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RAPID REORIENTATION OF ATTENTION IN CHILDREN
WITH AND WITHOUT ATTENTION DEFICITS

by

DEBORAH A. PEARSON

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
DOCTOR OF PHILOSOPHY

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HOUSTON, TEXAS
APRIL 1986
Abstract

Rapid Reorientation of Attention in Children
With and Without Attention Deficits

The ability to reorient attention rapidly in both the auditory and visual modalities was first assessed developmentally and then assessed in children diagnosed as having Attention Deficit Disorder with Hyperactivity (314.01, DSM III).

In the first experiment, eight-year old, eleven-year old, and college age subjects listened to dichotically presented lists for prespecified targets. On half of the trials, subjects were signaled to reorient their attention from one ear to the other during the list; on the other half, they remained on the same ear throughout the list. When performance was compared in the switch and no switch conditions, a progressive improvement with age was found in the ability to "switch gears."

The ability to reorient attention visually in the same age range was measured in a second experiment. In this experiment, subjects first oriented their attention to the center of a cathode ray tube. Subjects were then cued that a target would shortly appear either to the left or to the right of this central location. Following a variable interval, the target appeared at the cued location. A steady improvement with age was found in the speed of
reorientation from the central point to the target area.

In a third experiment, auditory reorientation of attention was measured in hyperactive and nonhyperactive children matched for age, sex, and IQ. Using the same task used in the first experiment, it was found that although nonhyperactive children were temporarily disrupted by the switch, they eventually reoriented to the correct ear. In contrast, once the hyperactive children were disrupted by the switch, they never seemed to recover, at least not within the time frame of this experiment. This pattern resembled that of the youngest group in the first experiment, thus lending support to the hypothesis that hyperactive children are developmentally immature.

A final experiment measured differences in visual reorientation in hyperactive and nonhyperactive children. Using the paradigm used in the second experiment, no differences were found between the two groups. It was suggested that the attentional abilities of hyperactive children may be highly dependent upon task characteristics.
Acknowledgements

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Finally, the author would like to thank her family and friends, especially Mr. and Mrs. Harry Pearson, Ms. Marybeth Pearson, and Mr. John Woodhouse, for their unswerving support during the extended process of completing this dissertation.
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Rapid Reorientation of Attention in Children
With and Without Attention Disorders

William James (1890) once declared that "Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneous possible objects or trains of thought. Focalization, concentration of consciousness are its essence. It implies withdrawal from some things in order to deal effectively with others ..." (pp. 403-404). This concept has evolved into the modern concept of selective attention.

Selective attention is commonly defined as the ability to attend to relevant information and ignore irrelevant information. An extensive literature has developed in this area over the last thirty years. Most of this work has been devoted to the study of selective attention in adults, with comparable little work having been done in children. Still less work has been done in the study of rapid reorientation of selective attention from one thing to another. The purpose of this study is to investigate the normal developmental course of this rapid attention switching and to then assess it in a special population of children with attention deficits.

This dissertation is divided into two major sections. The first section is entitled "The Development of Selective Attention," and is devoted to the normal developmental course of attention switching. A literature review of this area will be followed by Experiment 1, which studies attention switching in the auditory modality, and by Experiment 2, which studies attention switching
in the visual modality.

Having assessed the course of attention switching in children without any attention deficits, the focus of this presentation will shift in the second section to an assessment of attention switching in a special population. Entitled "Attention in Children with Attention Deficit Disorder with Hyperactivity," this section will focus on attention switching in hyperactive children. As in the first section of this presentation, attention switching will be studied in both the auditory modality (Experiment 3) and in the visual modality (Experiment 4).

The two sections will be compared throughout this presentation and in a final summary. The hyperactive literature arose largely out of the developmental literature, and it would be impossible to address it without first exploring its developmental foundation.
The Development of Selective Attention

In order to trace the growth of research assessing the developmental course of selective attention, it is necessary to discuss the "classic" theories of selective attention briefly. Virtually all subsequent studies in the attention field are based on the theoretical implications of these early works, including the developmental literature.

Theories of attention. One of the most influential theories of selective attention was proposed by Broadbent (1958). According to this theory, relevant stimuli are separated from irrelevant stimuli on the basis of an attentional filter through which only relevant stimuli can pass. The filter sorts on the basis of physical characteristics such as spatial position or voice quality, and further perceptual analyses are only carried out on messages that pass through the filter. All messages that do not pass through the filter are totally lost from the system.

Problems arose with this hypothesis largely because evidence was found suggesting that the unattended messages were receiving more than cursory perceptual analysis. Moray (1959) pointed out than an unattended message was more likely to be identified if it was preceded by a stimulus having a high degree of salience to the subject (such as their name). Triesman (1960, 1964) found that subjects would listen to messages on the unattended ear when the message on the attended ear was highly redundant. Gray & Wedderburn (1960) discovered that subjects will follow a message
according to meaning, such as following the message "mice eat cheese" from the left ear to the right ear and then back to the left ear. Collectively, these studies indicate that subjects can identify an unattended message to the level of speech.

In order to accommodate these findings, Triesman (1960) modified Broadbent's filter theory. Instead of characterizing the filter as preventing all but the most crude analysis of the unattended stimuli, she hypothesized that the rejected message is just attenuated, not completely dropped from the system. Whereas Broadbent had proposed a system which could only handle one stimulus at a time, Triesman suggested that parallel processing of inputs could occur because several analyzers could be working simultaneously. Furthermore, she proposed the existence of "dictionary units" in memory. When a sensory message enters the system, it activates these units. In order for a subject to become aware of a stimulus, this activation must reach a specific threshold. Significant stimuli such as a subject's name have permanently lowered thresholds and therefore are perceived even if attenuated.

Deutsch & Deutsch (1963) offered an alternative to Triesman's theory. They theorized that a message is processed to a great extent whether or not attention is brought to bear on it. Relevant inputs are selected much further along in the system in this view, so that irrelevant stimuli are not attenuated as early as Triesman would suggest. Later theories such as Duncan (1980) have postulated that unattended stimuli are processed all the way to meaning before the selection of relevant targets is made.
Although an entire literature has arisen over the controversy of where the selection of relevant stimuli from irrelevant stimuli takes place in the system, it is not the purpose of this dissertation to pursue this question. The aspect of these theories that is relevant to the present discussion is that relevant stimuli are separated from irrelevant stimuli during processing. At the beginning of this process, many inputs can be processed, but only relevant stimuli are selected into a limited capacity system for further processing which will eventually lead to consciousness.

*Developmental aspects of attention.* Developmental differences have been studied in a variety of ways, but the most cohesive literature focuses around studies using same/different judgments, speeded classification tasks, incidental learning tests, and selective listening tasks. In all of these paradigms, a subject must focus on a relevant detail while ignoring irrelevant stimuli. The research from each of these paradigms will be assessed in turn.

In the same/different paradigm, subjects are typically presented with two stimuli and are asked whether or not they are identical. Pick, Christy, and Frankel (1972) asked second and sixth-graders to judge whether or not two wooden figures varying in shape, color, and size were the same. There were two conditions under which the children performed. In the preinformed condition, the children were told the relevant dimension before seeing the figures. In the postinformed condition, the children saw the figures and then were told which dimension was relevant.

Sixth-graders were always faster than second-graders in making this
judgment and the age difference was greater in the preinformed condition than in the postinformed condition. Sixth-graders were thus better able to take advantage of this prior knowledge to exclude the irrelevant information.

In a follow-up experiment, Pick and Frankel (1973) asked second and sixth grade subjects to make same/different judgments about the size and shape of colored wooden animals. Again, pre- and postinformed conditions were used. During the first half of the procedure, all the pairs of animals that were presented on a trial were the same color. During the second half of the experiment, half of the children had color introduced as a distractor by varying the colors of the animals within pairs.

This color manipulation had no effect in the preinformed condition for either age group. All subjects showed a decrement in performance in the postinformed condition. The sixth graders were slowed down for a few trials following the introduction of the within-pair variation in color but promptly returned to the level of between-pair performance in a few trials. In comparison, the second-graders remained impaired by the color distraction. Apparently sixth-graders were able to learn to disregard the color distraction whereas second-graders could not filter it out.

Strutt, Anderson, and Well (1975) criticized these studies by pointing out that the preinformed and postinformed conditions should not have been compared because the processing demands were not the same in each condition. In the preinformed condition, the subject encodes the stimulus and arrives at a judgment during the recorded response time. In the postinformed condition, the subject encodes the stimulus but cannot make a
judgment until he is told the relevant stimulus. Even if the sixth-graders were faster at encoding, this difference would not show up in the postinformed task because subjects must wait for a cue before making a response. On the other hand, any greater encoding ability of the sixth-graders would be detectable in the preinformed condition in which there is no such wait. Under these circumstances, comparing pre- and postinformed conditions confounds the ability to take advantage of the cue with encoding speed.

Although the comparison of pre- and postinformed conditions is not informative, other aspects of Pick and Frankel's work is. Their finding that sixth-graders were able to recover from the effect of color distraction while second-graders were not was independent of the confounding mentioned previously and clearly demonstrates that sixth-graders were able to readjust their attention strategies when a new irrelevant factor was introduced.

This idea of attentional flexibility was further explored by Pick and Frankel (1974). Second and sixth-graders viewed slides varying in shape, color, and size. Subjects made same/different judgments under two types of presentation conditions. In the blocked condition, these judgments were based on the same criterion throughout a block of trials. In the unsystematic condition, the criterion changed from trial to trial.

Reaction time was always faster in the blocked condition than in the unsystematic condition and this difference was greater for younger children than for older children. Pick and Frankel concluded that older children are better able to readjust their strategies in order to search for different information each time.
Smith, Kemler, and Aronfreed (1975) extended this work by examining the effect of the distinctness of the irrelevant stimuli on voluntary selective attention. Children in kindergarten, second grade, and fifth grade performed a simple continuous matching task in which they had to make a series of judgments as to whether successive poses of a stick figure were the same or different from the one preceding it. Three types of distraction representing three levels of distinctness were used. In the most distinct condition, the distraction was in an entirely different modality than the matching task and consisted of piped-in noise. In the intermediate condition, the distractor was visual but spatially separated from the matching task and consisted of a border around the figures. In the least distinct condition, the distractor was not physically separated from the figure and consisted of another copy of the stick figure in a different color.

Performance was measured by accuracy rather than reaction time. Before the experiment began baseline performance was measured by testing the children without any distractors. Fifth-graders were only slightly disrupted by any of the three distractors and there were no significant differences among any of them. The performance of second-graders and kindergarten children depended upon the nature of the distractor. Second-graders were least disrupted by auditory stimuli but were poorer under border and color distraction. The kindergarten children were most disrupted by auditory and border distractors but were less disrupted by color.

In examining these results, it would seem that second and fifth graders
were able to ignore the most distinct distractors better than a distractor that was more integrated with the central task demands. These two groups were therefore apparently focusing their attention. By comparison, the kindergarten children had the hardest time in the most separable of conditions. Smith et al. (1975) hypothesized that perhaps the youngest children were trying to divide their attention between the central stimulus and the irrelevant stimulus. It would follow that performance would suffer the most when the sources of information were widely separated. According to this argument, then, children's processing strategies change with age.

Day and Stone (1980) examined the effect of a perceptual set on processing abilities. Five-year old, eight-year old, and adult subjects were shown a briefly presented target picture and were asked to determine whether or not it matched a standard picture. The standard could be shown before the target (thereby creating a perceptual "set" against which to match the target) or after the target had already appeared (the "no set" condition). Additionally, the target could be presented by itself (the "no noise" condition) or as the last picture in a distracting series of "visual noise" slides.

The proportion of correct responses increased with the use of perceptual set and declined under the presence of visual noise. This disrupting effect of distraction was greater in the younger age groups. Interestingly, the noise was less disruptive if the subjects had received a set than if they had not. Day and Stone concluded that a perceptual set can serve to counteract the effects of distracting visual noise.

Although there are some methodological problems with the early Pick
studies (Pick et al., 1972; Pick & Frankel, 1973), the same/different judgment literature does point to an increasing ability with age for children to ignore irrelevant stimuli. The performance of older children is not as easily upset by distraction as is that of younger children, particularly as this distraction is more separated from the task at hand.

Another research paradigm examining the disrupting effects of distraction on attention is that of speeded classification tasks. In this type of task, a subject is generally asked to sort a set stimuli on the basis of a particular criterion. Selective attention is assessed by measuring the extent to which a subject can focus his attention on the relevant dimension of a stimulus set while ignoring irrelevant dimensions of the same stimulus set.

Strutt, Anderson, and Well (1975) presented six-year old, nine-year old, twelve-year old, and adult subjects with a deck of cards that had one relevant dimension and zero, one, or two irrelevant dimensions.

All age groups were slowed down by the presence of irrelevant stimuli and performance was disrupted more when there were more irrelevant dimensions. This interference was greater for younger children than for older children and adults. The younger children were once again unable to filter out extraneous information.

Farkas (1978) performed a similar study with first and fifth graders. Using a manipulation similar to that of Smith et al. (1975), children sorted decks which had no irrelevant information, irrelevant information that was similar to the relevant stimulus, and irrelevant information that was dissimilar to the relevant stimulus.
All children sorted more slowly in the presence of irrelevant information. Additionally, they were more disrupted by the similar irrelevant distractors than the dissimilar distractors. The disruption was greater for the first-graders than the fifth-graders. Again, older children were processing stimuli more selectively than their younger peers.

Smith and Kemler (Note 1, 1977) extended their earlier work (Smith et al. 1975) in this area by examining the reason children could not block out irrelevant information. They reasoned that if young children were really dividing their attention in a focused attention task (as their earlier work suggested), then their performance should be disrupted by a manipulation that usually disrupts older children only in a divided attention task.

The manipulation they used was spatial separation. There were two sources of information which could either be together or be physically separated. Kindergarten and fifth grade children performed a divided attention task in which stimuli had to be sorted on the basis of both sources of information, and a selection task, in which the sorting was done only on the basis of one of the sources of information. The effect of separating the two sources was to retard performance of all children in the divided attention task. There was no effect of separating the sources of information in the selective attention task for the older children—they were zeroing in on the relevant source and ignoring the other dimension. The younger children were not able to do so, and their performance in the selective task was worse when the two sources were separated than when they were together. The younger children were distributing their attention between the two sources of
information, even when the task demands only required them to attend to one source.

Shepp and Swartz (1976) took this line of reasoning one step further by focusing on the relationships between the dimensions of relevant and irrelevant information. They hypothesized that children were unable to process two sources of information independently because they may be perceived in a unitary manner.

Shepp and Swartz borrowed the logic of Garner and Felfoldy (1970) in examining speeded classification of integral and separable stimuli. Integral dimensions are dimensions that are perceived holistically, for example, hue and brightness. Separable dimensions are dimensions that can be perceived separately, for example, size and shape.

Garner and Felfoldy developed three classification tasks using decks of stimuli based on one dimension, decks based on correlated dimensions, and decks based on orthogonal dimensions. Subjects were asked to sort on the basis on one dimension. Using adult subjects, they found facilitation for integral data in the correlated sorts compared to the one-dimensional sorts because of the redundancy of the correlated conditions. In contrast, there was interference for integral stimuli in the orthogonal sorts because subjects couldn't pick apart the relevant dimension from stimuli they were perceiving holistically. No such facilitation or interference occurred for separable stimuli.

Shepp and Swartz (1976) applied this paradigm to first and fourth-graders. For integral data, they found both facilitation in the
correlated condition and interference in the orthogonal condition for both age
groups (the adult pattern). For separable data, there was no facilitation or
interference for the fourth-graders (the adult pattern), but the first graders
displayed both facilitation and interference with separable stimuli. Shepp and
Swartz concluded that first-graders were perceiving separable dimensions as
integral dimensions—they were processing these stimuli holistically.

Smith and Kemler (1977) extended these findings by examining the
manner in which children of different ages spontaneously grouped items.
Stimulus sets were constructed in such a way that either a dimensional
structure (sorting on the basis of an exact match on one dimension, indicating
dimensional processing) or a similarity structure (sorting on the basis of
overall similarity, indicating a holistic processing of the dimensions involved)
was possible. Kindergarten, second grade, and fifth grade students were
shown the stimulus sets and told to "put stimuli together that go together."
Fifth-graders invariably sorted on the basis of dimensionality, whereas
kindergarten students sorted on the basis of similarity. The second-graders
were somewhere in between. Apparently the younger children were
classifying in a holistic mode the same stimuli that older children were
classifying dimensionably.

Kemler and Smith (1978) obtained further evidence for this position
using enforced sorts as opposed to spontaneous sorts. In a "filtering"
condition, sorting was based on the exact matching of one dimension only. The
two established sorting categories varied widely on the other dimension, so
overall similarity was low. In a "condensation" condition, the sorting was
based upon two dimensions, and the established categories were set up according to a high similarity structure.

Kindergarten, second grade, and fifth grade children were shown the appropriate categories and told to sort the items according to these categories. Second and fifth-graders sorted significantly faster in the filtering task than in the condensation task indicating that they processed dimensionally. The performance of kindergarten students was somewhat ambiguous: they did slightly better in the filtering task than in the condensation task, but this difference was not significant. Kindergarten students were not nearly as able as older children to benefit from being able to sort on the basis of one dimension. Clearly though, they did not find the condensation task easier than the filtering task, which would have been expected if they were processing exclusively on the basis of similarity. It would seem that even very young children do not process information in a completely holistic manner.

Other studies also reveal some dimensional processing in young children. Smith and Kemler (1978) found that even their youngest children used dimensional terms to describe stimulus sets that they had classified on the basis of overall similarity. Ward (1980) found that young children could be taught to classify material dimensionally even though when left to their own devices they would classify according to similarity. Further investigations by Smith (1979, 1981) demonstrate that although younger children have a clear preference for similarity structure, the beginning of a selective dimensional structure is there.
The speeded classification literature provides more evidence for the
development of greater selectivity in attentional processes for older children. The work of Smith et al. (1975) and Farkas (1978) demonstrates that older children are less likely to be disrupted by extraneous stimuli. The later work by Smith and Kemler indicates that the poorer performance of younger children is caused in part by a different processing mode than adults. Adults process information on a selective dimensional basis—they are able to focus on one dimension. Children, on the other hand, do not generally use this mode of processing. They function in a more holistic mode in which selectively attending to one dimension of a multidimensional stimulus is very difficult, if not impossible.

A third area of research suggesting that attentional selectivity improves with age is that of incidental learning. The premise on which this paradigm is based is that there is a limit to the amount of information that can be processed at one time. When this limit is exceeded, a central and a subsidiary task cannot be performed simultaneously. The ability to attend selectively in this situation can be assessed by how well the subject focuses on the central task while placing less emphasis on the subsidiary task. If subjects focus on the central task, they will be able to recall more information about that task. The inattention to the subsidiary (or incidental) task will be reflected by poorer recall of this information. Thus, more selective subjects should retain more relevant information and less irrelevant information than less selective subjects.

The two main lines of research in this area came from the laboratories
of Stevenson and his colleagues, and of Hagen and his colleagues. Each line will be considered separately.

Stevenson (1954) examined "latent" learning in children ranging in age from three to six years old. The children were presented with two boxes. In the first box, several irrelevant objects were interspersed with a key that would open the second box, which contained a prize. Following the search task, the children were tested for their memory of the irrelevant objects in the first box. Stevenson found that this latent (or incidental) learning increased from age three to age six.

Siegel and Stevenson (1966) examined subjects ranging in age from seven to adult in a three choice discrimination learning task. After the subjects had learned which button to press in response to the onset of a particular stimulus, they saw these same test stimuli again, this time embedded in a "stimulus complex" including three incidental objects. Again, subjects had to push the appropriate button for the test object. In the third part of the experiment, subjects saw a series of pictures consisting of all the test items and irrelevant items. They were told to press the same button they had hit when they initially saw them.

To the extent that irrelevant stimuli had been processed along with the test item, subjects would be able to select the appropriate key. Siegal and Stevenson found that incidental learning increased until about age twelve and then declined from age twelve to age fourteen. The adults had the highest incidental learning of anyone but the task was extremely easy for them so that no processing trade off was necessary.
Hale, Miller, and Stevenson (1968) wanted to see if this curvilinear relationship between age and incidental learning could be found in a naturalistic setting. Children in the age range represented by third grade to seventh grade were shown a film featuring a man and woman discussing everyday topics. Following the film, the children were quizzed on details unrelated to the central plot. They found that incidental learning increased through the sixth grade and then dropped off at grade seven.

The most extensive and influential work in this area has been done by Hagen and his colleagues. In the first of a series of studies, Maccoby and Hagen (1965) presented children in the age range represented by the first though the seventh grade with an array of picture cards with distinct color backgrounds. They were told to remember the location of the colored backgrounds. The cards were turned over after presentation, and the child was asked for the location of the backgrounds (the central task). After performing a block of these trials, the child was then unexpectedly asked to match the backgrounds with the pictures with which they had been paired (the incidental task).

Although central recall improved considerably with age, incidental recall stayed about the same from grade one through grade five, after which it declined. Maccoby and Hagen concluded that incidental learning increases during the early growth period when a child is learning to categorize. This period is followed by a decrease in incidental learning when the child learns to shut out unwanted stimuli.

Feeling that the 1965 study used materials that may have been of more
interest to younger subjects, Hagen (1967) modified the task using materials chosen to be potentially of equal interest to all age children. Children of the same age as the earlier study were presented with an array of index cards containing a picture of an animal and a picture of a common household object. For half of the children the central task was to learn the location of the animal in the array; for the other half, the central task was to learn the location of the household object. For all subjects, the incidental task involved matching the animal and the household object that had been paired.

As in the earlier study, central task performance increased with age. There was no significant age effect on incidental learning; however, there was a slight increase in it until fifth grade, followed by a decline in seventh grade.

This methodology has been used with a variety of modifications in numerous studies of incidental learning in children. In a manipulation not unlike that of Smith et al. (1975) in the same/different judgment research, Drucker and Hagen (1969) manipulated the spacing of the two objects and found that wider separations of the central and incidental stimuli reduced incidental learning in eighth grade children but had no effect on the performance of fourth or sixth grade children. Similarly, Wheeler and Dusek (1973) found no effect of spatial separation in kindergarten, third, or fifth grade subjects on incidental recall. They did find a significant effect of verbal labeling of the central stimulus: when subjects named the central stimulus as it was presented, incidental recall decreased at all age levels.

Other perceptual manipulations of the Hagen (1967) task have been performed. Perceptual salience has been found to facilitate recall of
incidental dimensions (Odom, 1972). Surprisingly, attenuation of the incidental stimulus (by making it fainter on the card) had no effect on its recall (Hallahan, Kauffman, & Ball, 1974). Along this line, separating central and incidental stimuli by color was also shown not to affect the amount of incidental material recalled either (Sabo & Hagen, 1973). It has been shown, however, that if the central and incidental stimuli are integrated to form one unitary stimulus, even older children wind up processing the incidental stimuli.

Other types of modifications involve changing actual task demands. Hagen and Sabo (1967) found that incidental performance was unaffected, regardless of whether the pairing task or the position task was the incidental measure. Hale and Alderman (1978) found that doubling the presentation time of the stimuli increased both central and incidental learning in nine-year olds but only central learning in twelve-year olds. The older subjects deployed their attention more efficiently during the extended time, indicating that age differences in selective attention do not just occur in the early stages of encountering a stimulus but are more related to the continuing maintenance of attention.

In one study (Zukier & Hagen, 1978) the modification in task demands occurred halfway through the experiment. Eight and eleven-year old children performed the basic Hagen (1967) task for a series of trials. In a second series, they were led to believe that they would be tested on both central and previously incidental material. As a result, all children demonstrated a significant increase in incidental recall, with a greater increase occurring in
the older group. Apparently the older children were more efficient at adopting a new strategy when confronted with modified task demands.

Finally, Anooshien and Prilop (1980) modified the Hagen (1967) paradigm into an auditory mode. Subjects ranging in age from first grade to college age adults heard lists of word pairs. The first word of the pair was the central word and second word was the incidental word. Following a probe for the central word, an unexpected matching test for the pairs was given.

Not surprisingly, older subjects remembered more central words than younger subjects. Incidental recall increased from first grade to fourth grade then stayed about the same to adulthood. Incidental recall was enhanced if irrelevant stimuli were associated with the central word (i.e., a rhyme or a synonym), echoing the earlier work of Odom (1970) and Hale and Piper (1973).

This body of research clearly demonstrates a curvilinear relationship between age and incidental learning (see Hagen & Hale, 1973, and Hagen & Stanovich, 1977, for more detailed reviews). Incidental learning stays the same or slightly increases until about age twelve and then decreases with age.

The maintenance or slight increase in incidental learning does not appear to reasonably reflect a decrease in selective attention from early to mid childhood. Rather, older children in this age range have greater processing capabilities than their younger peers. With the same or smaller percentage of this absolute capacity allocated to the incidental task, the older children will be able to process more incidental information simply because their overall capacity is higher. (See Lane, 1980, for a more detailed
discussion."

The eventual decrease in incidental learning does indicate an improved ability with age to ignore irrelevant stimuli. Older children are not lured away from the central stimuli as are younger children, even when they have ample time to do so (Hale & Alderman, 1978). Older children are also better able to change their strategies efficiently when doing so will enhance performance (Zukier & Hagen, 1978). Finally, these results are consistent across many experiments and are even generalizable to the auditory mode (Anooshien & Prilop, 1980).

The last major area to be discussed is that of selective listening.Selective listening can be thought of as the ability to listen to relevant stimuli while ignoring irrelevant stimuli. Although much of the recent research in this area has been devoted to the assessment of language development (Lenneberg, 1967), hemispheric asymmetry (Witelson, 1977) and laterality (Kraft, 1982), the research reported here will be devoted to only those studies which have used selective listening as a means of studying the developmental course of selective attention.

The first major research in this area was done by Maccoby and Konrad (1966). Five, seven, and nine-year old children heard pairs of words spoken simultaneously by a man and a woman. The words were presented dichotically (one voice was heard in each ear) or binaurally (both voices were heard in one ear). These words could be monosyllabic or multisyllabic. The words were presented one pair at a time, and the children were instructed to repeat the word that was spoken by only one of the voices and ignore the other voice.
The number of correct responses to the attended voice increased with age. Correspondingly, intrusion errors (words reported from the wrong voice) decreased with age. Children of all ages were better able to selectively attend in the dichotic presentation, in which the localization cues served to aid performance. Also, all ages made more correct responses to multisyllabic words than to monosyllabic words. The advantage of this redundancy gain was greatest for older subjects. These findings suggest a pattern of being better able to select relevant stimuli and avoid irrelevant stimuli with age.

Maccoby and Konrad (1967) extended their earlier work by examining the effects of word familiarity and preparatory set on selective listening. Children in the second, fourth, and sixth grades heard two syllable word pairs spoken by a man and a woman played over speakers located eighteen inches apart. The familiarity of the words was either high or low. The children were sometimes cued as to the appropriate channel before the presentation of the word pair and sometimes following its presentation.

Correct reporting of attended stimuli again improved with age and the number of intrusion errors declined. Performance was better for the target word if it was familiar and this improvement was the same across all age groups. Performance was further facilitated when the distractor word was not familiar (a finding replicated by Cherry, 1981). Finally, children were somewhat better able to attend selectively with the presence of a preparatory set. This improvement was found to be significant only for the youngest children--apparently the older children were able to easily hold both stimuli in memory, so getting the cue after the presentation was not detrimental.
Maccoby and Konrad (1967) manipulated sequential probability and presentation type in subsequent experiments of the same study. In keeping with earlier results, they found that phrases with high sequential probability (like "spider web") were more likely to be reported than phrases with low sequential probability. The advantage of high sequential probability increased with age. Interestingly, preparatory set had a significant improvement in the performance of all age groups using two word phrases—perhaps the memory load was too great for the older subjects this time so that the cue benefitted them.

Performance was better if only one voice came out of each speaker (the "split" condition, like the dichotic condition of the 1966 study) than if both voices came from both speakers (the "mixed" condition, like the earlier binaural presentation). This finding is consistent with their earlier (Maccoby & Konrad, 1966) results.

Doyle (1973) added another dimension to the selective listening studies that preceded her work by incorporating a forced choice recognition task into her design. Children of ages eight, eleven, and fourteen heard a man's voice and a woman's voice speaking lists of words presented binaurally over earphones. All subjects were told to repeat only the words spoken by the man and to remember them.

Following the selection task, subjects were tested for retention of the target word by means of a forced choice recognition test. The children who had listened to the distracting female voice were also tested for retention of these distractor words.
The results of the retention task indicate that although the number of targets that are retained increases with age, the number of distractors remembered did not change across age. This pattern is similar to that found in the incidental learning studies. With regard to the selection task, the older subjects reported more target words correctly, and made fewer intrusion errors. It would seem that the measures from the two tasks yielded discrepant results: if older subjects make significantly fewer intrusion errors, it would seem that they should have also retained significantly fewer distractor words, yet this did not happen. It would appear that older children processed the distracting information (as indicated by the high retention of this material) but did not allow it to intrude (as indicated by their low rate of intrusion errors).

Hiscock and Kinsbourne (1977) studied the effects of cueing on selective listening in three, four, and five-year old children. The children heard pairs of digits presented dichotically. They were told which ear to report either before or after hearing the word pair.

Older children made more correct identifications of target stimuli than their younger peers. Intrusion errors did not decline with age, but stayed about the same. There was no effect of cueing—precued and postcued performance was identical, and this pattern was the same for all age groups. These results are similar to those found by Maccoby and Konrad using single familiar words, although the children involved here were younger.

Geffen and Sexton (1978) employed a slightly different approach to study selective attention. Using a paradigm developed by Moray and O'Brien (1967),
seven and ten-year old subjects heard two lists of words and were told to
monitor one channel (voice in the binaural condition, ear in the dichotic
condition) for the occurrence of a target. Subjects were told not to pay
attention to the other channel, but to go ahead and respond to any targets on
the unattended channel that they happened to hear anyway.

The ten-year olds responded to more target words on the attended
channel than did the seven-year olds. The detection rate for targets on the
unattended channel was not significantly different for the two groups.
Although the ten-year olds were better at selectively attending to the target
stimuli, they were no better at resisting distraction than the seven-year olds.

Sexton and Geffen (1979) expanded upon this work by examining the
effect of instructions upon performance. They essentially repeated their
earlier (1978) experiment using seven, eleven, and twenty-year old subjects.
In this "partially focused" condition, they found similar results to their earlier
work: the hit rate on the attended channel increased with age while the hit
rate on the unattended channel stayed the same for seven and eleven-year
olds before finally decreasing in twenty-year olds.

In the "pure focused" condition, subjects were again instructed to listen
to one channel and ignore the other but this time only to respond to targets
heard on the appropriate channel. Using this strategy, hit rates were much
better for seven-year olds than they had been in the partially focused
condition, marginally better for eleven-year olds, and about the same for
twenty-year olds. Error rates were low, and there were no significant
effects associated with them. From these findings, Sexton and Geffen
concluded that selection of relevant material increases from age seven to age twenty. Attenuation of unwanted material is equally efficient in these three ages if a simple focusing strategy is used, but younger children have more difficulty in ignoring distracting stimuli if the experimental instructions are not as structured.

Geffen and Wale (1979) manipulated task complexity by introducing attention switching in their paradigm. Seven and nine-year old subjects heard tapes in which triplet pairs of digits were presented by a man and a woman simultaneously. These triplets could contain a) no switches (each voice remained on the same channel throughout the trial), b) one switch (in which subjects would have to switch their attention to the other channel), or c) two switches (in which subjects would have to switch their attention to the other channel, and then back to the original channel). The children were told to repeat the digits from one of the voices and to ignore the other.

The nine-year olds reported more digits than did the seven-year olds. In contrast to the last few studies, the older children were apparently better able to resist distraction than their younger peers, as indicated by the fact that they had fewer intrusion errors. Older children were also better able to switch their attention. Although everyone's performance declined as the number of switches increased, this detriment was greater in younger children.

Hiscock and Kinsbourne (1980) studied attention switching in a different manner. Children ranging in age from three to eleven years old listened to short lists of digit word pairs. The child was told to report the digits from
one ear. After completing this set of trials, the headphones were reversed and the child was told to report the other ear.

The number of correct responses increased with age while the number of intrusion errors declined. Hiscock and Kinsbourne also found that there was an asymmetrical effect of attention switching such that subjects found it much harder to reorient attention from the right ear to the left ear than the other way around. They explained this finding in terms of their work on cerebral lateralization (briefly, there is an advantage for verbal material presented to the right ear because it is processed by the left hemisphere of the brain, which includes the area associated with language functions).

Hiscock and Bergstrom (1982) followed up on this priming effect by extending the time span of the attention switching interval. In this study children seven to nine years old listened to dichotically presented triplet pairs of digits that were recorded at the rate of two pairs per second. Subjects were told to report the digits on one ear or the other. There were two experimental sessions in which the child first listened to one ear and then to the other in the second session. The interval between these sessions was either five minutes or one week.

The pattern of results was similar with regard to the number of correct responses and intrusion errors to the Hiscock and Kinsbourne (1980) study. Furthermore, the result of attention switching was the same whether the intersession interval was five minutes or one week. From these results, it would appear that the effect of priming persists for an interval of a week.

These studies demonstrate a definite improvement with age in the
ability to attend to relevant stimuli. There is less agreement about the ability to ignore irrelevant stimuli: some studies have demonstrated a decrease with age in the processing of unwanted stimuli (Maccoby & Konrad, 1966, 1967; Geffen & Wale, 1979; Hiscock & Kinsbourne, 1980; Hiscock & Bergstrom, 1982); while two studies note no such decrease (Hiscock & Kinsbourne, 1977 and Geffen & Sexton, 1978). It may be that the processes of attending to relevant stimuli and ignoring irrelevant stimuli do not develop simultaneously.

When the entire body of literature is taken collectively, a trend toward greater selectivity with age is apparent. Older subjects are consistently better able than younger subjects to attend selectively to relevant stimuli.

The ability to ignore irrelevant stimuli seems to decrease with age, although the evidence is not as clear cut. Doyle (1973) demonstrated that older children were just as likely to process an irrelevant stimulus as younger children but did not allow it to intrude upon their performance. Sexton and Geffen (1978) found that children processed roughly the same amount of irrelevant material during the elementary school years but that it declined by age twenty. This finding is consistent with the incidental learning literature, in which incidental learning stays the same or slightly increases throughout early to mid childhood and then declines at about age eleven or twelve. Overall, it seems reasonably clear that at least by the end of the elementary school years, children are able to ignore irrelevant stimuli while paying attention to relevant stimuli. The greatest improvements in this area seem to occur between age seven and age twelve, with smaller differences being noted between adolescents and adults.
Although the development of attentional selectivity has been studied in a variety of paradigms, the development of the ability to rapidly reorient attention has not. Attention switching has been briefly studied in the selective listening paradigm, however, none of this work has focused on the pattern of reorientation—i.e., what happens following an attentional switch, specifically how well and how long does it take for a subject to get back on track after having switched gears.

These aspects of attention reorientation have been studied in adults by Gopher and Kahneman (1971). In their paradigm, subjects were presented with two lists of stimuli dichotically and were asked to listen for specific targets. After having listened to these lists for a period of time, the subjects were either cued to rapidly reorient their attention to the other ear or to stay on the same ear.

Gopher and Kahneman (1971) found that the ability to reorient attention was correlated with skills related to proficiency in flying high performance aircraft. Gopher (1982) extended these findings by demonstrating that this task predicted success in flight training. It has also been shown to predict accident involvement in professional bus drivers (Kahneman, Ben-Ishai, & Lotan, 1973) and in commercial drivers (Mihal & Barrett, 1976; Barrett, Mihal, Panek, Sterns, & Alexander, 1977).

More recently, this auditory selection task has been studied in normal adults (Avolio, Alexander, Barrett, & Sterns, 1979, 1981). Panek, Barrett, Sterns, and Alexander (1978) found that the ability to do this task declines from age seventeen to age seventy-two, with a significant further drop
occurring in the early forties. Only total number of errors are reported in this study; there is no mention of whether the greater deficits occur during the maintenance part of the task or the reorienting part.

In a later study, Panek and Rush (1981) studied this topic in far more depth and demonstrated that although both maintenance and reorientation of attention decline with age, the far greater decline is witnessed in reorientation. In an extension of this work, Panek (1982) found that risky older adults (as determined by a personality test) made more errors than their more cautious peers.

Although the ability to reorient attention has been studied developmentally in older adults, it has not yet been studied in younger subjects. The studies to be reported here address the issue of whether or not the ability to reorient attention progressively improves with age. Also under study is when in development the greatest gains in this process occur. In light of the developmental literature surveyed in this section, one would expect a steady improvement with age in the ability to reorient attention. One would also expect the greatest gains in performance to occur during the elementary school years.

In Experiment 1, children eight years old, eleven years old, and college age subjects were compared to assess the developmental course of this ability from early elementary school to college.

Experiment 2 used visual stimuli to study the ability to reorient attention. In a task modeled after that of Tsai (1983), subjects were instructed to focus their attention on a central location. After they had had
time to pay attention to this location, they were cued to reorient their attention either to the right side or the left side of the screen. It is this shift in attention that will be studied in Experiment 2 in the same age range as that of Experiment 1.

Experiment 1

Subjects. Twenty-five third grade students (mean age = 8.7 years), twenty-two fifth grade students (mean age = 11.4 years) and twenty-seven college students (mean age = 19.7 years) participated in this experiment. The children were recruited from area private schools; the college students were recruited from introductory psychology courses at Rice University. The college students were compensated with class credit or money for their participation.

Apparatus. The tape of dichotic lists was presented on a Realistic tape played individually to each subject. Subjects wore Radio Shack headphones.

Procedure. Each subject was escorted into the experimental setting by the experimenter. An unused room in the school building was the setting for the children and an experimental cubicle at a laboratory at Rice was the setting for the adult subjects. The subject was seated in front of a table. The experimenter sat beside the subject in order to record the data.

The subject was told that he or she would hear two messages consisting of letters and numbers. One message would go to the left ear and the other message would go to the right ear. Their job was to listen to only one of the two ears and to report only the numbers from that message by saying it aloud immediately upon hearing it. They were instructed to ignore
the letters.

In an actual trial, the subject first heard a message number. He or she was told to repeat this number aloud to the experimenter. After a pause of two and a half seconds, the subject heard either a high (2500 Hz) tone or a low (250 Hz) tone. The high tone indicated that the subject should attend to the right ear; the low tone cued the left ear.

One and one half seconds after the tone, the two messages of Part I were played. Each message consisted of sixteen letters or numbers. In the relevant ear, either two or four numbers were presented; the balance of the items were letters. In the irrelevant ear, six numbers and ten letters were always presented. During this first section, a number on one channel was never presented at the same time as a number on the other channel. The items were presented at the rate of two items per second.

A second cueing tone was heard one half second after the last stimulus pair of Part I. On half of the trials, the tone indicated that the subject should reorient attention to the other channel; on the other half of the trials the tone indicated that the subject should remain on the same channel. Starting one half second after the tone, the subject would hear either zero, one, two, four, or six letters presented at the rate of two letters per second. These filler letters were designed to create a delay of one half second, one second, one and one half seconds, two and one half seconds, and three and one half seconds before onset of the critical message of Part 2. It was during this delay that subjects had the opportunity to reorient their attention.

Starting one half second after the final filler letter, the subjects heard
the critical message of Part 2. This message consisted of three numbers presented to each ear at the rate of two numbers per second. In contrast to Part 1, subjects heard letters in both ears at the same time. As in Part 1, the subjects reported the triplet as soon as they heard it. Following a pause of five seconds, the next message was presented.

A total of forty-six messages was presented, of which the first six were practice. In order for a subject to start the experimental trials, a criterion of one perfect switch and one perfect no switch practice trial had to be reached. If this criterion had not been reached by the end of the six practice trials, the practice trials were repeated until criterion performance was met. The entire session lasted approximately forty-five minutes.

The trials were designed with several constraints. In order to control for any effects of right ear advantage (Witelson, 1977), an equal number of trials consisted of relevant right ear and relevant left ear listening on the no switch trials at each delay period studied (0, 1, 2, 4, or 6 letters). In the switch trials, there were an equal number of left to right and right to left switches within each type of delay period.

A further constraint was that none of the relevant digits could be used as distractors on the irrelevant message. In pre-testing it was found that the digit eight and the letter A were highly confusable for subjects; neither of them was used in the final tapes. In a similar finding, pilot subjects often reported the letter O for the digit zero; consequently the letter O was dropped from the stimulus materials.

Results. Performance was measured by examining omission errors,
intrusion errors, and total errors (omissions + intrusions). An omission occurred when a subject did not report a target number. An intrusion occurred when he reported a number from the irrelevant channel.

The mean percent error rates for part one and part two were computed for omissions, intrusions, and total errors. Omission errors, intrusion errors, and total error rates for Part 1 can be found in Appendix A. Part 2 error rates can be found in Appendix B.

The ability to sustain attention was measured in Part 1 of this experiment in which the subject listened to a long series of items for target numbers. Older subjects made fewer omission errors, \( F(2, 71) = 32.14, p < .01 \), intrusion errors, \( F(2, 71) = 7.01, p < .01 \), and total errors, \( F(2, 71) = 32.42, p < .01 \) than younger subjects. Newman-Keuls tests revealed that all three age groups were significantly different \((p < .05)\) from each other for omission errors and total errors. The difference in intrusion errors between eight and eleven-year olds was significant \((p < .05)\), as was this difference between eight-year olds and adults. Eleven-year olds and adults did not significantly differ on intrusion error performance.

The ability to reorient attention was assessed by Part 2 performance. Since the pattern of results is the same for omissions, intrusions, and total errors, only total error performance will be discussed in this section. Complete analysis of variance tables for all three measures may be found in Appendices C, D, and E.

A three-way analysis of variance was performed on the data. The factorial design consisted of three levels of age group (eight-year olds,
eleven-year olds, and adults), two levels of switching (switch or no switch), and five levels of filler letters (0, 1, 2, 4, or 6 letters). These data are illustrated in Figure 1.

The most striking aspect of Figure 1 is the large main effect of age group. The mean error rate for eight-year olds was 24.4%, for eleven-year olds it was 12.9%, and for adults it was 4.6%. This difference was highly significant, $F(2, 71) = 35.62, p < .01$.

More errors were made when a subject switched ears from Part 1 to Part 2 (16.6%) than when he stayed on the same ear (10.9%), $F(2, 71) = 20.87, p < .01$. The difference between the switch and no switch conditions was largest in the eight-year olds (11.1%), smaller in the eleven-year olds (3.6%), and smallest in the adults (2.3%). This interaction was significant, $F(2, 71) = 4.96, p < .01$. The younger children seemed to be the most disrupted by the switch.

The more fillers (i.e., the more delay after the warning tone for Part 2), the fewer mistakes subjects subsequently made, $F(4, 284) = 18.67, p < .01$. They had more time to prepare for Part 2. As indicated by the Filler x Group interaction, $F(8, 284) = 3.24, p < .01$, it took considerably longer for younger subjects to make this transition.

This pattern of reorientation can be assessed by examining the difference between the switch and no switch conditions over the delay period occupied by the fillers. The Switch x Filler interaction was significant, $F(4,284) = 5.96, p < .01$. The difference between the switch and no switch conditions was largest at a delay of two filler letters (1.5 seconds) and
Figure 1. Percent errors as a function of switching condition and number of fillers in eight-year olds, eleven-year olds, and adults.
decreased after that point. Perhaps the warning tone upset performance until that point. This hypothesis is supported by the fact that performance generally deteriorated right after the tone in comparison to overall Part 1 performance in both the switch and no switch conditions. Other than the tone, there should have been no reason for performance in the no switch condition to deteriorate. A note of caution is indicated in directly comparing Part 1 and Part 2 performance as a triplet of numbers is monitored in Part 2 as opposed to a series of single numbers in Part 1.

The Switch x Filler x Age group interaction was not significant, $F(8, 284) = 1.40, \ p = .20$, indicating that the overall pattern of reorientation is similar for these age groups. Although the pattern is not significant, it is informative to examine the trends of the difference between the switch and no switch conditions over the delay filler time. The point in time at which there is no longer any difference between the switch and no switch conditions would represent the point at which the subject had completely recovered from the effect of switching and had therefore completely "switched gears."

In the eight-year old group, this recovery was not made within the time frame of the experiment. Even after a delay of six filler letters, the difference between the switch and no switch conditions remained significant ($t = 2.86, \ p < .01$). The eleven-year olds did not completely close this gap either during the time frame of the experiment, although at a delay of four filler letters, the difference between the switch and no switch conditions was no longer significant ($t = 1.63, \ p = .12$). The adults did completely recover from the effect of switching during the time frame of the experiment, as indicated.
by the fact that at a time delay of four fillers the switch and no switch conditions were identical.

Further evidence for older subjects reorienting their attention faster was provided by examining the gap between switch and no switch performance at each delay period. A subject was considered to have "switched gears" if the ratio of switch and no switch performance was less than 1.1. Using this criterion, an individual asymptote was calculated for each subject. If a subject did not asymptote by the six filler delay (the last delay interval), he was assigned an asymptote value equal to an eight filler delay.

The mean asymptote time for eight-year olds was 3.2 seconds, for eleven-year olds it was 2.6 seconds, and for adults it was 2.4 seconds. A Newman–Keuls analysis revealed that eight-year olds and adults were significantly different from each other whereas eleven-year olds were not significantly different from either eight-year olds or adults \( (p < .05) \). From these findings, it is clear that there is a steady progression with age in the ability to rapidly reorient attention in this task.

**Discussion.** This results of the experiment indicate that adults are better both at sustaining their attention in Part 1 and at reorienting their attention in Part 2.

In Part 1, older subjects were better able to correctly report target letters (as measured by omission errors) and refrain from responding to distractors (as measured by intrusion errors) that their younger counterparts. These results are consistent with the hypothesis that the processes of attending to relevant stimuli and ignoring irrelevant stimuli
develop simultaneously. This finding is also consistent with the developmental trend toward greater attentional selectivity as witnessed in the studies using the paradigms discussed earlier.

In Part 2, older subjects were better able to reorient attention from one ear to the other than were younger subjects, as indicated by the fact that the difference in errors between the switch and no switch conditions consistently decreased with age. Older subjects were also able to reorient their attention faster, as indicated by the fact that the point at which there was no longer any difference between the switch and no switch conditions came at shorter delays after the switch in older subjects.

When the results of this experiment are integrated with those of Panek et al., 1978 and Panek and Rush (1981), a lifetime pattern in the ability to reorient attention emerges. It appears that this ability increases from childhood to early adulthood and then declines throughout adulthood, thus a curvilinear relationship exists between age and the ability to reorient attention.

Experiment 2

This experiment was performed in order to study the developmental course of reorientation of attention in the visual mode. In order to assess visual reorientation, a task modeled after Tsal (1983) that measures the movement of attention from one point in the visual field to another was used.

In this task, a subject responds to letters presented on either side of a central fixation point. Shortly before a letter appears, the subject is given a cue indicating the side on which that letter will appear. This cue consists of a
flashing character at either the right or left periphery of the screen.

During the brief stimulus onset asynchrony (SOA) between the presentation of the cue and the target letter, the subject's attention shifts in the general direction of the target. The longer the SOA between the cue and the target, the further attention can travel prior to the onset of the target, the shorter the distance it needs to travel after the target appears, hence the shorter the reaction time needed to identify the letter. At some point in time, the SOA will become long enough so that attention will be able to reach the target area when the target is presented. Any lengthening of the SOA beyond this point will no longer reduce reaction time.

The pattern that should be generated is one in which reaction time declines initially as the SOA increases. At the point at which attention has had sufficient time to arrive at a target area, reaction time will cease to decline and hit an asymptote. It should stay at this asymptote throughout longer SOA's.

Based on the results of Experiment 1 in which older subjects were able to reorient their attention faster, the asymptotic value for older subjects should occur at shorter SOA's if indeed these results are generalizable to a visual modality. This prediction is also supported by the work of Lane and Pearson (1983), who found a developmental increase in the ability to process visual stimuli more rapidly and more accurately. If older subjects are indeed able to process stimuli more accurately, there should be lower error rates at all SOA's for older subjects.

Subjects. Twenty-five third graders (mean age = 8.6 years),
twenty-five fifth graders (mean age = 11.4 years) and twenty-six college students (mean age = 19.6 years) participated in this experiment. The children were recruited from area private schools; the college students were recruited from introductory psychology courses at Rice University. The college students were compensated with class credit for their participation.

**Apparatus.** The visual display was presented on a TRS-80 Model 3 Radio Shack microcomputer. Subjects were seated in front of the computer, and their heads were placed on a chin rest that produced a constant viewing distance of twenty-two inches between the screen and the subject's eyes. Subjects responded to the stimuli by pressing keys on the computer keyboard.

**Procedure.** Each subject was escorted into the experimental room by the experimenter. Children performed the experiment in an unused room in their school building; college students performed the experiment in a research cubicle in the psychology laboratory at Rice. The apparatus was adjusted in such a way as to make the subject's eyes level with the middle of the screen.

The subject was instructed to fixate on a cross that appeared at the center of the screen. He or she was told that a cue would momentarily appear either to the left or right of the cross. Following this cue, a W or an O would appear on the same side on which the cue had appeared. The letter would appear just a little closer in toward the center than the cue had. If the letter was a W, the subject was to press a response key with the left hand; if it was an O, the subject was to press a response key with the right hand. Subjects were told to respond as quickly as possible but were admonished not to make
mistakes.

In an actual trial, a cross appeared at the center of the screen. This cross served as the fixation point. One second following the onset of the cross, an exclamation point flashed to the right or to the left of the cross. This exclamation point served as the cue that a letter would shortly be appearing on that side. The cue was presented at visual angle 1.65° further toward the periphery than the letter. Following a variable interval, the letter appeared for 64 msec and was immediately covered over by a mask. The mask was used to prevent eye movements. The SOA’s between the onset of the exclamation point and the target letter were 50 msec, 83 msec, 150 msec, 200 msec, and 267 msec. These SOA’s were selected on the basis of pilot work. Reaction times were recorded, and subjects were given immediate feedback on the screen regarding their performance.

Each subject was tested in three conditions of peripheral locations of the target, which were counterbalanced between subjects. The target appeared at 2.8° of visual angle from the central location (the near condition), 5.5° of visual angle (the intermediate condition), and at 8.2° of visual angle (the far condition). Each condition consisted of 150 trials in which the two sides of presentation and five SOA’s were equally frequent and presented randomly.

Before the actual experiment began, subjects were given a block of practice trials to acquaint them with the task. The trial condition used in practice was always the medium distance, which had the most similarity to all three conditions. The entire session lasted approximately thirty-five
minutes.

**Results.** Ten eight-year olds and one adult were excluded from the analysis due to excessively high error rates. A three-way analysis of variance was performed on the data. The factorial design consisted of three levels of age group (eight-year olds, eleven-year olds, and adults), three levels of distance of target location (near, intermediate, and far), and five levels of SOA (50, 83, 150, 200, or 267 msec). A complete analysis of variance table for median reaction time performance can be found in Appendix 6.

The criterion used to assess performance was median reaction time. The means of these median reaction times are shown in Appendix F. These data are illustrated in Figure 2.

The main effect of age group was highly significant, $F(2, 62) = 52.03$, $p < .01$, indicating that older subjects responded faster to stimuli than did younger subjects. The main effect of distance was also significant, $F(2, 124) = 16.14$, $p < .01$, indicating that subjects responded more slowly to objects further out in the periphery of the visual field than they did in the center of it. The last main effect, SOA, was highly significant also, $F(4, 248) = 42.68$, $p < .01$, reflecting the fact that response time generally decreased as subjects were given longer intervals between the cue and the target letter.

The decrease in reaction time associated with longer SOA's was greatest in eight-year olds and least in adults, as demonstrated by the Age group x SOA interaction, $F(8, 248) = 5.30$, $p < .01$. This finding is consistent with faster attention movements in older subjects. If attention is moving
Figure 2. Reaction time as a function of age, distance, and SOA in Experiment 2.
faster, it will arrive at its target sooner, and there will not be much gain at longer SOA’s. By contrast, attention movement in younger subjects is slower so that it does not reach goal as rapidly. Longer SOA’s would allow more time for the movement of attention to take place, so further decreases in reaction time will occur at these longer SOA’s.

The same principal explains the Distance x SOA interaction, $F(8, 496) = 8.79, p < .01$. The further out from the center attention must travel, the greater the decline in reaction time associated with longer SOA’s. Since attention must move further in the larger peripheral distances, it will continue to benefit by the longer delays before stimulus onset.

The overall pattern of reorientation of attention in the three age groups is demonstrated by the Distance x SOA x Age group interaction, $F(16,496) = 3.89, p < .01$. By looking at the point at which reaction time no longer declines as SOA increases it is possible to determine the time it takes for attention to reach the target in each of the peripheral locations. This asymptotic value can be determined by assessing the differences in reaction time between successive SOA’s.

In the eight-year old group, reaction time declines in the near condition until an SOA of 150 msec. Unfortunately, it increases from 150 msec to 267 msec. In the intermediate condition, reaction time decreases to an SOA of 200 msec. The decline from 83 msec to 150 msec and the decline from 150 msec to 200 msec are both slightly above conventional significance levels (.09), but it is clear that reaction time between 83 msec and 200 msec is definitely declining. There is a slight increase in reaction time after 200
msec, but this increase is not significant. Reaction time in the far condition continues to decline throughout the time period measured in this experiment; it never asymptotes, indicating that attention never reaches its target.

In the eleven-year old group, the asymptotic value of reaction time for both the near and intermediate conditions occurs at an SOA of 83 msec. Visual inspection of the data in the intermediate condition suggests a further decrease in reaction time between an SOA of 83 msec and an SOA of 150 msec, but this decrease was not statistically significant. In contrast to the younger age group, reaction time in the far condition did asymptote; this asymptote occurred at 150 msec.

In the adult group, the reaction time asymptote occurred in the near condition at a surprisingly late 150 msec. Inspection of the data indicates that several extreme values were responsible for elevating the 83 msec SOA beyond that of the 50 msec SOA. The asymptotic SOA’s of the intermediate and far conditions are 83 msec and 150 msec respectively.

In order to further examine these asymptotes, the asymptotes at each distance were ascertained for each individual subject. A subject was considered to have asymptoted at a particular SOA if his reaction time never dropped sixteen milliseconds below that time in subsequent SOA’s. Using this criterion, the difference between the asymptotic SOA’s for the near and the far conditions was found to be 95 msec for the eight-year olds, 50 msec for the eleven-year olds, and 25 msec for the adults. That is to say, it took 95 msec for attention to move from the near distance to the far distance for the youngest group, half that time for the middle age group, and only a quarter of
that time for the oldest group. Attention is clearly moving faster with age, as indicated by a trend analysis of the linear effect of distance on age group, $F(2, 62) = 3.73, p < .03$.

An analysis of variance identical to the analysis of median reaction time was performed on the error rates associated with the task. A complete analysis of variance summary table can be found in Appendix I.

The mean percent error rates are shown in Appendix H. There were several significant findings. Older subjects made fewer errors than younger subjects, $F(2, 62) = 8.98, p < .01$. Errors increase successively at further distances from the center, $F(2, 124) = 64.98, p < .01$. Errors decreased at longer SOA's, $F(4, 248) = 14.30, p < .01$. Finally, the decrease in reaction time associated with longer SOA's is greater the further out from the center of the screen the target is located, $F(8, 496) = 6.75, p < .01$. No other effects were significant.

Discussion. A clear developmental trend emerges from these data. Attention moves faster in older subjects, as demonstrated by the fact that at a given target distance, attention arrives at the target sooner in older subjects than in younger subjects.

In the far condition, attention never reaches its goal in the 267 msec allotted in this experiment in the eight-year old group. In contrast, attention reaches the far target distance by 150 msec in both the eleven-year olds and the adults. In the intermediate condition, in which attention does not need to travel as far, the eight-year olds' attention manages to reach the target by 200 msec while the older groups reach it by 83 msec. Although the results in
the near condition are not as clear; it seems that the attention of younger children takes longer to reach its target than that of older subjects.

The greatest gain in performance seems to come between age eight and age eleven in this sample. In comparison, the difference in performance between eleven-year olds and adults is not as great. Although overall reaction time is still greater in eleven-year olds than adults, it appears that attention does not arrive at a target any earlier in the adults than in the eleven-year olds.

These findings are consistent with the literature surveyed earlier. The greatest gains in attentional abilities as measured by same/difference judgments (Pick et al., 1972; Pick & Frankel, 1973, 1974; Smith et al., 1975), speeded classification (Smith & Kemler, 1977; Strutt et al., 1975), and selective listening (Hiscock & Kinsbourne, 1980) are made between ages seven or eight and ages eleven or twelve. Further gains in performance between eleven-year old subjects and older subjects have not been found to be as great in either speeded classification tasks (Strutt et al., 1975) or in incidental learning tasks (Hagen & Hale, 1973).

These results are also consistent with the findings of Experiment 1. In addition to older subjects being faster at reorienting their attention, they are also more accurate at doing so, as reflected by their lower error rates.

In summary, then, in the course of normal development, the ability to reorient attention increases from childhood to adulthood. Evidence for this growth was found in both the auditory task studied in Experiment 1 and the visual task studied in Experiment 2.
The ability to focus on relevant stimuli was found to develop at the same time as the ability to ignore irrelevant stimuli in Part 1 of auditory task. In Part 2, there was a steady developmental gain in the ability to reorient attention in each successive age group. A developmental gain in this ability was also noted in the visual task, with a greater increase coming between age eight and eleven than between age eleven and adulthood.
Attention in Children With Attention Deficit Disorder

With Hyperactivity

Hyperactivity, or "Attention Deficit Disorder with Hyperactivity," as it has been formally renamed in the recent Diagnostic and Statistical Manual III (American Psychiatric Association, 1980), is the single most common chronic behavior disorder in preadolescents in America (Ross & Ross, 1982). It has been estimated to affect six to ten percent of the elementary school population (Renshaw, 1974). Far more boys than girls are affected, with sex ratio estimates ranging from 6:1 to 8:1 (Routh, 1983).

As the label ADDH implies, the most serious problem associated with hyperactivity is developmentally inappropriate inattention. According to DMS III, this child frequently fails to finish things he starts, has difficulty concentrating on the task at hand such that he is easily distracted and often does not seem to listen to others. The child is most often diagnosed on the basis of these attentional problems when the freewheeling atmosphere of the preschool playground gives way to the more structured environment of the elementary school classroom.

The hyperactive child is also highly impulsive. He often acts before thinking. He can turn a classroom into a three-ring circus by frequently calling out in class and not waiting his turn in group situations. This child typically is disorganized and requires much supervision (Ross & Ross, 1982).

Perhaps the most vivid symptom associated with the syndrome is that of excessive activity. This child is a virtual whirlwind of activity. He runs about and climbs all over anything—or anyone—in his path. He has trouble
staying seated and fidgets incessantly when forced to do so (Safer & Allen, 1976). He even moves excessively in his sleep (Feingold, 1975). In short, this child never shuts off.

In addition to these major characteristics, hyperactive children are frequently easily frustrated, have low self-esteem, and are emotionally labile (Fine, 1977). They are often at odds with their peers due to tendencies toward bossiness and temper tantrums. Due to their lack of motor coordination, boys in particular may find themselves excluded from group activities (Cantwell, 1975).

The etiology of hyperactivity remains speculative. Different researchers (see Ross & Ross, 1982 for a comprehensive review) have cited genetics, food additives, lead poisoning, arousal disorders, radiation stress, and a generalized maturational lag as possible antecedents for hyperactivity. At this point no definitive cause is known.

More is known about the usual course of the disorder. The onset of hyperactivity occurs before age three and must persist longer than six months in order to be classified as clinical hyperactivity. It is most commonly seen in children ages seven to ten. The symptoms of this disorder may disappear completely at puberty or may persist throughout adulthood in a residual form in which the excessive activity disappears but the attentional difficulties and impulsiveness remain.

Despite the serious and pervasive nature of this disorder, it has only been studied intensively in the last twenty years. Much of this research has focused on the attentional problems associated with the disorder. A great deal of this research has followed directly from the developmental research
reviewed in the last section, and focuses on studies using distraction paradigms, incidental learning tasks, and selective listening tasks. A selective review of these studies will be presented.

Many studies in this area had to be eliminated from this review due to methodological problems. One major problem was that of classification: many studies used children having assorted disabilities in addition to hyperactivity that included everything from mental retardation to all sorts of learning disabilities. Only studies which sampled children of normal intelligence who did not display any form of major learning disability in addition to their hyperactivity were included in this survey.

Many studies of hyperactivity have dealt with the effect of stimulants such as methylphenidate on the behavior of these children. Although a rich literature exists in this area, these studies have not been reviewed because they do not contribute to our understanding of the natural state of attention in these children.

All of the studies mentioned in this presentation used elementary school age children, typically between the ages of seven and ten years old. There is not a wide age spread because hyperactivity is usually not diagnosed until the child reaches the structured classroom setting and because as a group they usually outgrow it at puberty.

Only studies which included children who had been classified as hyperactive on the basis of clinical records or who had been categorized on the basis of standardized hyperactivity tests will be discussed here. Studies that used children who had been evaluated only by teachers as hyperactive have been omitted because teachers' reports of hyperactivity have been
questionable with respect to their accuracy.

The earliest consistent work done in this field used a variety of distraction tasks. One such early study was performed by Browning (1967). Hyperactive and nonhyperactive children were seated in front of a console on which three geometric shapes appeared on each trial. Their task was to determine which one of these stimuli would be rewarded by candy corn, and they responded by pressing buttons corresponding to the forms until a prespecified criterion of correct responses was met. In the experimental, i.e., distraction, condition, multicolored lights flashed on the walls and ceiling surrounding the console; in the control condition, no lights flashed.

The results indicated that only the nonhyperactive children were disrupted by distraction—the hyperactives were not. When the difference in I.Q. between the two groups was controlled for, there were no significant differences between the experimental and control groups in the number of trials it took to reach criterion. It would therefore appear that peripheral distraction resulted in no attention deficit in these hyperactive children.

In a 1971 study, Sykes, Douglas, Weiss, and Minde compared hyperactive and nonhyperactive children that were matched for age and I.Q. (as were all subsequent studies unless otherwise mentioned). They were instructed to monitor a C.R.T. and respond to a prearranged stimulus, which was a specific letter or geometric form. These letters were presented one at a time at a fast pace (one second interstimulus interval) or slow pace (one and one half second interstimulus interval). A distractor condition was created in which 80 decibels of intermittent white noise was piped into the experimental room, while no noise was used in the nondistraction condition.
Although distraction did not affect the number of correct responses made by either hyperactive or nonhyperactive children, the hyperactives made fewer correct responses overall. When the number of errors was analyzed, it was found that the two groups performed at the same level at fast stimulus presentation rates but that nonhyperactives made fewer mistakes at slower presentation rates. Sykes et al. attribute this result to the impulsive nature of the hyperactive child: whereas nonhyperactives apparently take advantage of the extra time, the hyperactives still respond impulsively, thereby making more errors. An alternative explanation is that since both fast and slow presentation rates used 200 stimuli, the trials using the slower presentation rate would have taken longer to complete than the fast rate trials and the hyperactive children may not have been able to sustain their attention throughout this longer session.

Another study which used distractors that were completely extrinsic to the task at hand was performed by Zentall and Zentall (1976). Hyperkinetic children were recruited from a special school, and no mention of subject I.Q.'s was made. No nonhyperactive comparison group was used either. The children were presented with arrays of letters and told to circle the letters in the order of the alphabet. The number of letters they circled was the performance measure.

Subjects performed this task in a "high stimulation" condition in which all sorts of distractors (including strings of blinking Christmas tree lights, Led Zeppelin music, and a cage full of mice) were present. These distractors appeared to have no effect on letter circling performance (a ceiling effect occurred), but the amount of activity (as measured by activity meters
strapped to the children) was substantially reduced in the distractor condition. Zentall and Zentall explained this result as evidence for hyperactive children being underaroused and being "stimulus-seeking" in the low stimulation condition (in which no distractors were present).

Bremer and Stern (1976) used a somewhat similar paradigm. They used hyperactives and matched nonhyperactives in a reading task in which eye movements and reading rate were measured. As in Zentall and Zentall (1976), extraneous visual and auditory distractions (ringing telephones and flashing lights) were introduced into the paradigm. All the children participated in both quiet and distraction conditions.

There were no differences between the groups in reading rates in either condition, but hyperactives tended to be more disrupted by the distracting stimuli, as indicated by their eye movements in the direction of the disruptions. Furthermore, once the hyperactives were distracted, they spent more than three times as long as hyperactives watching the distractors. Bremer and Stern concluded that although the two groups performed similarly on on-task behavior, the hyperactives were more easily distracted by extraneous stimuli. As this result appears to be at odds with previous results, they suggest that it may have been obtained because they were using a very well practiced skill (reading) which did not "lock in" the child's attention.

At this point, only studies that used distractors that were distinctly separable from the experimental task have been reviewed. On the whole, they indicate that hyperactive children are capable of performing well on the given task despite the presence of the distractors. But, what happens when the
distractors become less distinguishable from the task at hand? The next section will review studies which employed intratask distractors, that is to say, distractors that were incorporated into the task at hand.

The trend toward studying intratask distractors began in the 1970's and included examinations of choice reaction time tasks, span of apprehension tasks, and speeded classification tasks.

Sykes, Douglas, and Morgenstern (1973) performed a choice reaction time task in which hyperactives and nonhyperactives were presented with various figures on a C.R.T. to which they responded by pressing a corresponding button. In one condition, special distracting backgrounds to the forms were used. In the other condition, no backgrounds were present. Both groups were distracted by this background, but there was no differential effect on the hyperactives.

Denton and McIntyre (1978) studied the "span of apprehension" in hyperactive and nonhyperactive boys. The span of apprehension is defined as the amount of information processed simultaneously from a brief visual display. In order to measure this span, letter arrays containing the target letter T or F were presented tachistoscopically for 100 milliseconds. The boys could see arrays of one letter (no distractors), three letters (two distractors), five letters (four distractors), or nine letters (eight distractors). The boys reported the letter shown either by saying it aloud or else by pointing to a T or F card on display.

The results indicated that the span of apprehension was equal for hyperactives and controls when the matrix size was one letter (as measured by the number of correct responses). As the number of letters in the visual
display increased, the performance of the hyperactives fell way off to the point where their span was forty-five percent that of the controls when the matrix size was nine. The authors concluded that the hyperactive boys could not process as much information as the nonhyperactives. They speculate that this may reflect an underlying deficiency in the central processing mechanism that "extracts, analyzes, and encodes" information from brief visual displays.

In order to further evaluate the role of information processing in hyperactive children, McIntyre, Blackwell, and Denton (1978) performed a follow-up study that used some distractor letters that were physically similar (i.e., highly distractible) to the target and some which were physically dissimilar (not very distractible) to the target. The task was exactly the same as in Denton and McIntyre (1978), with the exception that only the nine letter matrix size was used.

The span of apprehension was lower for hyperactives than for nonhyperactives by about seventeen percent (which was a significant difference). Both groups were able to make use of the distractor–signal dissimilarity to increase their spans, but there was no greater distraction of the hyperactives in the higher distraction condition (when the targets and distractors were highly similar). From this follow up, it would seem that the hyperactives can process similarity information as well as nonhyperactives, but they are unable to deal with the same amount of information as their peers.

were told to pay attention to a specific level of a dimension (for instance, a triangle). On different trials they could see the stimuli with no irrelevant dimensions, or with varying irrelevant dimensions. The child responded by pressing one button if the target stimulus was present, and another if it was not. Finally, a hierarchy of dimensional salience was constructed for each child.

When no irrelevant information was present, both groups made the same number of errors. Also, no group differences were found when the irrelevant dimension's salience was low. However, when the irrelevant dimension was particularly salient to the child, the hyperactives were not able to ignore the distracting dimension and wound up making more errors than their nonhyperactive counterparts.

Along this line, Schnedler, Pelham, Bender and Pass (1981) performed the same task without taking into account perceptual salience, and found no differences in performance between hyperactives and nonhyperactives.

Radosh & Gittleman (1981) expanded upon this idea and created distractors that were intentionally distracting. In this task, hyperactives and matched controls performed arithmetic problems. There were three levels of appeal in the distractors. In the no appeal condition, the arithmetic problems were presented by themselves. In the low appeal condition, the arithmetic problems were bordered by colorful pictures without meaningful context. In the high appeal condition, the problems were bordered by colorful pictures of items such as animals, toys, and spacecraft. All the children performed all conditions.

When the mean number of errors on the arithmetic task was measured,
hyperactives were found to be more affected by the borders than nonhyperactives. From these results it seems that hyperactive children are more easily distracted when the distractors have a special appeal to them, providing support for the salience research of Rosenthal and Allen. It also echoes the developmental salience work of Odom (1972).

In contrast to the research using intertask distractors cited previously, the research using intratask distractors provides more evidence for an attention deficit in hyperactive children. Hyperactive children have more trouble than their nonhyperactive peers in "fishing out" a target when it is surrounded by numerous distractor letters (Denton & McIntyre, 1978). This inability to focus their attention is particularly apparent when the distractors are particularly salient or appealing to the child (Rosenthal & Allen, 1980; Radosh & Gittelman, 1981).

Another paradigm that has been used to study attention in hyperactive children is the incidental learning paradigm. Peters (1977) adapted the "picture order task" from the basic incidental paradigm developed by Hagen (1967). In this task, cards containing pictures of animals and household objects are presented to the children in a particular order. The children are told to remember the position of the animal and not to bother with the household objects. The cards are then covered and the child is asked to recall the position of a given animal (the central recall measure). As a test of incidental recall, the child is asked to pair the household objects with the animal pictures that had originally been paired with them. Peters also included a nondistraction condition in which the animal pictures were presented by themselves.
Peters first compared the number of animal pictures remembered in the nondistraction and distraction conditions, and surprisingly found no difference in performance between the two conditions. It seems that the distractors had no effect on central memory scores for either group. When the incidental memory scores of the hyperactives and nonhyperactives were compared, no significant differences emerged. Peters concluded that there was no attentional deficit for the hyperactives on this task.

Ceci and Tishman (1984) modified the Hagen task by varying the proximity of the incidental information to the central information. Subjects were presented with cards containing a central stimulus that they were told to remember. There was additional information that ranged from being in close proximity to the central stimulus (e.g., a worm in the bird’s mouth) to being very remote to it (pictures posted on the walls).

Nonhyperactive children were superior to hyperactive children on central recall. On the other hand, hyperactive children were superior to nonhyperactive children at recognizing missing incidental information when presented with cards that were slightly altered versions of the original cards. The hyperactives were also better at recalling the posted pictures. Ceci and Tishman concluded that attention of the hyperactive children was more diffuse than that of nonhyperactive children.

The findings from the incidental learning literature is obviously mixed. Peters (1977) found no differences in performance between hyperactives and nonhyperactives, whereas Ceci and Tishman (1984) did. Due to the lack of further comparison studies, these findings are at best inconclusive. If they indeed have attention deficits, it is quite surprising that hyperactive children
show no differences in performance on the Hagen task (Peters, 1977), which has detected consistent developmental differences.

The last paradigm that will be discussed in this section is that of selective listening. In an influential study, Davidson and Prior (1978) studied selective attention in hyperactive and nonhyperactive children by using a dichotic listening task in which subjects listened to two words (one word to each ear) through earphones. They were precued as to which word to repeat by lights that randomly flashed on either their left or right side. In this particular task, the distractor is the channel that is not cued.

Both hyperactive and nonhyperactive groups showed a significant right ear advantage, reflecting the verbal superiority of the left cerebral hemisphere (Geffen & Wale, 1977; Hiscock & Kinsbourne, 1977). As there was no difference between the groups on overall task performance, the hyperactive children did not appear to have an attentional deficit compared to the control group.

Peters (1977) performed a similar dichotic listening task modeled after Doyle (1973) that required subjects to recognize the target words in subsequent tests. In this task, hyperactives and nonhyperactives listened to two lists of words. The target list was always spoken by a male voice, and the distracting list was spoken by a female voice. Subjects were instructed to repeat each target word as they heard it. Following the shadowing task, the target words were presented in a recognition task in which the target word would appear on a card with three other words (a semantic word associate, a phonemic associate, and a word from the distractor list). This recognition test was designed to measure the extent to which the subject was able to focus
on the target list while excluding the distractor list.

As in Davidson and Prior (1978), there were no significant differences in performance between hyperactives and nonhyperactives on the shadowing task. The hyperactives did however make more intrusion errors than their nonhyperactive peers. On the recognition test, the hyperactive children were found to recall fewer of the target words than the nonhyperactive children. Although they recalled less central information, there was no difference between the groups on the incidental memory measure.

As with the younger subjects in the Doyle (1973) study, these two tests yielded discrepant results: although the hyperactive children were distracted by the irrelevant channel in the listening task (as indicated by their higher intrusion error rate), they did not recall more of this information on the recognition task. Peters uses a logic similar to that of Doyle to explain his finding: he states that although hyperactive and nonhyperactive children are aware of the distracting stimuli to the same degree (as indicated by the recognition task), the impulsive hyperactive children are not able to inhibit responding to the distracting voice when they hear it. An alternative explanation would be that hyperactive children do process more of this distracting information but are unable to retrieve it later on.

Loiselle, Stamm, Maltinsky, & Whipple (1980) used a slightly different type of dichotic listening task. On one channel, hyperactives and nonhyperactive controls heard a series of tone pips of 800 Hz as a background signal and 840 Hz as the target signal; in the other ear the background tone was 1500 Hz and signal was 1560 Hz. As indicated by these frequencies, it was very difficult to distinguish between the background and the signal for a given
ear. The children were instructed to listen for signal tones and depress a lever as fast as they could.

The hyperactives made fewer correct responses than nonhyperactives on this task, and they also made more "commission" responses. A commission response was one in which the child finally pressed the lever at a long latency after a signal tone, after an irrelevant tone was sounded. Finally, the hyperactives took significantly longer to respond to the tones than did their nonhyperactive counterparts, as measured by mean reaction time. These results indicate that hyperactive children do not perform as well on a task that requires very careful attention.

In a recent study, Prior, Sanson, Freethy, and Geffen (1985) studied selective listening using a task developed by Sexton and Geffen (1979). In this task, dichotic listening performance is measured under divided attention instructions (listening for the target on both ears) and under focused attention instructions (listening to the target on only one ear). Additionally, performance was studied in blocks in order to assess the ability to sustain attention.

Irrespective of the instructional set, hyperactive children did not demonstrate any significant deficits in the ability to sustain attention throughout the blocks of the experiment. A signal detection analysis revealed a significantly lower sensitivity to the targets in the hyperactive children, which would tend to indicate a lower capacity for target detection. These findings resemble the developmental differences noted previously by Geffen and her colleagues (Geffen & Sexton, 1978; Geffen & Wale, 1979; Sexton & Geffen, 1979), and the authors conclude that these differences suggest a
"qualitatively immature performance" by the hyperactive children.

Of the major research areas reviewed, the selective listening studies seem to present the most consistent evidence for attentional deficits in hyperactive children, although again, at least one study (Davidson & Prior, 1978) found no differences. Differences in performance between hyperactives and nonhyperactives seem to be most likely to occur when the task is more difficult, such as having to make very fine discriminations between targets and nontargets (Loisel et al., 1980) or having to listen to a long string of items for a target (Prior et al., 1985) than when the task is relatively easy, such as repeating a single word that is presented to each ear (Davidson & Prior, 1978).

As with the developmental literature, selective attention in hyperactive children has been assessed in a variety of paradigms, but the ability to rapidly reorient attention has not. The studies presented here, therefore, examined reorientation using auditory and visual tasks. If hyperactive children are worse at reorienting attention than nonhyperactive children, their performance should be more disrupted by a switch in the focus of attention and they should have more trouble getting back on track following the switch.

In order to explore this hypothesis, the same auditory task used in Experiment 1 was used in Experiment 3 to study the reorientation of attention in hyperactive and nonhyperactive children. If hyperactive children are unable to focus attention on the task at hand, they should make more omission errors—they will not be able to concentrate on the targets and they will "skip by" undetected. If hyperactive children are easily distracted, they should
make more intrusion errors as their attention is drawn to the irrelevant channel.

It was also possible to study two facets of attention using this task. The inability to sustain attention was measured by Part 1 performance, in which subjects listened to a long list of letters and numbers for targets. The ability to reorient attention was measured by Part 2 performance, in which subjects reported a triplet of numbers after they had either switched ears or had stayed on the same ear from Part 1. Finally, it was possible to analyze the pattern of reorientation—how long it took for the hyperactives to get "back on track" following the switch.

Experiment 3

Subjects. Twenty-two hyperactive boys and three hyperactive girls were recruited from a summer program for hyperactive children and from the hyperactivity clinic of a large metropolitan hospital. All of these children had been formally diagnosed as having Attention Deficit Disorder with Hyperactivity (314.01, DSM III). All of these children were of normal intelligence, had no other major disturbances, and were not medicated at the time of testing. The mean age of their group was 10.4 years and the mean I.Q. as measured by the Peabody Picture Vocabulary Test (PPVT) was 107.

Twenty-five children matched for sex, age (mean age = 10.3 years), and I.Q. (PPVT = 109) formed the nonhyperactive comparison group. These children were recruited from area schools.

Apparatus. The apparatus was identical to that used in Experiment 1.

Procedure. The procedure was identical to that of Experiment 1. The hyperactive children were tested in the research cubicles at Rice University;
the nonhyperactive children were tested in an unused room in their school building.

Results. As in Experiment 1, performance was measured in terms of omission errors, intrusion errors, and total errors. The means of these three types of errors were computed for both Part 1 and Part 2. Part 1 error rates can be found in Appendix J; Part 2 error rates can be found in Appendix K.

The ability to sustain attention over a series of items was measured by Part 1 of this task. The effect of group was highly significant such that hyperactive children made more omission errors (52.4% vs. 29.5%), $F(1, 48) = 25.88, p < .01$, more intrusion errors (16.4% vs. 2.2%), $F(1, 48) = 27.68, p < .01$, and more total errors (28.4% vs. 11.3%), $F(1, 48) = 40.43, p < .01$, than their nonhyperactive counterparts. Apparently the hyperactive children were unable to focus their attention on the relevant channel as well as the nonhyperactive children were.

The ability to reorient attention was assessed by Part 2 performance. Again, as the pattern of results for omissions, intrusions, and total errors is similar only total error performance will be discussed with a few exceptions. Complete analysis of variance tables for all three measures can be found in Appendices L, M, and N. The analysis of variance that was used to analyze these data was identical in design to that used in Experiment 1, with the exception that there were only two levels of group (hyperactives and nonhyperactives). These data are illustrated in Figure 3.

The largest effect was that of group, $F(1, 48) = 20.46, p < .01$. The mean total error rate for hyperactives was 35.9%, nearly twice that of the
Figure 3. Percent errors as a function of switching condition and number of fillers in hyperactive and nonhyperactive children.
nonhyperactives, 19.3% Both groups made about twice as many omissions as intrusions, with the hyperactives making significantly more omission errors, $F(1, 48) = 17.18, p < .01$, and more intrusion errors, $F(1, 48) = 12.10, p < .01$.

The main effect of switching was also highly significant, $F(1, 48) = 19.86, p < .01$ such that overall, subjects made more mistakes when they switched ears between Part 1 and Part 2 (34.2%) as when they stayed on the same ear (21.0%). The difference between the switch and no switch condition was slightly higher for the hyperactive children (14.4%) than the nonhyperactive children (11.9%), but this difference in performance between the two groups was not significant, $F(1, 48) = 0.16, p = .69$.

The main effect of fillers was significant, $F(4, 192) = 10.21, p < .01$. The more filler letters subjects heard before the onset of the critical message in Part 2, the fewer errors they made in Part 2. The nonhyperactive children seemed to be better able to take advantage of this delay than were the hyperactives: following an initial increase in errors (that was also seen in Experiment 1), the nonhyperactive children showed a steady decrease in error rate as the delay interval lengthened whereas the hyperactive children were erratic, with their error rates increasing between some intervals and decreasing between others. Despite this difference, the Filler x Group interaction did not reach significance, $F(4, 192) = 1.59, p = .18$.

The pattern of reorientation can be analyzed by examining the difference in performance between the switch and no switch conditions at each delay interval (number of fillers) after the tone for Part 2. The Switch x Filler interaction was significant, $F(4, 192) = 7.10, p < .01$. As in Experiment 1, the
difference between the switch and no switch conditions was maximized at a
delay of two filler letters and declined after that.

The pattern of reorientation was not significantly different between the
two groups, as indicated by the Switch x Filler x Group interaction. This
interaction was marginally significant for intrusion errors $F(4, 192) = 2.29,$
$p = .06$, but was not significant for omission errors, $F(4, 192) = 1.38, p = .24$.

As in Experiment 1, the difference between switch and no switch
performance at each delay interval was computed for both groups in order to
determine the point at which there was no difference between switch and no
switch performance. At this point, the subject could be said to have "switched
gears" and be on track again.

In the nonhyperactive group, there was a steady decline in the
difference between switch and no switch performance from the two filler
delay interval on for both omission and intrusion errors. At the longest delay
measured in this experiment (six filler letters), this difference was no longer
significant for omission errors ($t = 1.99, p = .06$) and only marginally
significant for intrusion errors ($t = 2.07, p = .05$). This group had just about
closed the gap by the end of this time period and had therefore just about
"switched gears."

By contrast, in the hyperactive group, the difference between switch
and no switch performance increased steadily from the two filler to the six
filler delay for intrusion errors. In the case of omissions, it declined from
two to four fillers and then increased from four to six fillers. The difference
between switch and no switch performance at the longest delay interval
interaction was highly significant for both omission errors ($t = 1.47, p < .01$)
and intrusion errors \((t = 3.35, \ p < .01)\). Instead of closing the gap at this point, the hyperactives were widening it. They were clearly not recovering from the effect of switching, even at the longest delay measured in this experiment.

Discussion. The results of this experiment indicate that hyperactive children show some deficits as compared to nonhyperactive children at both sustaining their attention in Part 1 and in reorienting their attention in Part 2.

In Part 1, the hyperactive children missed more targets than did the nonhyperactive children. These findings would tend to indicate that they were not able to focus as well as the nonhyperactives on the relevant channel. The hyperactive children also made more intrusion errors, indicating that they were not as able to filter out irrelevant information as were their nonhyperactive peers.

In Part 2, the hyperactive children again made significantly more omission and intrusion errors. It is inappropriate to conclude solely on this basis that there are reorienting problems in this group. To the contrary, although hyperactive children were slightly more upset by switching than were the nonhyperactive children, this difference was not significant.

The best evidence for reorienting problems in hyperactive children was found in examining the trends of the Switch x Filler x Group interaction. While nonhyperactive children were steadily closing the gap between performance in the switch and no switch conditions for both omission and intrusion errors, hyperactive children showed no indication of doing so. Instead of closing the gap at the largest delay period, they were widening it. From these results, it seems that once hyperactive children have been thrown off by switching, their
performance does not recover. Nonhyperactive children do make such a recovery and are therefore capable of "switching gears." Caution should be taken in interpreting these results, however, since the three-way interaction was only marginally significant for intrusion errors and not significant for omission errors.

At any rate, these findings are consistent with the previous literature in which hyperactive children were not as capable as their nonhyperactive peers of controlling the focus of their attention. This task required very careful attention, as in Loiselle et al. (1980), and clearly differentiated between hyperactive and nonhyperactive children.

Of particular interest was the fact that the difference in the pattern of reorientation between the hyperactives and the nonhyperactives resembled the difference found in Experiment 1 between the younger and older subjects. In the case of the nonhyperactive and the older subjects, the difference between switch and no switch performance was either identical or not significantly different by the end of the last delay interval measured. In the case of hyperactive and younger subjects, this gap was not closed by the end of the last delay interval and showed no sign of closing—indeed, the gap between switch and no switch performance was actually growing between the four and six filler interval for the youngest children in Experiment 1 and the hyperactive children of Experiment 3. These findings concur with those of Prior et al. (1985), who found the performance of hyperactive children to be "qualitatively immature" to that of nonhyperactive children.

Experiment 4

This experiment was performed in order to assess the reorientation of
attention in the visual mode by hyperactive and nonhyperactive children. Prior et al. (1985) have speculated that there may be differences in the pattern of attention between auditory and visual modalities in hyperactive children. They suggest that hyperactive children may have more problems in the visual modality because processing in this mode is generally less structured and less predictably paced.

Differences in visual attention between hyperactive and nonhyperactive children were studied using the same task used in Experiment 2. If the hyperactive children demonstrate the difficulty and delay in reorienting attention that they did in Experiment 3, it would be reasonable to predict that their asymptotic SOA's (the point at which attention has been completely reoriented) should be longer than the asymptotic SOA's of nonhyperactive children. This prediction could also be drawn from the developmentally immature pattern that arose in Experiment 3: if the attention of hyperactive children is "qualitatively immature" compared to that of nonhyperactive children, the differences between these two groups should mirror the differences between older and younger subjects in Experiment 2.

Subjects. Eleven hyperactive boys and one hyperactive girl were recruited from the hyperactivity clinic of a large metropolitan hospital. All of these children were of normal intelligence, had no other psychiatric disturbances, and were not taking any medication at the time of testing. The mean age of this group was 9.8 years, and the mean IQ (as measured by the PPVT) was 104.

Twelve children matched for sex, age (mean age= 10.0 years), and IQ (mean IQ as measured by the PPVT= 105) formed the nonhyperactive
comparison group. These children were recruited from area schools.

**Apparatus.** The apparatus was identical to that used in Experiment 2.

**Procedure.** The procedure was identical to that of Experiment 2. The hyperactive children were tested in the research cubicles at Rice University; the nonhyperactive children were tested in an unused room at their schools.

**Results.** Three hyperactive boys and three nonhyperactive boys were excluded from the data analysis due to excessively high error rates. The remaining hyperactive group had a mean age of 10.3 years and a mean IQ of 105 (PPVT). The remaining nonhyperactive group had a mean age of 10.4 years and a mean IQ of 106 (PPVT).

A three-way analysis of variance was performed on the data. The factorial design was identical to that of Experiment 2, with the exception that there were only two levels of group (hyperactive and nonhyperactive). The criterion used to assess performance was again median reaction time. The means of these median reaction times are shown in Appendix O. A complete analysis of variance table for median reaction time performance can be found in Appendix P. These data are illustrated in Figure 4.

The main effect of group missed conventional levels of significance, $F(1, 16) = 3.68, p = .07$, with hyperactive children responding more slowly to stimuli than nonhyperactive children. The main effect of SOA was highly significant, $F(4, 64) = 12.58, p < .01$, reflecting the fact that response time tended to decrease at longer SOA’s.

Surprisingly, the main effect of distance was not significant, $F(2, 32) = 1.62, p = .21$. Subjects responded faster to stimuli in the intermediate distance than the near distance. This finding can probably be explained by the
Figure 4. Reaction time as a function of age, distance and SOA in Experiment 4.
fact that a preponderance of the nine subjects remaining after the high error rate subjects were excluded performed the near condition first. Lack of practice in this first condition apparently resulted in longer reaction times in this small sample size.

The Group x SOA interaction missed statistical significance, $F(4, 64) = 2.21$, $p = .08$, indicating that although the decrease in reaction time that is associated with longer SOA's is slightly larger in hyperactive children than in nonhyperactive children, this difference is not significant. As in Experiment 2, this finding would be consistent with faster attention movement in nonhyperactive subjects. If attention moves faster in these subjects, it will arrive at its goal earlier and there will not be much gained at longer SOA's.

Associated reasoning explains the Distance x SOA interaction, $F(8, 128) = 3.13$, $p < .01$. The further out from the center that attention must travel, the greater the decline in reaction time associated with longer SOA's. As in Experiment 2, attention movements will have longer to reach their goal in the longer SOA's, so reaction time in these longer SOA's will continue to decline.

The overall pattern of reorientation of attention is revealed by the Distance x SOA x Group interaction, $F(8, 128) = 1.48$, $p = .17$. The sample size was too small to show as clear cut a trend as was demonstrated in Experiment 2, but this interaction does not reveal any significant differences in the switching abilities of hyperactive and nonhyperactive children.

The time it takes attention to reach the target in each peripheral location can be assessed by looking at the assymptotic SOA values at that
location. Although t-values of successive reaction times were computed as a way of determining this asymptotic value, due to small sample size, it seems prudent to simply examine the pattern of successive reaction times visually.

In the hyperactive group, reaction time reached a minimum at 150 msecs for both the near and medium distances and then increased from 150 msec to 200 msecs, followed by a subsequent decline. This pattern is difficult to interpret. Perhaps these children cannot judge where to stop in the target area. If they hit the target area at 150 msecs and attention kept on moving beyond this area, reaction time would be longer at 200 msecs because they would have to come back to the center to compensate for this overshooting. Reaction time in the far condition did not seem to asymptote within the time frame of this experiment.

The pattern of attention in the nonhyperactive children is somewhat more coherent. Attention movements appear to have asymptoted in the near condition at 150 msecs, as in the hyperactive children. Unlike the hyperactive children, no asymptote was reached in the intermediate distance, indicating that attention had not yet reached its goal. In the far condition, the performance of the nonhyperactive children again mirrored that of the hyperactive children in that no asymptote was reached.

An analysis of individual asymptotic values (as in Experiment 2) revealed no differences in attention movements between the two groups. The effect of the linear trend of distance on group was not significant, F(1,16) = .05, p = .81. It took hyperactive children 56 msec longer to move attention to the far distance as compared to the near distance; this difference was 67 msec for nonhyperactive children.
An analysis of variance identical to the one mentioned above was performed on the percent error rate scores. The means of these error scores are shown in Appendix G. A complete analysis of variance summary table can be found in Appendix R.

The results were similar to those associated with the reaction time data. Hyperactive subjects made more errors than nonhyperactive subjects, $F(1, 16) = 11.84$, $p < .01$. Errors decreased at longer SOA's, $F(4, 64) = 9.15$, $p < .01$. In contrast to the reaction time data, errors consistently increased at successively further distances from the center, $F(2, 32) = 21.13$, $p < .01$. Lastly, the decrease in reaction time associated with longer SOA's was greater the further out from the center the target was located, $F(8, 128) = 2.57$, $p = .01$. No other effects were significant.

**Discussion.** It is difficult to draw many solid conclusions from this data due to the small sample size. Hyperactive children definitely made more errors than their nonhyperactive peers, reflecting their impulsive nature. All other effects associated with the two groups indicated that they were not significantly different in performance.

In Experiment 3, the difference in the pattern of reorientation between hyperactive and nonhyperactive resembled the developmental differences found in Experiment 1. Since no differences in performance between the two groups occurred in this experiment, no evidence for a "qualitatively immature" performance of hyperactive children was found.

If any difference exists in the pattern of reorientation between these two groups, it is that the hyperactive children were more inconsistent in their performance than the nonhyperactive children. In the near and intermediate
distances it seemed that the attention of these children "bounced around" such that they overshot the target and came back to it. This same pattern of attentional waxing and waning was seen in Experiment 3, in which the difference between the switch and no switch conditions appeared to close and then to widen at longer delays. In contrast, once the normal children closed the gap it stayed closed.

These trends were not significant, and only future study with greater numbers will be able to detect any differences that were not detected in the present study. This lack of a difference is not consistent with Prior et al.'s (1985) speculation the differences in performance between hyperactive and nonhyperactive children would most likely be detected in visual tasks. At the same time, they said that most visual tasks that had been used in the previous literature were less structured and less predictably paced than the audio tasks previously studied. In contrast, the visual task that was used in this study was highly structured and very predictably paced. As such, it may have "locked in" the attention of the hyperactive children as few previous tasks have done. What may have previously been interpreted as a modality difference may simply be a difference in task demands.
General Summary

There is clearly a developmental gain in the ability to reorient attention in both the auditory and the visual modalities. In Experiment 1, the performance of the youngest children was the most upset of all groups when they were instructed to switch their attention from one ear to the other. After the switch younger subjects required longer delays to reorient. Even at the longest delay time examined in this experiment, the eight-year olds had not yet recovered to the point where their switch and no switch performances were no longer significantly different, (in fact, the difference in performance between switch and no switch performance was actually growing larger at the longest delay interval). The eleven-year olds had just about reached that point by the end of the time frame of the experiment, and the adults had reached it rather early on during the experiment.

This more rapid reorientation of attention in older subjects was again demonstrated in Experiment 2, this time in the visual modality. At each distance, there was a developmental trend such that older subjects generally were able to reach that distance faster than each successively younger group. An individual analysis of the asymptotic values at each distance revealed that adults took half as long to travel the distance between the near location and the far location as did the eleven-year olds. The eleven-year olds in turn took half as long to cover this distance as did the eight-year olds.

Having solidly demonstrated a developmental progression in the ability
to reorient attention, the focus of this presentation shifted to a special group of children with attention deficits. The purpose of this shift was to investigate the nature of attention in hyperactive (ADDH) children.

Attention switching in the auditory modality for hyperactive and nonhyperactive children was studied in Experiment 3. Following the switch, nonhyperactive children were temporarily thrown off balance but eventually reoriented to the correct ear. The hyperactive children were also thrown off course, but never seemed to reorient correctly. There was a pattern of waxing and waning over the different time delays such that they appeared to be reorienting and then would become more disoriented. Once they were disrupted by a switch, they did not appear to get permanently back on track, at least not within the time frame of Experiment 3.

Experiment 4 assessed attention in the visual modality in hyperactive and nonhyperactive children. Previous literature had suggested that hyperactive children may have more problems with visual processing, and this experiment sought to examine that hypothesis. It had also been noted that the hyperactive children in Experiment 3 performed in a similar manner to the youngest children in Experiment 1, and it was wondered if the hyperactive children in the visual task would display the developmentally immature pattern that they had in the auditory task.

Neither of these hypotheses was supported in Experiment 4; the hyperactive and nonhyperactive children demonstrated a similar pattern of reorientation in this visual task. It was suggested that the modality differences that had been noted by previous researchers may well have been a difference in task demands. In this task, which contained discrete trials,
elicited the child's attention on every trial, was continuously reinforcing, and was very predictably paced, the hyperactive children were easily able to perform as well as their nonhyperactive peers in reorienting their attention.

If these experiments were to be replicated in future research, the delays periods which were used to monitor reorienting performance would have to be extended. Although pilot work indicated that these delay periods would be satisfactory to study the complete course of reorientation in all the groups studied in this presentation, this clearly was not the case. The youngest children were not able reorient in some of the conditions of the visual or auditory tasks. The hyperactives did not reorient in the auditory task; much longer delay periods would reveal whether they ever reorient or simply take much longer than their nonhyperactive children to do so.

Another extension of this work for future research would be to do this visual task in older adults. By combining the results of Experiment I with those of Panek and his coworkers, a curvilinear relationship between age and the ability to reorient attention in the auditory modality was demonstrated. Perhaps a similar relationship exists for visual processing.

In summary then, an unambiguous developmental pattern was found in the ability to reorient attention such that older subjects reorient faster and better than younger subjects. The pattern of reorienting for hyperactive children was not as unambiguous. Although these children appear to have some difficulties reorienting attention in the auditory task studied here, they did not have any discernable difficulties in the more enjoyable visual task. Attentional abilities in these children seem to be highly dependent upon the particular task demands of a given situation.
Reference Note

References


Appendix A

Mean Percent Error Rates in Part 1 of Exp. 1

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Appendix B

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## Appendix C

### Analysis of Variance Summary Table

#### Part 2 Omission Errors, Experiment 1

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### Appendix D

**Analysis of Variance Summary Table**

**Part 2, Intrusion Errors, Experiment 1**

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Appendix E

Analysis of Variance Summary Table

Part 2 Total Errors (Omissions + Intrusions), Experiment 1

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Appendix F

Median Reaction Time, Exp. 2

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Appendix G

Analysis of Variance Summary Table

Median Reaction Time, Experiment 2

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### Appendix H

Mean Percent Error Rate, Exp. 2

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### Appendix I

#### Analysis of Variance Summary Table

**Mean Percent Error Rate, Experiment 2**

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Appendix J

Mean Percent Error Rates in Part 1 of Experiment 3

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Appendix K

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Appendix L

Analysis of Variance Summary Table

Part 2, Omission Errors, Experiment 3

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## Appendix M

### Analysis of Variance Summary Table

#### Part 2, Intrusion Errors, Experiment 3

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Appendix N

Analysis of Variance Summary Table

Part 2 Total Errors (Omissions + Intrusions), Experiment 3

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Appendix O

Median Reaction Time, Experiment 4

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### Appendix P

**Analysis of Variance Summary Table**

**Median Reaction Time, Experiment 4**

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<th>Total Prob.</th>
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Appendix Q
Mean Percent Error Rate, Experiment 4

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### Far Distance

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Appendix R

Analysis of Variance Summary Table

Mean Percent Error Rate, Experiment 4

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