A DEVELOPMENTAL STUDY OF THE UNDERLYING MECHANISMS OF AUDITORY SELECTIVE ATTENTION

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CHAPTER I

STATEMENT OF THE PROBLEM

Developmental research has placed particular emphasis on determining whether children respond less to irrelevant stimuli as they grow older. The most common way in which the developmental aspects of attention have been studied involves the introduction of irrelevant stimuli into an experimental task. Performance is then monitored in order to determine how well a subject can attend to the central task in the presence of this extraneous stimulation (Lane & Pearson, 1982). A variety of experimental paradigms which incorporate this approach have been employed to address questions in attention development.

A problem with this area of research is that the majority of the emphasis has been placed on determining the existence of the developmental difference, that is a decrease in responding to irrelevant stimuli with age. Consequently, the research has not focused on the mechanisms underlying this developmental difference in selective attention. In a review of the literature, Lane and Pearson (1982) demonstrated that even across various paradigms this developmental difference is found. However, the basis for mechanism(s) underlying this difference is still unclear. Lane and Pearson proposed three possible stages at which the interference may be occurring: 1) encoding, 2) stimulus selection (i.e., attending to the proper channel such that relevant stimuli may be selected), and

3) response selection. The present study attempted to investigate the manner in which irrelevant stimuli cause interference at different developmental levels while focusing on stimulus selection and response selection.

CHAPTER II

LITERATURE REVIEW

Developmental Changes In Childhood

Cognitive developmentalists have recognized that during certain periods of childhood, children experience developmental changes which enable them to perform at an increased level. Piaget proposed that there were four such stages of cognitive development: sensory-motor, preoperations, concrete operations, and formal operations (Piaget, 1970). During the transition from preoperations to concrete operations many changes have been noted particularly in children between the ages of five and seven years (White, 1970). Most importantly, children attain abilities enabling them to perform tasks which they will encounter in school. Among these changes is an increase in attentional abilities. The following review will demonstrate changes which occur between the ages of five and seven, as well as discuss the state of the developmental selective attention literature.

Cognitive Changes

Cognitive advances between the ages of five and seven years have also been well documented (Piaget, 1970; Flavell, 1982; Fischer & Silvern, 1985). Children show an ability to solve problems which they could not solve previously. For instance, it is during this time that children attain the abilities necessary to correctly solve Piagetian tasks of conservation, such as conservation of liquid (testing knowledge that liquid amounts are unaffected by the size or shape of the container), conservation of weight (testing knowledge that weight is unaffected by changing the physical shape of material), and conservation of number (testing knowledge that number is unaffected by spreading out objects or massing them together). Another such skill attained during this time is classification, which is the ability to divide things into different sets and subsets and to consider their interrelationships (Fischer, 1980). Although these abilities do not appear in synchrony, it is between the ages of five and seven that we see the transition and broadening of these skills.

Changes in Brain Functioning

In addition to the cognitive changes mentioned above, children also experience periods in which changes in the functioning of the brain occur. These changes have been found to parallel the cognitive developmental stages of childhood as described by Piaget (Fischer & Pipp, 1984; White, 1970). Developmental researchers have used the electroencephalogram (EEG) to obtain a fuller understanding of and more direct access to the functioning of the human brain (Hillyard & Hansen, 1986). Matousek and Peterson (1973) collected EEG data on subjects ranging in age from 1 - 21 years in a quiet and awake state. The authors did not analyze their data to test for relations with developmental level; however, Fischer (1987) reanalyzed Matousek and Peterson's data with this goal in mind. The results indicated that relative energy in alpha waves in the occipital-parietal area was consistently related to the ages of onset of cognitive development levels. The discontinuities occurred in the alpha growth curve at approximately 4, 8, 12, and 15 years of age. (Fischer et al., 1984). These findings suggest that there are measurable changes (by EEG) in brain functioning that coincide with the cognitive developmental levels (i.e. preoperations 3-7; concrete operations, 7-11; and formal operations, 11-15) proposed by Piaget (1970). Similarly, Thatcher (1991) has found that shifts in the coherence of the EEG -- that is, the degree to which different areas of the brain are in functional synchrony -- also correspond to major cognitive developmental changes.

Epstein (1980) found that between the ages of five and seven years, a period of brain growth occurs. This growth is reflected in changes in brain wave patterns which show a sharp increase to a higher frequency. Other changes in the brain's electrical activity have also been documented (Milner, 1967). The results indicated that the amplitude of visual evoked potentials, elicited by delivery of a flash of light to the eye, increases through the age of six. After this time, the increase tapers off as amplitude becomes more consistent with adult levels.

It needs to be restated that these brain changes parallel the psychological changes. The causal relationship between brain changes and cognitive development are not clear. It is not known whether changes in the brain functioning causes changes in cognitive development or if the reverse is true.

These studies illustrate the biological and psychological developments which signal major developmental changes. This cluster of phenomena is called the 5 - 7 shift reflecting the age at which it occurs (White, 1970). Changes during the 5 -7 shift are not restricted to such areas as problem solving abilities; it has been shown that an increase in attentional abilities also occurs during the 5 - 7 shift (see Lane & Pearson, 1982 for review; Odom, 1982). The increase in abilities peaks and maintains at this level until the next major transitional period which occurs around the time of onset of formal operations (i.e., puberty).

Attentional Changes

One of the most profound changes in the development of the child is improvement in the ability to selectively respond to task-relevant attributes of a stimulus (Day, 1975; Enns & Cameron, 1987; Gibson, 1969; Hagen & Hale, 1973; Lane & Pearson, 1982). However, the basis for this developmental difference is still unclear. A review of the developmental literature on selective attention conducted by Lane and Pearson (1982) indicated that future research should begin to :

investigate more thoroughly, the mechanisms underlying the developmental differences in performance. For instance, do irrelevant stimuli interfere with encoding, the selection of stimuli into a limited-capacity system, or response selections? (p. 334).

Review of the literature demonstrates that the specific mechanisms outlined by Lane and Pearson have been repeatedly implicated by developmental studies. However, these mechanisms have not been directly investigated in relation to auditory processing.

The present study will address the issues of selection of stimuli and response selection in the domain of auditory selective attention. The proposed paradigm for the present study is an auditory paradigm in which stimuli are presented at a fairly rapid pace and their presentation is nearly simultaneous to both ears. Consequently, encoding demands are minimized and as such will not be investigated in the present study. However, throughout the following review of the literature every attempt will be made to categorize the literature according to the stages at which distraction may interfere (i.e., encoding, stimulus selection, and response selection).

Research Investigating Selective Attention

Studies which have investigated developmental aspects of selective attention have typically utilized tasks such as same/different judgements, speeded classification, and selective listening (Anooshian & McCulloch, 1978; Cherry, 1981; Lane & Pearson, 1982; Maccoby & Konrad, 1966, 1967; Pick, Frankel & Hess 1975). A brief description of the tasks required by these paradigms follows. The same/different paradigm generally requires subjects to make judgments about figures which vary in some dimension such as size, shape, or color. The ability to selectively attend is measured by how well the subjects are able to restrict their responses to the relevant dimension. This task requires subjects to encode stimuli into memory in order to perform the task. Speeded classification tasks require a subject to classify stimuli according to a prespecified dimension as rapidly as possible without making errors. Ability to selectively attend is measured by the rate at which a subject can accurately sort. This paradigm also relies on the encoding of information into short-term memory in order to perform the task. Selective listening tasks are somewhat varied in what is expected of the subject. Generally, these tasks involve the presentation of auditory stimuli and subjects are required to respond to, or later report, what the relevant stimuli were. Selective listening tasks generally minimize encoding processes and do not assess the encoding of stimuli into memory due to the simultaneous presentation of stimuli and the quick pace of presentation.

Research Which Implicates Encoding

Encoding is generally referred to as the process in which a stimulus is coded for placement into memory such that it can be used at a later time. Encoding may involve the use of strategies which serve to facilitate the entry of stimuli into short-term memory.

Various studies have implicated the stage of encoding as one in which interference from irrelevant stimuli may affect younger children. Encoding was implicated in a study conducted by Shepp and Swartz (1976), who investigated the possibility that young children's difficulties in ignoring irrelevant stimuli are derived partially from their tendency to encode multidimensional stimuli holistically rather than dimensionally. In two experiments, 6- and 9- year-olds performed a task in which subjects were required to sort cards into two piles as quickly as possible. Cards were sorted based on stimuli with either integral or nonintegral (separable) dimensions. Integral and nonintegral stimuli were presented on line drawings of a house and were located on the door of the house. Integral dimensions were hue and brightness of the door. The nonintegral stimuli were color of the door (Hue - red/orange or Brightness - light/dark) and the shape of the door window (square and circle) placed in the upper third of the door. The speeded sorting task was modeled after that of Garner and Felfoldy (1970) used in an experiment with adults. As with adults, in the Garner and Felfoldy study, subjects in the Shepp and Swartz study sorted based on three types of stimulus sets 1) single dimension - one dimension varied in its two designated values while the second was absent or constant, 2) correlated dimensions - one value on one dimension was consistently paired with one value on the other, and 3) orthogonal dimensions - both values of one dimension were paired with each value of the other. In the task of correlated dimensions the value of the target dimension (X) and the constant dimension (Y) are redundant such that X1Y1 are sorted into one pile and X2Y2 in the other. Further, in the task of orthogonal dimensions Y1 and Y2 are paired equally often with X1 and X2 such that X1Y1 and X1Y2 are placed in one pile, while X2Y2 and X2Y1 are placed in the other.

Results of the first experiment for the integral condition indicated that, 9-year-olds sorted faster than 6-year-olds. Single dimension sorts and correlated dimension sorts required less time than orthogonal sorts. Both groups sorted integral stimuli much like adults from Garner and Felfoldy (1970). Performance suggested age related differences in perceived structure and selective attention.

For all conditions of the nonintegral (separable) task the 9-year-olds sorted faster than the 6-year-olds. With the 9-year-olds, sorting times did not differ between dimensions nor on stimulus set. Performance of the 9-year-olds was again similar to adults. However, the 6-year-olds sorted separable stimuli as if they were integral. As expected, the 6-year-olds also experienced difficulty with the orthogonal dimension task. The authors were left with the question of whether the performance of the 6-year-olds indicated that they perceive nonintegral dimensions as integral or if they analyzed nonintegral dimensions but failed to attend selectively.

The second experiment attempted to address the question on nonintegral dimensions by employing the same stimuli, task and procedure of experiment one. However, the only condition involved was that of nonintegral dimensions. Performance of the 9-year-olds mirrored performance in experiment one and 6-year-old performance was somewhat mixed. Results indicated that, as in experiment one, 9-year-olds sorted more quickly than the 6-year olds with the 6-year-olds demonstrating consistently faster sorting times on the correlated-dimensions tasks and reliably slower times on orthogonal dimension tasks as compared to one dimension tasks.

Results from both experiments taken together demonstrate that children's sorting patterns of integral stimuli resembled those of adults. With the separable dimension, 9-year-old's performance was again similar to that of the adults. The 6-year-olds, when asked to sort the separable stimuli, appeared to do better with correlated dimensions and had greater difficulty and interference of attention with orthogonal dimensions. Based on the results, Shepp and Swartz (1976) proposed that the developmental differences found between older and younger children may be due to the way younger children perceive nonintegral stimuli. The authors suggested that younger children perceive nonintegral stimuli in much the same way as adults would see integral stimuli. Therefore, young children's inability to avoid distraction by irrelevant stimuli may not be the result of a decreased ability to screen out unwanted information but rather a developmental change in the way dimensions are perceived and encoded, at least when complex multidimensional stimuli are used.

Shepp, Barrett, and Kolbert (1987) also attempted to assess the developmental difference in children's ability to respond less to distraction as age increases. This study also indicated that interference from irrelevant stimuli may occur at the stage of encoding. A speeded sorting task was administered to children in two experiments to assess children's ability to perceive stimuli as separable or integral. Three types of decks were employed. Children age 5, 7, and 11 years were instructed to sort cards into two piles as quickly as possible based on values on one dimension while the values of a second irrelevant dimension were held constant, were correlated with values on the target dimension, or presented values that were varied orthogonally. For this experiment dimensions were illustrated on cards as a circle with lines in the outer ring and a pointer placed in the middle. Dimensions consisted of 1) the number of lines in the outer ring (10 vs. 15), 2) the orientation of the pointers (330 degrees vs. 30 degrees) and 3) the color of the inner configuration (red vs. red-orange). Spatially separate dimensions were designated as the number of lines in the outer ring vs. the color of disc (pointer was removed). The spatially integral dimensions were color vs. angle of pointer (which was located inside a circle).

For the spatially integrated dimensions, a comparison of sorting times for correlated values of color vs. angle with times for single dimensions indicated improvement in sorting times for the 5-year-old in the correlated dimension sort, but only minimal improvement for 7- and 11-year-olds. These results suggested that with spatially integrated dimensions there is an age trend from holistic perception to featural perception. With the spatially separated dimensions, color vs. number of lines, the speed of sorting on correlated dimensions relative to the sorting on single dimensions showed no improvement at any developmental level thereby indicating that the dimensions were perceptually independent. Results supported the hypothesis that there were developmental differences in perceived structure of spatially integrated and spatially separate dimensions and the encoding of them (i.e. as integral vs. independent features) is due to the age of the subject. Thus, this study implicates the process of encoding stimuli and also provides further support that an increase in attentional abilities occurs between the ages of 5 and 7 years.

A more recent study of visual-spatial selective attention (Enns & Akhtar, 1989) attempted to directly address the issue of underlying mechanisms of attention and the sources of the interference raised by Lane and Pearson (1982). Up to this time, researchers had not investigated these particular mechanisms of attentional changes. Enns and Akhtar had 56 subjects (14 from the age groups 4, 5, and 7 years and adults aged 20 years) perform a simple visual filtering task (speeded classification) to examine five sources of filtering interference in a selective attention task. The five sources of interference investigated by the authors were 1) attentional set - measured the cost of preparing to inhibit distractors, 2) encoding interference number type - measured the interference associated with the simple presence of distractors, 3) encoding interference feature type - measured interference associated with the activation of a larger number of feature detectors, 4) response competition - measured interference of distractors from the same category vs. distractors from a different category, and

5) stimulus generalization - measured the way in which targets were processed. On each trial subjects were asked to respond as quickly and as accurately as possible when the target was identified. Half of the subjects for each age group were instructed to press the left button if the target was a '+' or an 'X' and the right button if the target was a square or a circle and the opposite instructions were given to the other half. The target was always located in the center of the screen and on some trials the target was flanked by distractor stimuli which the subjects were asked to ignore.

Results indicated that subjects of all ages were unable to avoid processing stimuli that flanked a target. With respect to interference, the results showed that the attentional set measure was the largest source of interference for all age groups. This measure also showed the largest relative decrease with age. Only one of two measures of encoding interference, feature number, showed reliable interference in all four age groups.

Results of the study replicated an earlier finding that older subjects were better able to inhibit the processing of distractors than were younger subjects (Akhtar, 1988; Enns & Cameron, 1987; Enns & Girgus, 1985; Wells, Lorch, & Anderson, 1980). Enns and Akhtar (1989) provided further evidence that the mechanisms underlying the developmental differences of selective attention may involve encoding as well as stimulus selection. Response selection was eliminated based on nonsignificant results from the data on response competition.

Research which Implicates Stimulus Selection

Stimulus selection refers to the process of selectively attending to the relevant channel and the target within the channel. This process serves to enhance the opportunity for relevant stimuli to be selected for further processing. Throughout the literature, paradigms used to investigate the development of selective attention have involved attending to relevant stimuli and ignoring irrelevant stimuli. This mechanism of stimulus selection is a common factor in accounting for the developmental differences in the ability to selectively attend. Further, research has indicated that younger children often have more difficulty attending to the relevant stimuli and ignoring the irrelevant stimuli than do older children (Lane & Pearson, 1982; Odom, 1982). While attempting to establish the existence of a developmental difference in children's ability to selectively attend, several studies have implicated the process of stimulus selection.

In one such study, Geffen and Sexton (1978) compared divided and focused attention in the auditory modality in an attempt to study the development of auditory strategies of attention. They studied 24 children aged 7 and 10 years. The subject's task was to monitor a series of auditorily presented word pairs and to press buttons every time the target word was heard. Focused attention involved listening for target words in one ear and ignoring targets in the other ear. Divided attention consisted of listening for target words in both ears. Results indicated that 10-year-olds responded to target words more frequently than did 7-year-olds. Within the focused conditions, the attended input received a higher target detection rate than the unattended input. This difference, which was assumed to reflect the efficiency of selective attention, was greater for 10-year-olds than 7-year-olds. Thus, the authors concluded that in the focused attention condition, selecting one input designated as relevant, improved markedly between 7 and 10-year-olds. Geffen and Sexton monitored stimulus selection and response selection and found that stimulus selection (differences between attended and unattended inputs) improved significantly with age, while response selection (selection of a particular target word) remained constant, thus indicating that stimulus selection may represent an underlying mechanism of selective attention.

Another study which implicated stimulus selection was conducted by Smith, Kemler, and Aronfreed (1975). They investigated the developmental difference in children's ability to respond less to distraction with age using 27 subjects, aged 5, 7, and 10 years. These children were asked to make a series of same/different judgements as to whether or not successive poses of a stick figure were identical. Smith et al. used three types of distraction which varied in level of distinctiveness. All subjects were required to attend to a target stick figure drawn in color under three levels of distraction. The first distractor, which was the most distinct, consisted of tones varying in frequency. The second distractor, consisted of a black stick figure surrounded by a frame. The third distractor, consisted of a second copy of the stick figure in another color and with no frame. Before the experiment began, a baseline measure was taken in order to determine performance level for each condition in the absence of these distractors. Smith et al. compared the performances under the distraction conditions and during the baseline performance. The difference found, demonstrates that for all three distraction conditions, children responded less to distraction with increasing age. The 5-year-olds were most disrupted under all distractor conditions and the two older age groups were most accurate when the distinctiveness of distractors was high. Due to this difference in performance of 5-year-olds and 7- and 10-year-olds under distraction conditions, the authors concluded that 5-year-olds are less able to apply strategies that focus on the relevant stimulus than the two older groups. It appears that encoding is not implicated as a possible mechanism in this study because it was demonstrated that children were able to perform the task and identify poses at varying speeds when distractors were not present. However, the subjects' poorer performance under the distraction conditions suggests that young children may have experienced difficulty separating the incoming information, implicating selection of stimuli and possibly the subsequent process of response selection. The paradigm in this study did not allow for the separation of selection of stimuli and response selection; thus, an independent evaluation of interference which occurred at either of these stages was not conducted.

Further evidence for the developmental difference in selective attention was provided by Day and Stone (1980). Using a same/different paradigm the authors asked 144 subjects to judge whether or not a briefly-presented target picture matched a standard picture. Subjects consisted of 5-year-olds, 8-year-olds and adults (age 22). Two experimental conditions were established: 1) the "set" condition (standard picture presented before the target picture) and, 2) the "no-set" condition (standard picture followed presentation of the target picture). The authors proposed that presentation of the standard picture (for a longer duration than the target picture) before presentation of the target picture would create a momentary set which would help subjects avoid distraction. To examine the effects of irrelevant stimuli, the target was presented either by itself or in the context of "sequential visual noise." The visual noise was irrelevant information which consisted of a series of pictures. The authors likened this noise to "the successive scenes that would fall on the retina as one peered out the window of a moving car while searching for a street sign" (p. 323). When visual noise was used, the target was always the last picture in the rapidly presented series of pictures. Results indicated that both the attentional set condition and the presence of irrelevant stimuli had effects on all age levels, but had greater effects on 5-year-olds as compared to the 8-year-olds and adults.

The authors suggested that the developmental trend toward a resistance to the distracting effects of irrelevant stimuli is really a growing ability to establish and maintain a set. In other words, the data suggested that the establishment of a 'set' may provide older children with a means to select only relevant stimuli and thus enabled them to attend better and more selectively. Along these lines the results also suggested that younger children have difficulty with the process of selection of stimuli. If so, the probability that they will also have difficulty with the consequent process of response selection is increased (subjects may not have the proper input from which they can select a relevant response). In addition, the data do not rule out the possibility that interference may be occurring at the level of encoding for younger children as no measures were taken to address this. Results of this study again indicated that an increase in attentional abilities occurs during the ages of 5 and 7 years.

Research which Implicates Response Selection

A third factor which has been implicated as a possible explanation of the developmental difference in selective attention is response selection. Response selection refers to the process of selecting (and sometimes inhibiting) a behavioral response once a stimulus has been classified as either target or non-target. Response selection was implicated as a possible mechanism by a study which investigated the developmental difference in selective attention in the auditory modality. Maccoby and Konrad (1966) investigated age trends in selective listening using 96 subjects from three age groups of 5-, 7-, and 9-year-old children. Subjects listened twice to 23 pairs of words spoken simultaneously by two speakers, one male and one female. The first time through the list, the subjects were instructed to report what the male voice was saying, and the second time through the list they were to report what the female voice was saying. For each subject the stimulus words were presented on the first occasion binaurally (mixed condition, i.e. the voices of both speakers came to both ears). On the second occasion the words were presented dichotically (split condition, i.e. all of the male words came to one ear, and all the female words to the other ear). Results indicated that skills in selective listening did increase with age as evidenced by correct reports of the repeated word which increased with age, and the decrease in the number of intrusive errors. Reporting words improved from 5-year-olds to 7-year-olds and levelled off. For all ages combined, performance was significantly better under the dichotic condition of presentation.

These results served to establish the developmental difference in the area of auditory selective attention. With respect to the analysis of errors, results indicated that younger childrens' errors tended to involve nonsense responses more often than older children. The older subjects tended to restrict their responses to real English words indicating that younger children were unable to edit their responses as well as older children. The authors thus suggested that response selection may play a role in this developmental difference.

Doyle (1973) presented auditory information binaurally to subjects in an attempt to provide evidence to support the developmental difference in the ability to selectively attend. Subjects aged 8, 11, and 14 participated in three distraction conditions. In two conditions, (DIST-1 and DIST-2) subjects were expected to hear and repeat the target list with distraction from another voice speaking simultaneously. The subjects in the third condition, Non-DIST, heard the target list alone. Subjects were then tested for retention of the target words in a four forced-choice recognition task. Also, subjects who experienced distraction were tested as to retention of the distracting words. Subjects in DIST-1 were tested for retention of the distracting words before the third target retention tests while subjects in the DIST-2 were tested after in order to counterbalance for order effects on distraction retention.

One prediction made by Doyle (1973) was that younger children would retain more of the distracting message than older children and less of the target message. Results support this prediction. Doyle found that there was a developmental increase with age in ability to focus on information designated as relevant. Results also indicated a developmental increase with age in the ability to retain some distracting information but to inhibit responding to that distracting information during the selection task. This suggests that older children have better control over their response selection abilities in that they edit out the undesired or irrelevant message at the point of reporting. Alternatively, the data suggest that older children's improvements in performance are due to a greater ability to select the proper stimulus representation within the limited capacity system (i.e., attend better to the proper channel). The analysis of intrusion errors in Doyle's study in this light suggested that this may be the case (i.e., younger subjects were more likely to report a word presented in the irrelevant message than were older children). These results differ from those of Geffen and Sexton (1978) in that they indicate that interference may occur at either of the stages of stimulus selection or response selection.

The review of the literature supports the existence of developmental differences in selective attention. In addition, it is evident that highly significant changes in attentional abilities occur between the ages of five and seven years which corresponds to other developmental changes reviewed previously. Further, the research indicates that as children develop they respond less to distraction while attending better to relevant stimuli.

Throughout the literature pertaining to the investigation of selective attention the ability to selectively attend to the relevant channel appears as a common factor of the paradigms which have been used. Although this factor is common to all research investigating the development of selective attention, it is not the only explanation or mechanism implicated as the reason for the developmental difference in the ability to selectively attend. A further study of the literature indicates that encoding and response selection are also implicated as possible explanations of the developmental difference in selective attention which exists. It is not clear from the review of the literature whether one of these mechanisms is a more likely candidate than the other. Researchers such as Lane and Pearson (1982) have outlined these mechanisms as ones which warrant further investigation. In addition, Lane and Pearson suggest that current research should be aimed at directly investigating these mechanisms. The present study is an attempt to respond to this directive and address the mechanisms of stimulus selection and response selection in the domain of auditory selective attention.

Selective Attention and ERPs

Event-related potentials (ERPs) have been useful in providing information about selective attention in adults. While ERPs have been applied within a variety of paradigms to the cognitive processing of adults, little has been done for the study of development with children. Research paradigms (i.e., those used with adults) using ERPs have not been widely used in the study of the development of selective attention. However, the present study employed an ERP paradigm to study selective attention in children. The following review will demonstrate the success of ERP research in the area of adult selective attention.

Event-Related Potentials

Event-related potentials (ERPs) represent neural activity (i.e., changes in the electrical activity of the nervous system) which have a definite relationship to the occurrence of a specific physical stimulus or psychological event (Loveless, 1983; McPherson, 1996; Picton & Hink, 1974). A sensory stimulus normally triggers a sequence of negative and positive voltage deflections in the scalp-recorded EEG that have characteristic time delays. These electrical responses may be synchronized with time-locked external or internal events, hence, they are known as event-related potentials (ERPs).

ERP Research

Hillyard, Hink, Schwent, and Picton (1973) were among the first to use an experimental paradigm designed to elicit the process of selective attention to be measured by ERPs. Hillyard et al. described the process of selective attention as one which enhances stimuli perceived from the chosen source and at the same time, suppresses irrelevant information.

Subjects were presented tones to both ears at short intervals. The auditory stimuli to the two ears were randomized and subjects were instructed to attend selectively to tones in one ear with their goal being to detect occasional target tones of a slightly higher pitch. In the first experiment the left ear presentation consisted of a sequence of 800 Hz tone pips which were 50 ms in duration. The right ear received a sequence of 1500 Hz tone pips which were independent of the left ear but of similar intensity and duration. Signal tone pips were 840 Hz for the left ear and 1560 Hz for the right ear. Throughout each sequence, the signal tone pips occurred randomly every 3 - 20 stimuli. Presentation of the sequences was repeated six times in succession for each subject under three instructional conditions. In the first condition, subjects were instructed to attend to the left ear, count the number of signals and report that number at the end of the sequence. In the second condition, subjects were instructed to attend to the right ear and count the number of signals while in the third condition subjects were instructed to read a book and ignore tone pips.

Results demonstrated that the N1 peak, a negative component which peaks at approximately 80 - 110 ms after stimulus presentation in adults, was substantially larger when the stimuli were attended versus non-attended. This was evidenced in the amplitude of N1 evoked by the right ear tones which was 20 - 75 percent larger when the subjects were attending to the right ear than when they were attending to the left ear. Left ear tones produced an N1, 22 - 78 percent larger when subjects attended to the left ear as compared to when they were instructed to attend away from the left ear to the right ear.

Experiment 2 included some changes in methodology. One change was that the tones were presented as a single sequence rather than as two independent, overlapping sequences as in Experiment 1. Other changes occurred in the time intervals between tones which was randomized between 100 and 800 ms, and the right ear received tones of 800 Hz, while the left ear received tones of 1500 Hz. Results from Experiment 2 were consistent with Experiment 1 in that Hillyard et al. found directing attention to one of the channels resulted in enlargement of the N1 component. Thus, the amplitude of N1 was indicative of basic attentional processes which blocked out the irrelevant stimuli and admitted sensory input for further processing.

Schwent, Hillyard and Galambos (1976) based a study on the paradigm employed by Hillyard et al. (1973). Schwent et al. modified the experiment by adding background white noise to the channels of tone information in an attempt to detect an even larger attentional enhancement of the auditory N1. They also added tone intensities of loud and soft. This experiment consisted of a total of six conditions which were: a) attention directed to one of two channels, b) loud or soft tone intensity, and c) white noise present or absent. Schwent et al. (1976) concluded that the results of their experiment supported the proposal made by Hillyard et al. (1973) that "N1 amplitude indexes a 'stimulus set' mode of attention whereby stimuli are selected for or rejected from further processing on the basis of their 'channel of origin' " (p. 620, 1976). Further, these results reinforced the hypothesis that the amplitude of N1 was related to the process of selectively attending to a given channel.

Naatanen, Gaillard, and Mantysalo (1978) conducted an experiment similar to Hillyard et al. (1973). However these authors interpreted their findings slightly differently than Hillyard and his colleagues. Naatanen et al. presented stimuli one at a time and randomly to either ear of the subject at constant interstimulus intervals of 800 ms. As in the Hillyard et al. paradigm, the subjects' task was to detect and count the signal stimuli (which would occasionally replace standard stimuli) either in the left ear or in the right ear. Naatanen et al. failed to find the early N1 enhancement to the attended ear as compared to the unattended ear. However, they did find a later negative shift superimposed on potentials elicited by the attended stimuli. Naatanen et al. believed that this later shift of negativity was responsible for the N1 enhancement found by Hillyard et al. Naatanen et al. suggested that this "processing negativity" reflected a step by-step process by which the subject ends up with some degree of subjective certainty that something deviating from the standard has occurred. This discrepancy between Naatanen et al. and Hillyard et al. raised the question as to whether the increase in N1 amplitude was due to an actual increase in the amplitude of that component or a new negative component (processing negativity) occurring to attended stimuli which overlapped with N1 and consequently increased the N1 amplitude.

Hansen and Hillyard (1980) addressed this question of whether channel selective attention produces a graded enlargement of the exogenous or evoked N1 component, or does it cause each attended stimulus to trigger an "endogenous" negative wave that is additive with the exogenous N1 and increases its measured amplitude. (N1 is said to be exogenous because it is a response to stimulus characteristics per se and not higher cognitive processes [Hillyard & Picton, 1987; McPherson, 1996].) Hillyard et al. (1983) investigated this possibility that an endogenous ERP contributes to the measured N1 amplitude under conditions of channel selective attention. They predicted that any endogenous ERPs associated with attention would vary in latency and thus be dissociable from the more stable exogenous N1.

Tone pips were presented binaurally to subjects. Tones of 51 ms duration were designated as standards, and tones of 102 ms were the targets. Different channels were defined by the frequency of standard tones rather than as different ears. For each active attention condition, tones of two different frequencies were presented in random order with equal probability, at inter-stimulus intervals of

200-500 ms. The lower tone frequency was always 300 Hz, while the higher frequency was set 350 Hz, 400 Hz or 700 Hz in different conditions. Thus, three frequency separations were established creating six active attention runs in that subjects received two consecutive runs at each frequency separation. Subjects were instructed to quickly press a button as soon as they detected a longer duration target.

EEGs were recorded from Fpz (midline pre-frontal), Cz (vertex, i.e., midline central), and Pz (midline parietal) scalp sites. Nd waves were calculated for each active attention condition by subtracting (point by point) the average ERPs to the respective stimuli when they were not attended from the average ERP when they were attended (see Figure 1). The effect of attention seen in the difference wave was a broad negativity as opposed to a single sharp peak. This broad negativity arose before the N1 peak at the 400 Hz channel separation (300 Hz vs. 700 Hz) and persisted throughout the analysis epoch. The latency of onset of Nd increased progressively and its amplitude declined as the separations between the channels were reduced. This was indicative of a temporal separation between the evoked N1 wave and the attention-sensitive Nd which was brought about by manipulating the inter-channel discriminability. With regard to peak amplitude, the data showed a significant Nd amplitude increase as frequency separation increased thus suggesting that fewer attentional resources were allocated to the channel to be ignored as frequency separation became larger.

Hansen and Hillyard (1980) concluded that the effect of selective auditory attention on the N1 component (100 ms latency) is not due solely to an enlargement of the exogenous N1 component of the vertex potential but rather included the addition of a prolonged endogenous component. The effect of attention was manifested in difference waves which consisted of a broad multiphasic negative component (Nd). The later phase of Nd (300-400 ms) was more frontally distributed than the earlier phase (100 ms latency).

The Nd paradigm has provided vital information concerning selective attention in adults. The Nd component is an attention-sensitive component defined as the ERP difference between conditions of attention and inattention (Hansen & Hillyard, 1986). The amplitude of the Nd wave is related to the ability to selectively attend to one channel and ignore the other channel such that as the attentional resources allocated to the unattended channel decreases the amplitude of Nd increases (Hansen & Hillyard, 1980, 1984; Hillyard & Picton, 1987; Okita, 1988). For example, in the results from Hansen and Hillyard (1980), it was found that Nd amplitude increased as frequency separation increased. That is, as the task became easier and fewer attentional resources were needed for allocation to the channel to be ignored to make the discrimination, Nd amplitude increased.

Developmental Research With ERPs

Nd

Developmental researchers have recently begun to utilize ERPs in the study of cognitive processing. Although ERPs have not been widely used in the study of cognitive development, this trend is changing. The study of ERPs can and has contributed to the analysis of attentional mechanisms on both physiological and psychological levels (Courchesne, 1987). Few studies have been conducted using the Nd paradigm to study the development of selective attention. Brooker (1980 as reported in Berman and Friedman, 1995) is one such study. Subjects for this developmental study were children (ranging in age from 6-13) divided into groups with mean ages of 8, 10, and 12 years of age, and young adults. The Nd paradigm was utilized as a measure of selective attention and data were recorded only from the Cz electrode site. Brooker also utilized P3 as a measure of attention to target stimuli.

No significant Nd waveform was present until age 12. This was found to be due to the fact that the processing negativity (PN) elicited by stimuli in the irrelevant channel decreased with age. PN elicited by stimuli in the relevant channel appeared to remain the same with age. This suggests that older subjects processed stimuli in the irrelevant channel to a lesser degree than the younger subjects indicating that with increasing age there is a narrowing of the attentional focus and an increase in the ability to reject stimuli in the unattended channel.

A second developmental study of auditory selective attention was conducted by Berman and Friedman (1995). The experimenters utilized ERPs and behavioral measures in their assessment of attentional abilities. Three groups of subjects were comprised of children 7-10 years (mean age = 8.1), adolescents 14 - 16 (mean age = 14.4), and young adults 20 - 30 (23.8). Stimuli consisted of consonant-vowel (CV) syllables (ba,da, and ga) presented by a male speaker and pure tones (high/low pitched). Two sequences of stimuli were delivered in different blocks, pure tones or CV speech stimuli.

Berman and Friedman operationalized attention as Nd (the negative difference resulting from the subtraction of the ERP waveform of the irrelevant standards from that elicited by the relevant standards). Target and standard sequences were presented binaurally and subjects were instructed to attend either to tones or CVs to detect a target embedded within the attended sequence, while ignoring the other stimulus sequence, which was also comprised of a standard and target.

Results from the behavioral measures indicated that reaction time decreased with age while accuracy increased. The number of targets correctly rejected in the irrelevant channel increased with age. All groups demonstrated effects of selective attention by appropriately responding to the attended target and producing a very small percentage of responses to the unattended target.

Results from the physiological data demonstrated that for pure tones and

CVs there was a developmental progression in both the latency and amplitude of the Nd waveform such that amplitude increased as age of the subject increased.

Selective attention to CVs elicited smaller amplitude Nds than selective attention to pure tones. The magnitude of this difference between the pure tones and the CVs was larger in the adolescents and adults than in the children. Smaller Nds in children appeared to be due to a greater effect of age on the processing negativity elicited by the unattended than the attended stimuli. This suggests that with development, fewer processing resources are allocated to the unattended channel. Small Nds in the youngest children appeared to be due to equal magnitude processing negativity elicited by both the attended and unattended standards (i.e. children showed equal amounts of processing of both relevant and irrelevant standards).

P3

P3 is a large positive component which has a peak latency of 300-600 ms after stimulus presentation. This wave has often been studied in relation to attention, memory, and decision-making (Hillyard & Picton, 1987). The endogenous P3 wave (also known as P300), can be elicited by stimuli that are task relevant (and therefore attended to) or improbable (Hansen & Hillyard, 1986). Generally, researchers investigating the P3 wave make use of the "oddball" paradigm. In the "oddball" paradigm, subjects are required to detect infrequent auditory stimuli which results in slow, positive waves in the 300-600 ms range of the ERP. Research has indicated that there is strong support for developmental changes in both the latency and amplitude of the endogenous P3 wave (Courchesne, 1990). Because of this, it is believed that this ERP wave is useful in the developmental investigation of selective attention.

Courchesne (1979) studied ERP waveforms in children and adults in an attempt to find developmental changes in late ERP waves in subjects age 6 - 36. Groups were comprised of 6 and 8-year-olds, 10-13-year-olds and adults aged 26-36. In this study, Courchesne presented subjects with tachistoscopically flashed slides which bore either the letter A or B. ERPs were recorded from Pz, Cz, and Fz, above the eyebrow, and on the infraorbital ridge. Subjects received two different types of events: those which were explicitly categorized for the subjects (i.e., targets and backgrounds), and those which were not (i.e., "dims' and "novels"), thereby leaving the subject to categorize the event according to his/her own internal rules.

Courchesne looked at explicitly categorized events and found that these events elicited similar ERP waves in all subjects. The waves elicited were N1, P2, N2 and P3. These scalp distributions did not change with age. The author also found that P3 waves to targets did not change in amplitude with repeated presentation of targets in both 6 and 8-year-olds and adults. The most dramatic age-related change was in P3 latency, which was nearly 300 ms longer in children (700 ms) than in adults (410 ms). This progressive decrease in P3 latency with age was associated with a corresponding decrease in discriminative reaction time. Courchesne surmised that although the ERP waveforms were similar in subjects 6-36 years of age, which indicates that the mode of processing explicitly categorized events is similar in adults and children, it appears that the speed of this processing decreases with age.

Courchesne and his colleagues reported results from a series of studies which investigated changes in auditory and visual ERPs associated with development from childhood to adulthood (Courchesne, 1977, 1978, 1979). Age groups studied were 4-5, 6-8, 10-13, 14-18, and 23-44 years. The auditory and visual paradigms each incorporated two types of events: bizarre "unrecognizable" or novel events, and precisely categorized events. Subjects were asked to press a button as quickly as possible to the presentation of events. ERPs were recorded from electrodes below the right eye (LoE), above the left (UpE), at the left outer canthus, Fz, Cz, and Pz.

Results from the series of studies along with information from a previously published visual study were presented in a combined data analysis (Courchesne, 1983). This analysis indicated several general findings. With regard to target ERPs, the results indicated that in visual and auditory modalities in each age group, the P3 component was maximal in amplitude at the parietal electrode. Further findings indicated that in both modalities, P3 decreased in latency with increasing age.

Friedman, Sutton, and Putnam, (1987) conducted a cross-sectional sampling of subjects who ranged in age form 6-39 years. The seven age groups studied were 6-7, 10-11, 12-13,14-15, and 16-17-year-olds, and adults 20-39 years. The authors' goal was to investigate child - adult differences in cognitive ERPs elicited by pictorial stimuli. Subjects were asked to make same/different judgements and communicate their choice by pressing one of two keys to a two-alike pictorial slide sequence. Results revealed that P3 was seen in all age groups, at about 700 ms in children and at 500 ms in adolescents and adults. The authors also found that P3 latency decreased with increasing age, and P3 latency increased with complexity of the instruction condition.

P3 has provided vital information concerning selective attention. The P3 component has been elicited by improbable stimuli which occur and attract the subject's attention. P3 is an indicator of late cognitive processing and research has demonstrated that it occurs in response to such events as stimulus evaluation and categorization time (Hillyard & Kutas, 1983; McCarthy & Donchin, 1981), and level of mental workload (Donchin, 1985). Further, it is accepted that P3 is a measure of the extent to which the processor manifested by P3 is utilized (Donchin & Coles, 1988). In other words, the amplitude of P3 is indicative of processing by the subject such that the more a subject has processed the stimuli, P3 amplitude increases. Small or non-existent P3s are indicative of lower levels of processing of the irrelevant stimuli. In the present study, P3 amplitude to target stimuli was used as a measure of the degree to which the subject has processed these stimuli. This strategy of measuring P3 to target tones while measuring Nd to standards (non-targets) has also been used by Brooker (1980) and Berman and Friedman (1995) to study attention in children.

Berman and Friedman (1995) examined ERPs elicited by attended and unattended targets and found that all age groups demonstrated a large amplitude for P3 elicited by the target when it was in the attended channel.

Brooker (1980) further indicated that the P3 target mechanism (assessed as the difference between P3s elicited by stimuli in relevant and irrelevant channels) was present at the earliest age (8 years). P3 decreased in amplitude with age when elicited by stimuli in the irrelevant channel.

Purpose and Hypothesis

Summary of Literature Review

As the review of the literature indicates, a decrease in responding to irrelevant stimuli as age increases has been consistently documented across various paradigms. Since the developmental difference in susceptibility to distraction has been so well documented, Lane and Pearson (1982) have proposed that the task at hand is to investigate the mechanisms which underlie the development of selective attention. Research has implicated several stages at which irrelevant stimuli may interfere. These include encoding, stimulus selection (attending to the proper channel and to the relevant stimuli within that channel), and response selection. However, the research is equivocal as support has been documented for each of these stages. Research designed to isolate these stages has been somewhat limited. There has been some attempt to address the specific mechanisms outlined by Lane and Pearson in the area of visual selective attention. However, there has been less of an attempt to follow suit in the auditory domain.

Developmental research of selective attention has not fully taken advantage of the use of ERPs. However, the study of adult information processing in the auditory domain has demonstrated that the ERP paradigm can be quite useful in the study of selective attention. Further, ERP studies of P3 have been successful in providing developmental information which is indicative that these paradigms can be used successfully with children.

Purpose

The purpose of the present cross-sectional study with children from the age groups of 5, 7, and 9 years is to address the mechanisms of the interference of irrelevant stimuli in stimulus selection and response selection in auditory selective attention. These factors were addressed because of the lack of research emphasis on the mechanisms outlined by Lane and Pearson (1982) in the area of auditory selective attention. Furthermore, using ERPs, stimulus selection has been examined with regard to both channel selection (by measuring Nd) and specific target stimulus selection (by measuring P3). Behavioral response selection was assessed by comparing behavioral accuracy with the two ERP measures.

Hypotheses

The present study applied the Nd selective attention paradigm using the left and right ears as the two channels to investigate the mechanisms underlying the developmental difference in selective attention in children. Data for Nd was collected at scalp locations of Fz (frontal), Cz (central) and Pz (parietal). Data for the two conditions (ears) were combined.

Hypothesis one predicted that the amplitude of Nd would increase with age. Hypothesis one was assessed by examining the mean amplitude of the first 600 ms of the Nd wave. Planned comparisons were conducted to evaluate differences between 5-, 7-, and 9-year-olds for each electrode site. Comparisons were made between groups of subjects separately for Fz, Cz, and Pz to assess whether there was an increase in attentional resources to the target channel. It was expected that as age increased, there would be an increasing ability to attend to the relevant channel and ignore the irrelevant channel and that this difference would be evidenced primarily in the Nd wave.

Hypothesis two predicted that younger children would exhibit large P3s to irrelevant targets in the unattended channel as well as relevant targets in the attended channel; older children would exhibit smaller P3s to irrelevant targets and large P3s to relevant targets in the attended channel. These P3 amplitude effects would indicate that younger children were processing the targets in the unattended channel to a greater extent than older children. Hypothesis two was assessed utilizing P3 which was measured as the mean amplitude for the 300-600 ms epoch of the ERPs recorded to the target stimuli in both the attended and unattended ears. This allowed for a comparison of the attend vs. ignore conditions which occurred within each age group. It was then possible to assess attention to target stimuli within each channel. Comparison between P3 amplitude to attended targets vs. ignored targets were carried out within each age group at the three electrodes, Fz, Cz, and Pz.

Hypothesis three predicted that the 9-year-olds would demonstrate a greater ability to accurately detect the target in the identified channel than either the 7-year-olds or the 5-year-olds. This would indicate that the older children were not only attending to the relevant stimuli and ignoring the irrelevant stimuli, but that they were also able to respond when appropriate and inhibit responding when it was inappropriate. Behavioral accuracy was assessed as hits, misses, and false alarms. Hits were measured as the percent of attended targets correctly identified. Misses were measured as the percent of responses to ignored or 'wrong ear' targets. False alarms were measured as the percentage of behavioral responses to the standards in the attended ear. Planned comparisons between age groups were used to evaluate hypothesis three.

CHAPTER III

METHOD

Participants

Participants were recruited from birth announcements published in a local newspaper and through referrals from parents of participants in the project. Subjects were assigned to three groups based on their age. Throughout the experiment data for a total of 10 subjects were rejected: seven subjects were lost due to failure to meet criteria of number of good trials, one subject was lost due to equipment failure, and two subjects were lost due to a lack of cooperation. The final sample consisted of 36 children (twelve each of 5-year olds, 7-year olds, and 9-year olds) with no known history of neurological or auditory problems and no known learning disabilities. Mean age for the three groups was 5.7, 7.2, and 9.4 years while the age range in months for the 5-, 7-, and 9-year-olds respectively were 60 to 71, 79 to 90, and 102 to 114. With permission of the parent(s), each subject received $5.00 as compensation for time spent in the laboratory.

Stimuli

Stimuli consisted of tones presented in a selective attention paradigm similar to that used by Hansen and Hillyard (1980) but adapted for use with children. Tones were presented over Realistic headphones while the subject was seated in a sound-attenuated and electrically shielded room. Stimuli were presented and heard in only one ear at any given time. Tones of 300 Hz

(100ms, 70dB) were designated as standards while targets were a rapid 5-tone series presented for 100ms at 70dB, that is a 250-600-250-600-250 Hz sequence with each tone presented for 20ms and 0 ms inter-tone interval. Interstimulus intervals (ISI) were determined for each age group in order to equate task difficulty across ages. Based on pilot testing, appropriate ISIs for each group were determined by calculating 80% accuracy of target tone identification for each group at various ISIs. The present study used ISIs of 1250 ms, 950 ms, and 650 ms respectively, for the 5-year-olds, 7-year-olds, and 9-year-olds.

Subjects received a presentation of 400 stimuli (200 per ear) for each of two conditions. Overall probability of 300 Hz standards was .75 while the overall probability of targets was .25 for each condition.

Apparatus

The electroencephalogram (EEG) electrodes were placed over the midline of the cerebral cortex at Cz, Fz, and Pz, of the International 10-20 System (Jasper, 1958). The scalp electrodes were referenced to linked earlobes (A1 and A2) with the ground located on the forehead. Eye movements (EOG) were monitored by electrodes placed super-orbitally and over the outer canthus of the left eye (Connolly & Kleinman, 1978). This total of eight electrodes required approximately 10 minutes per subject to be affixed. Impedances for all electrodes were kept below 10 Kohms and were checked at the time of placement and at the end of the final condition.

The EEG was amplified by Grass Model 7p511 amplifiers with bandpasses of 0.1-100 Hz. EEG and EOG data were collected for 50 ms prior to stimulus onset and for the entire ISI, which was 1250 ms for 5-year-olds, 950 ms for 7-year-olds, and 650 ms for 9-year-olds. The EEG was digitized and stored on computer disk at a rate of one sample every 5 ms. Stimulus presentation and analog-to-digital conversion were controlled by a personal computer.

Procedure

Parents were contacted via telephone and were told the purpose of the study and the procedure involved. During this contact an initial screening was conducted to determine that the child had no known neurological and/or hearing deficits and no known learning disability. Parents were encouraged to ask any questions concerning the experiment after which consent for participation was sought. Upon gaining verbal consent an appointment time was scheduled, parental assent for monetary compensation was obtained and directions to the laboratory were provided. At the laboratory, the parent(s) and the child were given detailed information about the study. The parent(s) provided written consent and received a copy of the consent form which also contained the purpose and procedures of the study. Any further questions were addressed at this time.

Upon entering the laboratory subjects were given the first phase of the instruction in the form of a story about an invisible rabbit which was stealing food from the lab. Subjects were then seated in an easy chair in an electrically shielded, sound attenuated room. During the next phase of the experiment, subjects were shown the electrodes and received a brief explanation of their use. Electrodes were described as part of the special rabbit tracking gear which would allow the experimenter to monitor the child's progress in tracking the rabbit. Next, the electrodes were placed and secured using Grass Instruments EC2 paste with a small piece of cotton placed over the electrode. Clip electrodes were used on the earlobes. After the electrodes were affixed the subjects were instructed to press a button as quickly as possible when they heard the "rabbit sound" (target) in the identified ear. The experimenter then went into the control room and began practice trials.

Each subject participated in two attention conditions. In the first condition subjects were instructed to attend to the identified ear (predetermined for the subject by randomized counterbalancing) and press the button as quickly as possible when the target (rabbit sound) was heard in the identified ear. In condition two the identified ear was the opposite of that in condition one. In each condition, the subject was instructed to focus on one channel (left or right ear) and ignore the other channel. Each condition contained 400 tones (200 per ear). Standards and targets occurred with an overall probability of .75 (150/ear/cond) and .25 (50/ear/cond) respectively.

Subjects were allowed to practice as each sound was introduced to familiarize them with the discrimination task and to establish that subjects understood the nature of the task. Order of presentation of sounds was as follows. 1) Rabbit sound alone (target): instructed to press button each time the target was heard. 2) Guard sound alone (standard tone): instructed to do nothing when this sound was heard. 3) Target tone in both ears (alternating presentation): instructed to press button only when the target was heard in identified ear. 4) Rabbit and guard sound in both ears (alternating presentation): instructed to press button when target tone was heard in identified ear and ignore all other presentations. Practice was continued until performance was accurate to eliminate substantial practice effects during the experiment.

After completing the practice trials, subjects were encouraged to relax and stare at a fixed point in the room to decrease eye movement. Subjects whose eye movement remained at significant levels received instructions to relax and close their eyes. Lights were dimmed to enhance a relaxed state and the experimenter went into the control room to begin presentation of the trials for the experiment.

Data Processing (Reduction)

Single trials contaminated by EEG artifact were rejected and excluded from the average ERPs. A trial was rejected if the voltage value of any channel exceeded 100 microvolts. A criterion of 35 artifact-free trials was set as the minimum number needed in each condition for inclusion of a given subject's data.

For each subject 12 ERPs were calculated by averaging the artifact-free trials; ERPs were then digitally filtered at 50Hz. Four ERPs were calculated from each electrode site (Cz, Fz, and Pz). These four ERPs were to the standard tones, attended ear; standard tones, unattended ear; target tones, attended ear; and target tones, unattended ear. Two Nd waves were then calculated per subject per electrode location (Cz, Fz, Pz) by subtracting the ERP generated to standards in the ignored ear from the ERP to the standards in the attended ear (Alho, Paavilainen, Reinikainen, Sams, & Naatanen, 1986; Hansen & Hillyard, 1980). Each subject's data that were submitted for analyses consisted of Nd waves from three electrode locations (Fz, Cz, Pz).

For each Nd wave, mean amplitude was calculated for the first 600 ms and the last 300 ms of the waveforms for each group at Fz, Cz, and Pz. Waveform length varied by age and was 1250 ms for the 5-year olds, 950 ms for the 7-year olds and, 650 ms for the 9-year olds.

P3 was measured as the mean amplitude for the 300-600 ms epoch of the ERPs recorded to the target stimuli in both the attended and unattended ears. These measures were assessed at the three electrodes, Fz, Cz, and Pz.

Behavioral responses to targets in the attended channel were measured. A response was considered a hit when it occurred following an attended target tone or following the tone after the presentation of the target. Three behavioral measures were calculated: 1) hits (percent of attended targets correctly identified), 2) misses (percent of responses to targets in the unattended ear, and 3) false alarms (percent of response to standards in the attended ear).

CHAPTER IV

RESULTS

The general approach for analyzing the data was to use planned comparisons based on the modified Bonferonni method developed by Keppel (Hays, 1988). This approach adjusts the familywise error rate based on the number of comparisons made while also considering the degrees of freedom available. For instance, if the familywise error rate is set at .05 and the three possible paired comparisons are to be made among the 5-, 7-, and 9-year-olds, the p value which must be obtained is [2 df x .05]/[3 comparisons] = .033, one-tailed. If deemed appropriate follow-up analyses of variance (ANOVA) were carried out.

Hypothesis one predicted an increasing ability with age to attend to the proper channel and that this difference would be evidenced primarily in the Nd wave. Nd was derived by subtracting ERPs to the ignored-ear standards from the attended-ear standards and calculating the mean amplitude of the first 600 ms of the Nd wave. Data for the two conditions (ears) were combined . Hypothesis one would be supported if Nd amplitude increased as age increased. It was assessed by examining the mean amplitude of the first 600 ms of the Nd wave. Planned comparisons were conducted to evaluate differences between 5-, 7- and 9-year-olds for each electrode site. Comparisons were made between groups of subjects separately for Fz, Cz, and Pz for the 5- vs. 7-year-olds, for the 7- vs. 9-year-olds, and the 5- vs. 9-year-olds. The probability value that had to obtained for each of the three families (Fz, Cz, and Pz) was [2 df x .05]/[3 comparisons] = .033.

Figure 1 shows each age group's grand average Nd waveforms at each electrode site. No significant differences were found at the Fz site for any of the comparisons. However, at Cz, age differences were evident with the 9-year-olds showing significantly greater negativity than the 5-year-olds, $t(22) = 2.51$, $p = .01$. Significant age differences were also found at Pz, again with the 9-year-olds showing greater negativity than the 5-year-olds $t(22) = 1.97$, $p = .031$. Age differences in Nd were found only in the planned comparisons. An Age (3) X Electrode (3) ANOVA found no age main effect or interactions for the first 600 ms of the Nd waveform.

Figure 1 shows that there were apparent differences in Nd magnitude among the three age groups, especially at Cz and Pz. In general, the 9-year olds showed negativity (Fz mean = -1.36 μV, Cz mean = -.75 μV, Pz mean = -.74 μV), the 7-year-olds showed values close to 0, (Fz mean = .16 μV, Cz mean = -.02 μV, Pz mean = -.12 μV), and the 5-year-olds showed positivity (Fz mean =.10 μV, Cz mean =1.38 μV, Pz mean =.91 μV). Figures 2, 3, and 4 show that the negativity in the 9-year-olds occurs from a greater negativity in the attend condition such that when the ignore waveform is subtracted from the attend waveform to calculate the Nd wave, a negative waveform results. The positivity in the 5-year-olds occurs from a greater positivity to the attend condition compared to the ignore condition (see especially Cz and Fz in Figure 2).

Closer examination of the Nd waveforms (see Figure 1) appeared to indicate that all three groups demonstrated negativity in the latter part of their respective waveforms. Therefore, a post hoc Age (3) X Electrode (3) ANOVA on the last 300 ms of the Nd waveform of each group was conducted (300-600 ms for the 9-year-olds, 600-900 ms for the 7-year-olds, and 900-1200 ms for the 5-year-olds). No main effects or interactions were found.

Modified Bonferonni t-tests on the last 300 ms of each group's waveform were conducted to examine possible differences with less conservative tests. Although there were no significant differences found, even with these liberal t-tests, there did appear to be a trend in that 9-year-olds showed the greatest negativity followed by the 7-year-olds and by the 5-year-olds who showed the least negativity of the three groups.

Hypothesis two predicted that younger children would exhibit large P3s to attended targets but also large P3s to ignored targets. Older children would exhibit large P3 amplitudes to attended targets but small P3s to the ignored targets. P3 waves were evident only at Cz and Pz as is typical with adults (Hillyard & Picton, 1987) and was largest at Pz. Planned comparisons were conducted to evaluate differences within each age group by comparing P3 amplitude to the attended and ignored targets at both Cz and Pz. P3 was the largest at Pz and it was at this electrode that effects were found. Five-year-olds showed no differences in amplitude between the attended and ignored targets, but both older groups showed significantly larger P3 amplitude (greater positivity) to the attended vs. ignored targets, $t(11) = 3.83$, $p = .0015$ for the 7-year-olds and, $t(11) = 2.55$, $p = .014$ for the 9-year-olds. For these comparisons a p-value of .017 was considered significant. Figure 5 shows these data. It is clear that the 5-year-olds show equally large P3s to both attended and ignored targets while 7-year-olds and 9-year-olds show greater positive amplitude to the attended tones.

Hypothesis three predicted increased behavioral response accuracy as age increases. Behavioral accuracy was assessed as hits, misses, and false alarms. Planned comparisons between age groups were used to evaluate hypothesis three. For these comparisons a p-value of .033 was considered significant. Hits were measured as the percent of attended targets correctly identified. Comparison of the 7-year-olds vs. 5-year-olds found a significant difference, $t(22) = -2.36$, $p = .014$. A significant difference was also found between 9-year-olds vs. 5-year-olds, $t(22) = -2.26$, $p = .017$. No significant difference was found between the 7- and 9-year-olds. A one-way ANOVA on the measure of hits found a significant main effect for age, $F(2, 33) = 4.45$, $p = .019$, confirming the results of the planned comparisons. See Figure 6 for these data.

Misses were measured as the percent of responses to ignored or 'wrong ear' targets. The 7-year-olds demonstrated a 12% miss rate while the 5-year-olds demonstrated a 25% miss rate and the 9-year-olds showed a 22% miss rate. This difference between the 7- and 9-year-olds, $t(22) = -2.05$, $p = .027$, was statistically significant. This difference between the 5- and 7-year olds was statistically marginal, $t(22) = 1.69$, $p = .053$. A one-way ANOVA did not find a significant main effect for age.

False alarms were measured as the percentage of behavioral responses to the standards in the attended ear. Planned comparisons of the false alarms indicated a significant difference between 5- and 7-year-olds, $t(22) = 1.98$, $p = .03$, no significant difference between the 5- and 9-year-olds, and a significant difference between the 7- and 9-year-olds, $t(22) = -2.75$, $p = .006$. Investigation of the actual percentage of errors revealed that 7-year-olds demonstrated a 3% false alarm rate, 9-year-olds a 9% false alarm rate and the 5-year-olds an 11 % false alarm rate. A one-way ANOVA revealed a marginal age main effect, $F(2,33) = 2.50$, $p = .098$.

CHAPTER V

DISCUSSION

The present cross-sectional study with children from the age groups of 5-, 7-, and 9-year-olds attempted to directly investigate mechanisms of the interference of irrelevant stimuli in stimulus selection and response selection in auditory selective attention. Three methods were employed to investigate these mechanisms, namely Nd, P3, and behavioral accuracy. Examining the attention process through the use of the Nd waveform allowed for the assessment of attention to the appropriate channel. Furthermore, Nd is a difference waveform and therefore subtracts out the brain response to the stimulus per se, which in turn results in a measure of the brain's attentional resources. The P3 component, which has been identified as being representative of decision-making processes in adult studies, allowed for the examination of the responses to the target stimuli and thereby assessment of stimulus selection within each channel. The behavioral data presented a way to measure accuracy of the process of response selection.

Hypothesis one, that Nd amplitude would increase with age, was generally supported by the results. Nd data found significant age differences between the 5- and 9-year-olds with the 9-year-olds showing greater negativity than the 5-year-olds as expected. Each group appeared to demonstrate some negativity by the end of their respective waveforms, possibly indicating some ability to direct their attention to the identified target and channel. However, the negativity was evidenced in the entire waveform for the 9-year-olds whereas the two younger groups showed negativity only in the very latest phases (see Figures 1-4). This indicated that the 9-year-olds were better at allocating their attentional resources to the identified target and channel than the 5-year-olds.

In the present study, P3 was utilized to examine the underlying process of stimulus selection within channels by comparing within each group the ability to attend to identified target stimuli in the attended ear and ignore irrelevant target stimuli in the ignored ear. The present study found that, as with adults, P3 was largest at Pz (Hillyard & Picton, 1987). Five-year-olds showed no differences in amplitude between attended and ignored ears. However, both older groups showed significantly larger P3 amplitude (greater positivity) to attended vs. ignored targets. Based on P3, the 9- and 7-year-olds were clearly attending to the identified targets and ignoring the irrelevant targets. The 5-year-olds appeared to attend to both the irrelevant targets as well as to the attended targets.

The measures of behavioral accuracy in the present study found that 7-year-olds were superior to both other groups in general. Examination of the means for the two younger groups showed that the 7-year-olds were significantly more accurate than the 5-year-olds in responding to attended targets, in ignoring irrelevant targets, and in ignoring standards in the attended channel. This finding is consistent with previous data which shows significant changes that occur in children during the 5-7 shift (Flavell, 1982; White, 1970).

The 9-year-olds were also significantly more accurate than the 5-year-olds in responding to attended targets. However, 9-year-olds had hit rates similar to the 7-year-olds (75% vs. 78%, respectively); consequently, the difference between these groups was not significant. This finding was contrary to hypothesis three, which predicted that the 9-year-olds would demonstrate the greatest amount of accuracy for the three groups.

When examining the miss rate (or the response to wrong ear targets) 9-year-olds made significantly more errors (22% vs. 12%) than the 7-year-olds and were comparable to the 5-year-olds (25%). Similarly, when examining the false alarm rate (or the response to the correct ear standards), the 7-year-olds were significantly better at not responding to standards in the correct ear than the 5-year-olds and the 9-year-olds. Surprisingly, there was no significant difference between the 5-year-olds and the 9-year-olds in the ability to withhold responding to standards. In essence, the 9-year-olds made as many false alarms as the 5-year-olds.

Overall, results of the present study provided electrophysiological as well as behavioral support for the existence of a developmental change in attentional abilities. This developmental change is consistent with changes which developmentalists have demonstrated in cognitive abilities, physical growth, and attention between 5 and 7 years (White, 1970). More specifically, previous research utilizing behavioral measures has repeatedly demonstrated an increase in attentional abilities between 5-year-olds and 7-year-olds (Day & Stone, 1980; Maccoby & Konrad, 1966; Shepp, Barrett, & Kolbert, 1987; Smith et. al., 1975). Behavioral measures in the present study demonstrated a significant difference in the performance of the 5-year-olds vs. 7-year-olds with the 7-year-olds showing a significant increase in accuracy over the 5-year-olds. There was also a significant difference in the performance of the 5-year-olds and 7-year-olds in the ability to selectively attend to the identified targets and ignore the irrelevant targets. The 5-year-olds demonstrated a tendency to attend to both the irrelevant targets as well as to the attended targets

Paradigms used to investigate auditory selective attention in children have primarily been behavioral in nature (Berlin, 1973; Day & Stone 1980; Doyle, 1973; Geffen & Sexton, 1978; Hiscock & Kinsbourne, 1980; Sexton & Geffen, 1979; Smith et al., 1975). However, use of electrophysiological paradigms in studies with adults have provided a way to directly investigate the processes of attention (Hansen & Hillyard, 1980; Hillyard & Picton, 1987; Naatanen, Gaillard, & Mantysalo ,1978). In an attempt to utilize these paradigms with children, Berman and Friedman (1995) and the present study each employed Nd and P3 as well as behavioral measures of accuracy as means of measuring attentional changes. Findings were similar in that each found a developmental increase in the ability to focus attention on target channels and the allocation of fewer attentional resources to irrelevant channels as age increases as evidenced in the Nd waveform. In addition, the P3 measure indicated that the youngest groups for each study allocated greater attentional resources to targets in the unattended channel. The Berman and Friedman (1995) study, however, provided information regarding developmental attention over a broad range of age groups. The present study utilized younger, more specifically-defined age groups, as well as age groups younger than those of Berman and Friedman. For example, the present study shows children as young as 7 years demonstrate a definite ability to selectively attend based on both physiological and behavioral data.

The present developmental study also provided information different from that of Brooker (1980) who indicated that Nd was not present until age 12. Figure 1 shows the clear presence of Nd in the 9-year-old age group. In addition, the present study found physiological as well as behavioral evidence documenting the existence of the developmental change between 5-year-olds and 7-year-olds which neither the Brooker (1980) nor the Berman and Friedman (1995) were able to address due to unavailability of data.

With respect to the performance of the 7-year-olds and the 9-year-olds, some measures of attention indicated a significant difference between these two groups but on other measures of attention no differences were found. Examination of the first 600 ms of the Nd wave showed that, the 7-year-olds fell between the 5-year-olds and the 9-year-olds and were significantly different from neither group. The nature of the attentional process indexed by the Nd component is still being debated. The most widely accepted view is that the Nd is a sign of post-selection processing that extracts information from stimuli in the attended channel and that the amplitude of Nd reflects the distribution of attention among the different channels (Hansen & Hillyard, 1980; 1984; Hillyard & Picton, 1987; Okita, 1988). This suggests the presence of a linear age trend in the present study for the allocation of attention to the appropriate channel which is consistent with previous research (Berlin, 1973; Berman and Friedman, 1995; Day & Stone, 1980; Doyle, 1973; Geffen & Sexton, 1978; Hiscock & Kinsbourne, 1980; Sexton & Geffen, 1979; Smith et al., 1975).

Measures of the last 300 ms of the Nd wave (which show that by the end of their respective waveforms each group evidenced some negativity) suggest that 9-year-olds may be faster than the 7-year-olds but, no better at carrying out the attentional processes manifest in Nd. However, the finding that negativity is evident in the entire post-stimulus Nd waveform of the 9-year-olds, but only in the tail-end of the 7-year-olds' Nds, argue against this interpretation (see Figure 1).

Hillyard and Picton (1987) put forth a widely accepted hypothesis regarding P3 as the second of two distinct, hierarchically ordered stages of stimulus selection with Nd being the first. According to this view, whereas Nd represents attention to channels, P3 is triggered once the target is identified by a more detailed processing of stimuli in the attended channel. On the attentional measure of P3, both 7-year-olds and 9-year-olds showed strong differences between attended targets and unattended targets while the 5-year-olds showed none. This suggests that both older groups displayed similar abilities in the detection of, and attention to, relevant targets while ignoring non-attended targets.

On the behavioral measures of attention, the 9-year-olds had hit rates similar to the 7-year-olds (75% vs. 78%, respectively) and the difference was not significant. However, a difference was found between 7-year-olds and the 9-year-olds responses to standards in the attended ear. Although on first examination it may appear that this finding contradicts conclusions drawn from the Nd data, further investigation reveals that no such violation occurred. Nd, (which focuses on the standards) measures attention to the appropriate channel, not to the targets. Therefore, the 9-year-olds could be excellent at attending to the appropriate channel but poor relative to the 7-year-olds in selecting the proper stimulus in that channel or in selecting the appropriate behavioral response.

However, there does appear to be a contradiction between the P3 data and the behavioral data. Examination of the P3 data indicates that the 9-year-olds attended to correct-ear targets and ignored wrong-ear targets. On the other hand, the behavioral data shows that the 9-year-olds' miss rate was high, that is, they responded to targets in the ignored ear 22% of the time compared to 12%

for 7-year-olds. However, closer examination of P3 (see Figure 5) reflects that attention (i.e., positivity in the waveform) was present to both attended and non-attended targets with greater attention being focused on the relevant targets in the attended ear. It is possible that this P3 data represents some processing of the non-attended targets which in turn implies poor stimulus selection. However, examination of the 7-year-old data indicates that they too were processing some of the non-attended targets (as evidenced by positivity in the P3 waveform) but appear more able to inhibit responding to those non-attended targets, possibly due to a greater amount of time (ISI) to process and select their responses. Therefore, a possible explanation of this apparent contradiction between P3 data and behavioral data is that 9-year-olds, who had the shortest ISIs, were as good as the 7-year-olds at channel and stimulus selection, but made more mistakes in their response selection.

In examining the behavioral data for the 7- and 9-year-olds there are problems in interpreting the superiority of the 7-year-olds as a developmental regression in the ability to accurately select a response. In an attempt to equate the difficulty of the tasks across groups, ISIs were selected during pilot testing based on an 80% hit rate. Based on these pilot data, ISIs were presented to the 5-, 7-, and 9-year-olds at 1250 ms, 950 ms, and 650 ms respectively. Consequently, when considering the difference between the 7-year-olds and the 9-year-olds, the 9-year-olds may have shown more false alarms and misses because they had to make a decision in 300 ms less time than the 7-year-olds. Thus, there is an open question about whether there is an actual developmental difference between the 7- and 9-year-olds, or if the faster ISI simply made the task more difficult.

These electrophysiological findings add to the evidence that younger children have difficulty in focusing their attention in the presence of competing inputs and that as age increases so does the ability to selectively focus attention. Conclusions from the present study show that for 5-year-olds there is an inability to attend channels differentially (demonstrated by the lack of an Nd wave), an inability to select the relevant stimulus within the appropriate channel (evidenced in equal amplitude of the P3 for both attend and ignore conditions), and possibly a difficulty in choosing correct responses (evidenced in behavioral data). Consequently, the likely underlying mechanism which interferes with the ability to selectively attend to auditory information for the 5-year-olds involves all three mechanisms. Channel selection and stimulus selection are clearly involved and subsequently their presence confounds the third stage of response selection in that it is difficult to select an appropriate response if the two previous stages have been affected such that the appropriate response is not available,

The 7-year-olds by far appear to demonstrate superior abilities when compared to the 5-year-olds. Although they do not demonstrate a clear ability to attend to channels differentially (demonstrated by the absence of a distinct Nd wave), 7-year-olds do show a superior ability to select the relevant stimulus within the appropriate channel (evidenced by the greater positivity of the P3 amplitude for the attend condition), and good ability to select relevant target responses while inhibiting responses to irrelevant stimuli (evidenced in the high hit rate and low miss and false alarm rates).

The 9-year-olds appear to show good channel selection as evidenced by the distinct negativity found in the Nd wave. They also appear to demonstrate good stimulus selection by selecting stimuli within the relevant (attended) channel although they also allocated attention to the irrelevant (non-attended channel). However, they also demonstrated a poorer performance in response selection by being unable to inhibit responses to irrelevant stimuli in the unattended channel possibly because they were taxed by the short ISI. Due to the imperfect stimulus selection in the ignored channel and to standards in the attended channel, it appears that response selection is likely the underlying mechanism which interferes most with selectively attending to auditory information.

Future research in the area of auditory selective attention in children will need to endeavor to resolve the question of age and ISI and its effect on response selection in 7- and 9 year-old children. Are the differences in behavioral responding between the 7- and 9-year-olds due to differences in development or is it due to some unexpected ability of the 7-year-olds? Because of the different ISIs in the present study it is difficult to make judgments about 9-

year-olds' accuracy of response selection. Further research is necessary to disentangle the confound of age and inter-stimulus interval.

The present study has provided information regarding auditory selective attention in children. As expected, a developmental trend towards an increase in the ability to selectively attend to auditory information was supported. In addition, it was demonstrated that the more direct analysis of attention through the use of Nd and P3 as measures of attention can be utilized with young children to acquire new information regarding the development of attention.

Information from the present study can be utilized in classrooms to facilitate the acquisition of new information presented auditorially. Five-year-olds clearly have difficulty paying attention to relevant information and disregarding irrelevant information in the presence of auditory stimulation. The current data supports utilization of extra measures to increase 5-year-olds' ability to attend, particularly in highly stimulating environments. For example, it is vitally important to decrease competing or extraneous auditory stimulation during presentation of important information in the classroom whenever possible to increase the likelihood of attention and learning in five year olds.

In addition, information from the present study sheds light on children's ability to attend to relevant information in the presence of distracting information. It demonstrates that for young children it is difficult and nearly impossible to filter out the distracting information and respond only to the relevant information for children with no known neurological deficits such as those present in Attention Deficit Hyperactivity Disorder (ADHD). The data suggest that children who experience ADHD would demonstrate an impaired ability to selectively attend. The current paradigm would be useful in providing direct information regarding this issue.

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APPENDICES

APPENDIX A:

Figures

Figure 1. Nd grand average waveforms for each age group at each of the three scalp electrodes (Fz, Cz, Pz).

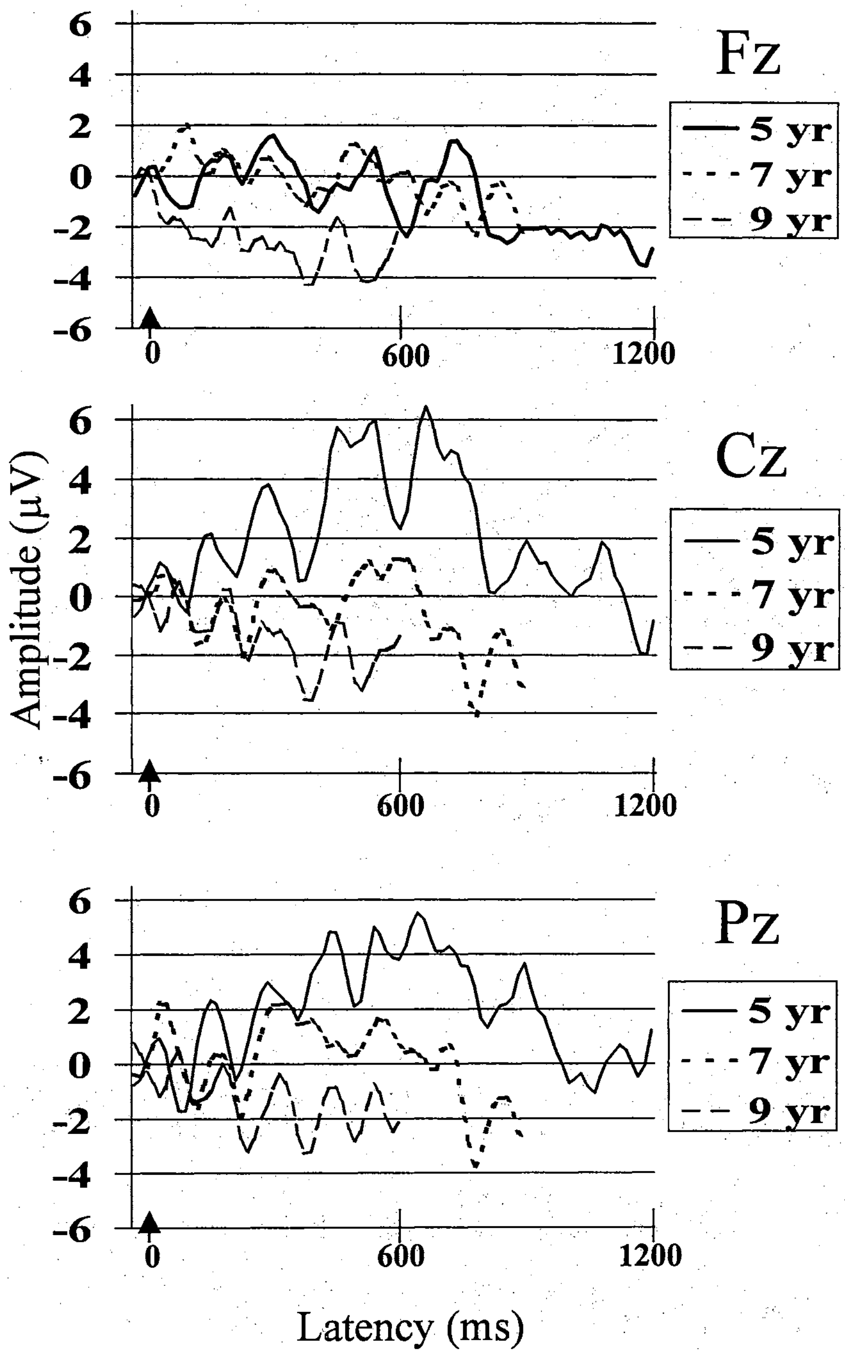

Figure 1. Nd grand average waveforms for each age group at each of the three scalp electrodes (Fz, Cz, and Pz).

Figure 2. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Fz (frontal) scalp electrode.

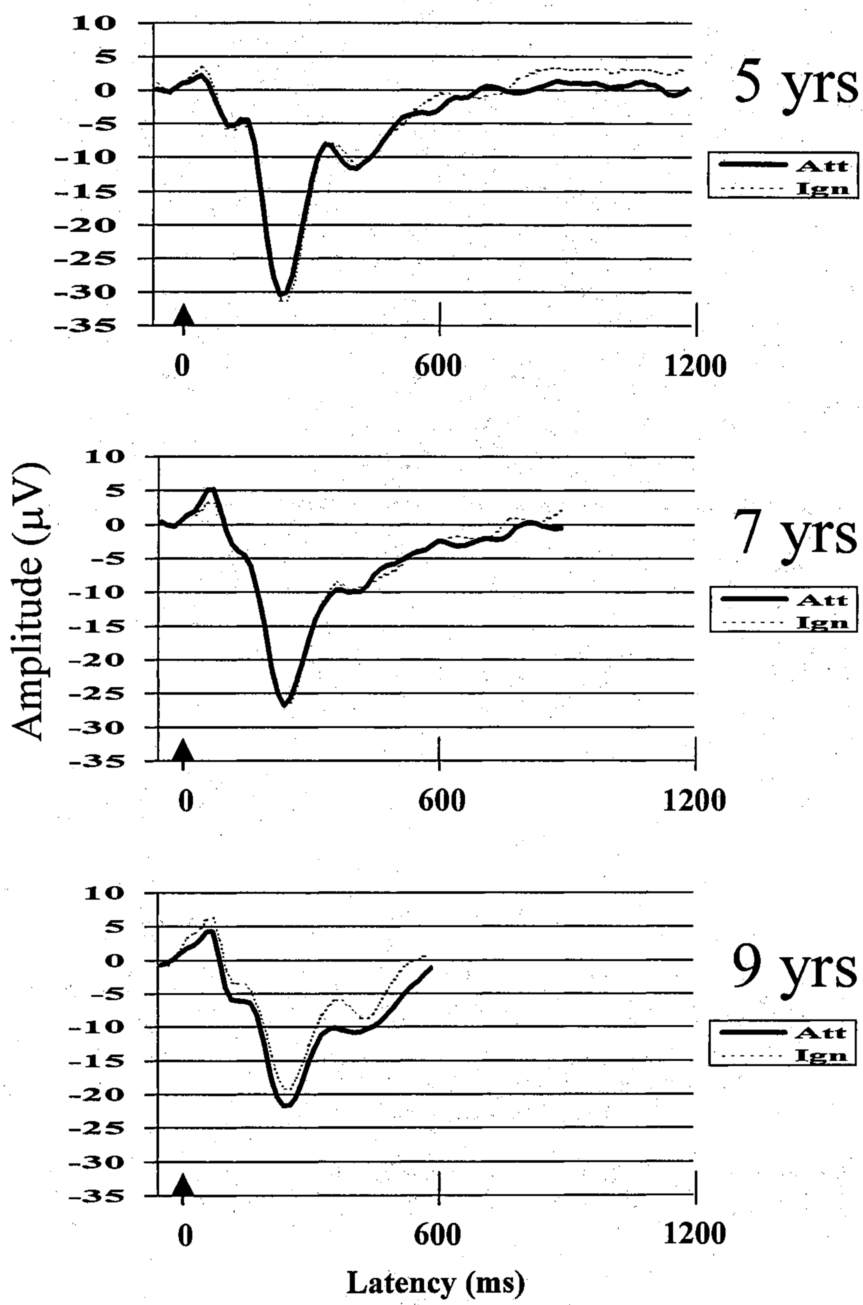

Figure 2. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Fz (frontal) scalp electrode.

Figure 3. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Cz (vertex) scalp electrode.

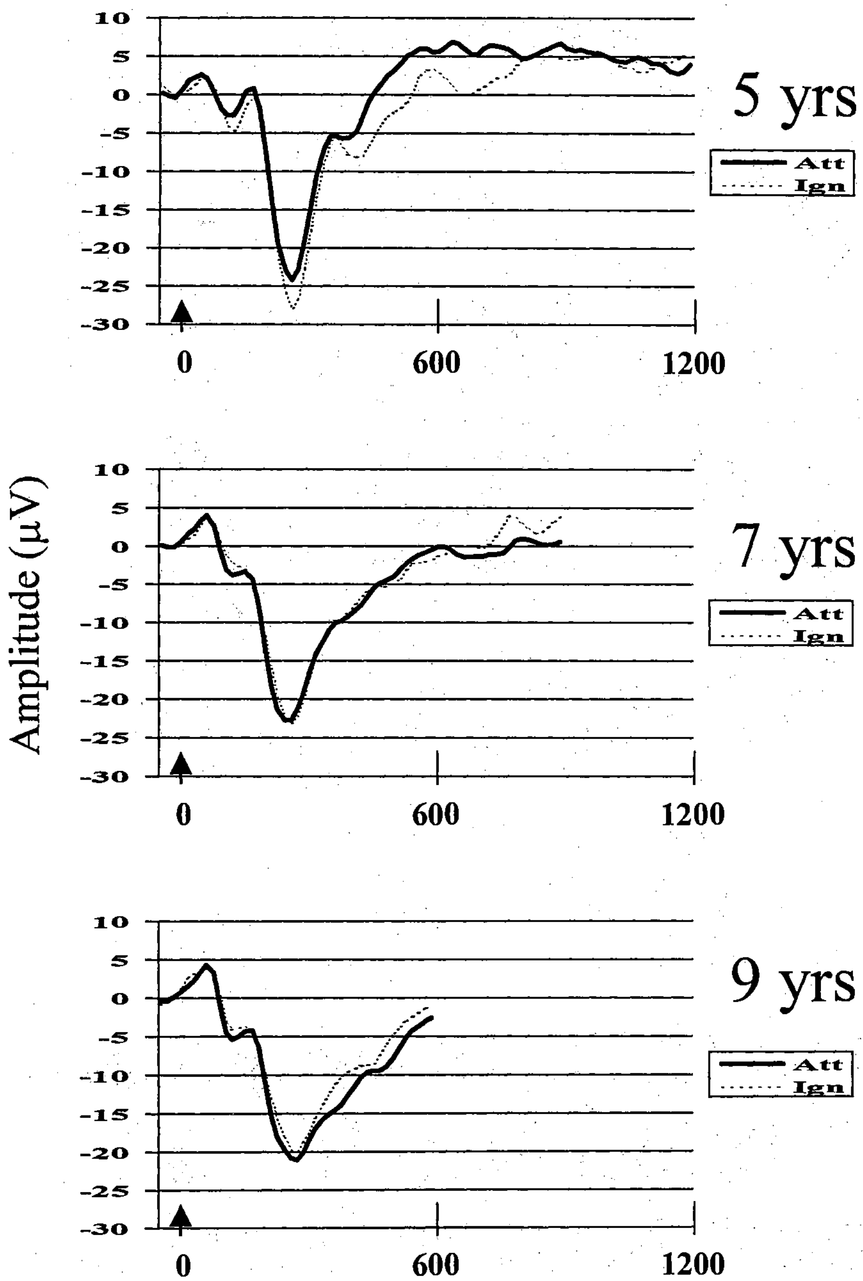

Figure 3. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Cz (vertex) scalp electrode.

Figure 4. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Pz (parietal) scalp electrode.

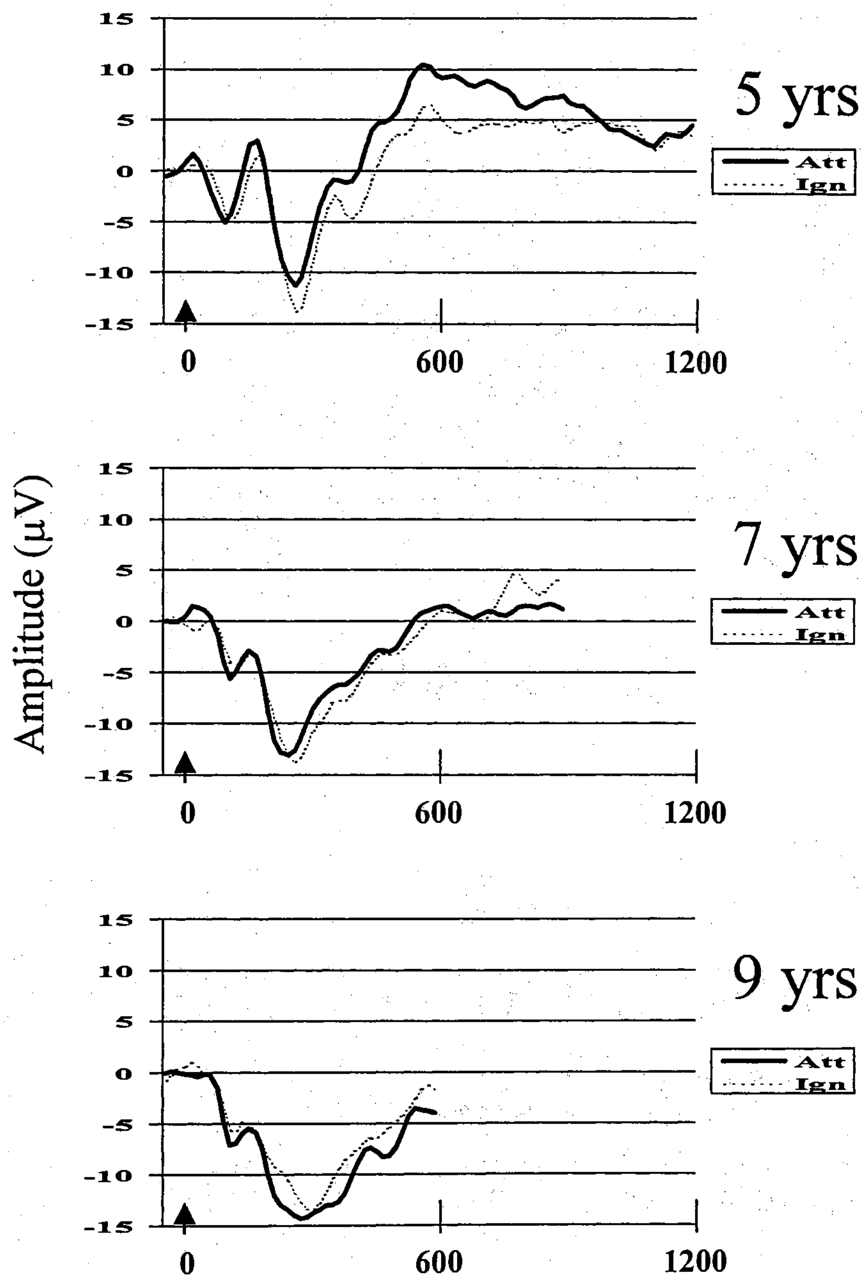

Figure 4. Grand average ERP waveforms to standards in the attended (Att) and unattended (Ign) ears for each age group at the Pz (parietal) scalp electrode.

Figure 5. Grand average ERP waveforms to targets in the attended (Att) and unattended (Ign) ears for each age group at the Pz (parietal) scalp electrode.

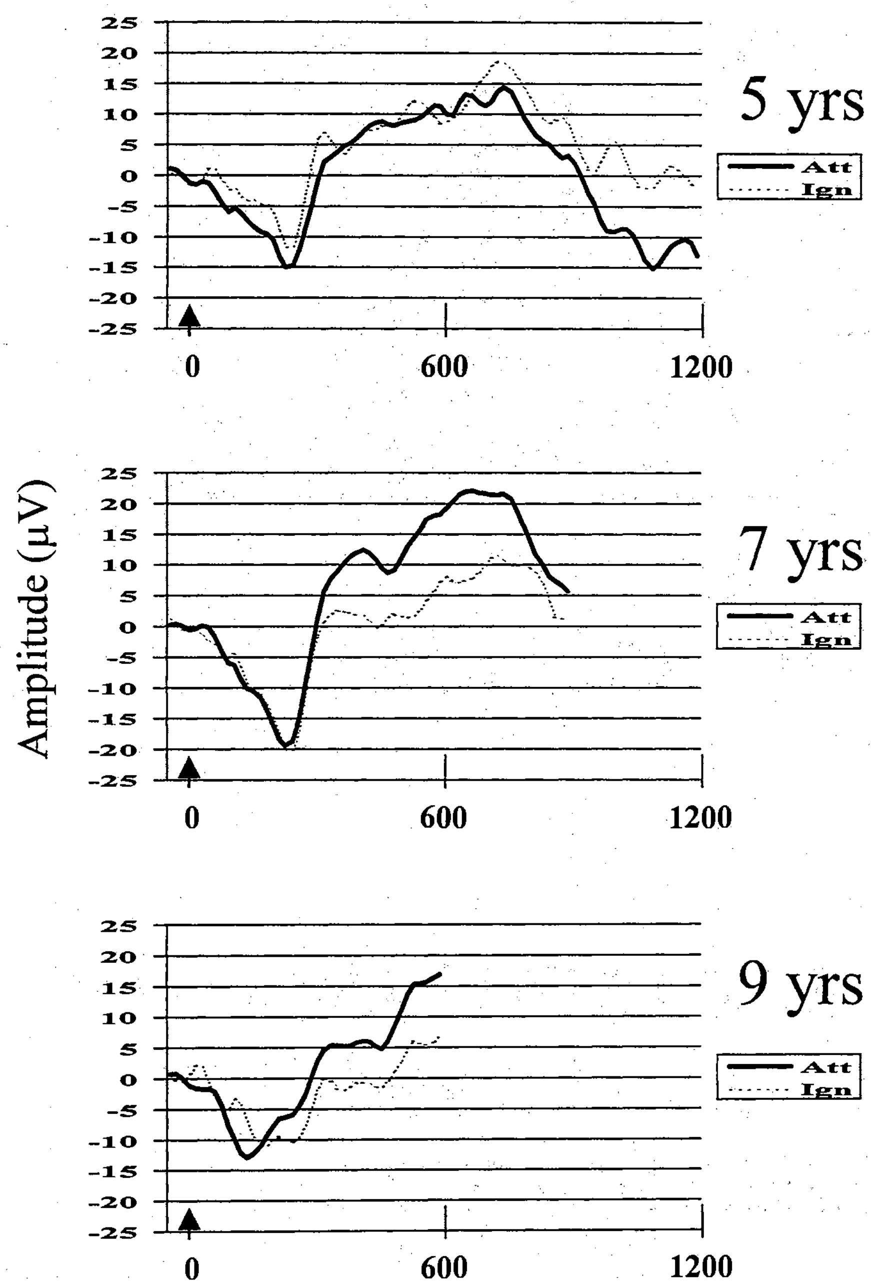

Figure 5. Grand average ERP waveforms to targets in the attended (Att) and unattended (Ign) ears for each age group at the Pz (parietal) scalp electrode.

Figure 6. Percentage of behavioral responses for hits (correct responses to attended-ear targets), misses (incorrect responses to ignored-ear targets), and false alarms (incorrect responses to attended-ear standards) for each age group. Error bars represent one standard error of the mean.

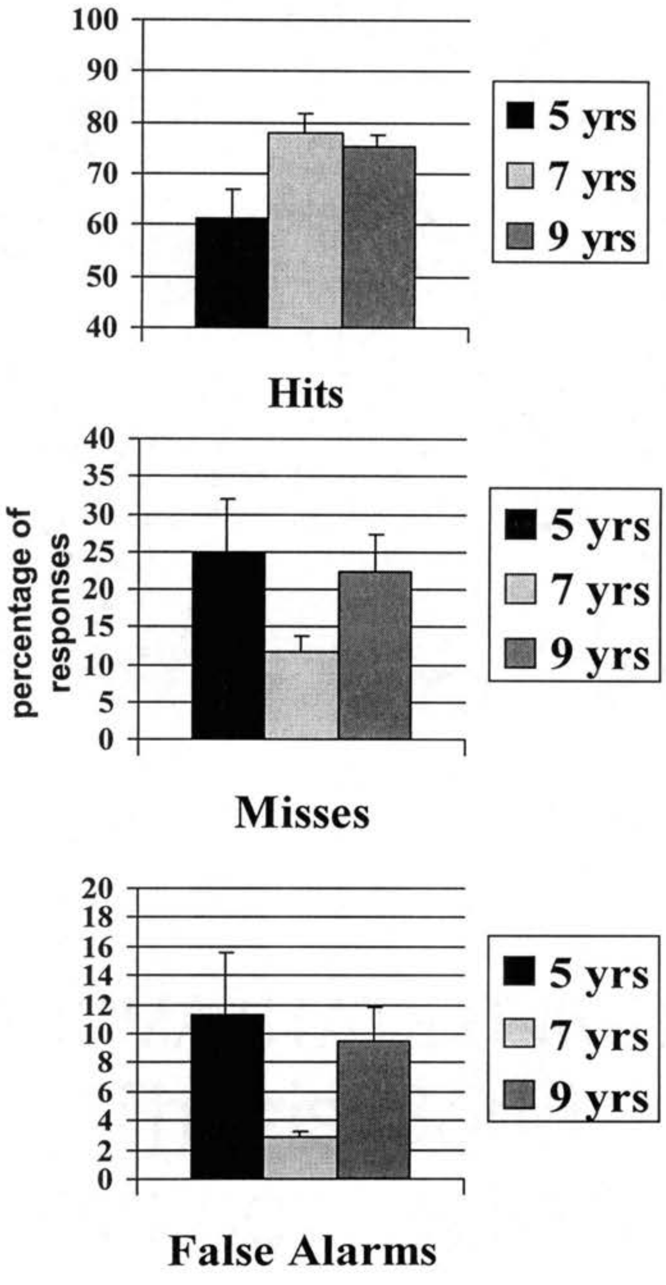

Figure 6. Percentage of behavioral responses for hits (correct responses to attended-ear targets,), misses (incorrect responses to ignored-ear targets), and false alarms (incorrect responses to attended-ear standards for each age group. Error bars represent one standard error of the mean.

APPENDIX B:

Institutional Review Board of Human Subjects Review

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 04-14-95 **IRB#:** AS-95-056

Proposal Title: A DEVELOPMENTAL STUDY OF THE UNDERLYING MECHANISMS OF AUDITORY SELECTIVE ATTENTION (WAS AS-91-048)

Principal Investigator(s): David G. Thomas, Alesha R. McGee

Reviewed and Processed as: Expedited

Approval Status Recommended by Reviewer(s): Approved

APPROVAL STATUS SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

Signature: John H. Wyckoff

Chair of Institutional Review Board

Date: April 18, 1995

VITA

Alesha R. McGee

Candidate for the Degree of

Doctor of Philosophy

Dissertation: A DEVELOPMENTAL STUDY OF THE UNDERLYING MECHANISMS OF AUDITORY SELECTIVE ATTENTION

Major Field: Psychology

Biographical:

Personal Data: Born in Atoka, Oklahoma, on November 9, 1964, the daughter of Bobby and Bettye Johnson.

Education: Graduated from Atoka High School, Atoka, Oklahoma in May 1983; Received Bachelor of Science Degree in Psychology from East Central University, Ada, Oklahoma, in May 1987; Received Master of Science in Psychology from Oklahoma State University, Stillwater, Oklahoma in July of 1988. Completed the requirements for the Doctor of Philosophy degree with a major in Psychology at Oklahoma State University in December, 1998.

Experience: Practicum Experiences at: Psychological Services Center, Stillwater, Oklahoma; Sac & Fox Nation, Stroud, Oklahoma; Red Rock Community Mental Health Center, Oklahoma City, Oklahoma; Payne County Guidance Clinic, Stillwater, Oklahoma. Clinical Psychology Internship at Oklahoma Child Health Consortium, Oklahoma City, Oklahoma.

Professional Memberships: American Psychological Association