq	22.05	2	1.42	0.2320
C X Sq X G	36.72	12	1.18	0.3146
C X Sq X S	12.97	6	0.83	0.5000
C X Sq X G X S	15.21	12	0.49	0.8545
ERROR	746.78	288		
BLOCK	24.19	2	5.60	0.0071
B X G	29.71	4	3.44	0.0152
B X S	0.06	2	0.01	0.9775
B X G X S	9.33	4	1.08	0.3682
ERROR	207.54	96		
C X B	6.46	4	0.76	0.5313
C X B X G	32.88	8	1.93	0.0729
C X B X S	15.69	4	1.84	0.1366
C X B X G X S	18.23	8	1.07	0.3856
ERROR	409.70	192		
Sq X B	13.24	6	1.50	0.1897
Sq X B X G	22.88	12	1.30	0.2327
Sq x B X S	5.36	6	0.61	0.6973
Sq X B X G X S	17.79	12	1.01	0.4385
ERROR	423.94	288		
C X Sq X B	49.77	12	2.44	0.0194
C X Sq X B X G	66.06	24	1.62	0.0734
C X Sq X B X S	39.23	12	1.92	0.0657
C X Sq X B X G X S	64.41	24	1.58	0.0846
ERROR	980.32	576		

Table 2

Analysis of Variance Source Table for Reaction Time to Correct Responses

SOURCE	SS	DF	F	P
GRCUP	173094.34	2	11.88	0.0001
ERROR	276954.06	38		
CONDITION	2829.96	2	0.98	0.3752
C X G	12029.88	4	2.07	0.0995
ERROR	110194.69	76		
TRIAL	8921.56	3	5.16	0.0055
T X G	1182.43	6	0.34	0.8715
ERROR	65738.71	114		
C X T	38677.07	6	9.09	0.0001
C X T X G	5848.27	12	0.69	0.7148
ERROR	161738.24	228		
BLOCK	11154.61	2	18.16	0.0001
B X G	1727.65	4	1.41	0.2434
ERROR	23336.59	76		
C X B	13946.83	4	12.48	0.0001
C X B X G	1318.62	8	0.59	0.7732
ERROR	42456.39	152		
T X B	8133.08	6	4.32	0.0011
T X B X G	5980.25	12	1.59	0.1150
ERROR	71594.64	228		
C X T X B	20566.28	12	4.53	0.0001
C X T X B X G	7395.44	24	0.81	0.6566
ERROR	172660.60	456		

Table 3

Analysis of Variance Source Table for the Number of Omission Errors

SOURCE	SS	DF	F	P
GROUP	3201.93	2	31.07	0.0001
SEX	471.48	1	9.15	0.0040
G X S	377.78	2	3.67	0.0330
ERROR	2473.33	48		
CONDITION	1664.77	2	63.87	0.0001
C X G	789.35	4	15.14	0.0001
C X S	11.17	2	0.43	0.6394
C X G X S	91.27	4	1.75	0.1499
ERROR	1251.12	96		
SEQUENCE	27.03	3	3.25	0.0256
Sq X G	49.61	6	2.98	0.0101
Sq X S	13.98	3	1.68	0.1765
Sq X G X S	34.91	6	2.10	0.0602
ERROR	399.77	144		
C X Sq	22.05	6	1.42	0.2320
C X Sq X G	36.72	12	1.18	0.3146
C X Sq X S	12.97	6	0.83	0.5000
C X Sq X G X S	15.21	12	0.49	0.8545
ERROR	746.72	288		
BLOCK	24.19	2	5.60	0.0071
B X G	29.71	4	3.44	0.0152
B X S	0.06	2	0.01	0.9775
B X G X S	9.33	4	1.08	0.3682
ERROR	207.54	96		
C X B	6.46	4	0.76	0.5313
C X B X G	32.89	8	1.93	0.0729
C X B X S	15.70	4	1.84	0.1366
C X B X G X S	18.23	8	1.07	0.3856
ERROR	409.71	192		
Sq X B	13.24	6	1.50	0.1897
Sq X B X G	22.88	12	1.30	0.2327
Sq X B X S	5.36	6	0.61	0.6973
Sq X B X G X S	17.79	12	1.01	0.4385
ERROR	423.94	288		
C X Sq X B	49.77	12	2.44	0.0194
C X Sq X B X G	66.07	24	1.62	0.0734
C X Sq X B X S	30.30	12	1.92	0.0657
C X Sq X B X G X S	64.60	24	1.58	0.0846
ERROR	980.33	576		

Table 4

Analysis of Variance Source Table for the Number of Insertion Errors

SOURCE	SS	DF	F	P
GROUP	122.29	2	5.61	0.0063
ERROR	545.01	50		
CONDITION	290.49	2	19.25	0.0001
C X G	97.42	4	3.23	0.0314
ERROR	754.41	100		
SEQUENCE	7.60	3	2.71	0.0641
Sq X G	17.91	6	3.16	0.0132
ERROR	141.85	150		
C X Sq	14.68	6	2.75	0.0588
C X Sq X G	29.23	12	2.74	0.0245
ERROR	266.79	300		
BLOCK	2.67	2	2.26	0.1195
B X G	2.75	4	1.16	0.3311
ERROR	59.23	100		
C X B	7.85	4	3.22	0.0405
C X B X G	6.19	8	1.27	0.2852
ERROR	121.91	200		
Sq X B	9.75	6	2.46	0.0552
Sq X B X G	18.20	12	2.30	0.0290
ERROR	197.66			
C X Sq X B	12.85	12	1.78	0.1317
C X Sq X B X G	34.45	24	2.39	0.0166
ERROR	360.05	600		

Table 5

Analysis of Variance Source Table for the Number of Substitution Errors

SOURCE	SS	DF	F	P
GROUP	105.74	2	14.60	0.0001
ERROR	181.11	50		
CONDITION	4.72	2	3.36	0.0386
C X G	1.63	4	0.58	0.6522
ERROR	70.17	100		
SEQUENCE	3.36	3	2.48	0.0720
Sq X G	3.36	6	1.24	0.2926
ERROR	67.71	150		
C X Sq	12.58	6	4.90	0.0003
C X Sq X G	6.02	12	1.17	0.3100
ERROR	128.27	300		
BLOCK	0.11	2	0.28	0.7209
B X G	0.82	4	1.03	0.3905
ERROR	19.86	100		
C X B	2.31	4	1.82	0.1380
C X B X G	2.11	8	0.83	0.5632
ERROR	63.73	200		
Sq X B	1.06	6	0.54	0.7433
Sq X B X G	4.18	12	1.06	0.3919
ERROR	98.36	300		
C X Sq X B	10.42	12	2.59	0.0092
C X Sq X B X G	16.04	24	2.00	0.0126
ERROR	201.10	600		

Table 6

Analysis of Variance Source Table for Number of Exchange Errors

SOURCE	SS	DF	F	P
GROUP	1173.35	2	13.24	0.0001
ERROR	2259.23	51		
CONDITION	46.38	1	3.89	0.0539
C X G	54.16	2	2.27	0.1134
ERROR	607.77	51		
SEQUENCE	13.94	3	1.11	0.3441
Sq X G	11.36	6	0.45	0.8350
ERROR	637.97	153		
C X Sq	51.49	3	4.94	0.0074
C X Sq X G	21.56	6	1.03	0.3959
ERROR	531.49	153		
BLOCK	23.70	2	4.28	0.0249
B X G	14.10	4	1.27	0.2896
ERROR	282.66	102		
C X B	39.79	2	6.17	0.0065
C X B X G	35.34	4	2.27	0.0477
ERROR	328.66	102		
Sq X B	50.55	6	3.62	0.0070
Sq X B X G	48.59	12	1.74	0.0904
ERROR	712.02	306		
C X Sq X B	21.32	6	1.83	0.1115
C X Sq X B X G	28.66	12	1.23	0.2754
ERROR	594.87	306		