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LATERAL DIFFERENCES IN REACTION TIME TO VERBAL AND NON-VERBAL AUDITORY STIMULI IN CHILDREN

by

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ABSTRACT

LATERAL DIFFERENCES IN REACTION TIME TO VERBAL AND NON-VERBAL AUDITORY STIMULI IN CHILDREN

by

Elayne Helfgott

Adviser: Professor Tina Moreau.

The present study investigated lateral differences in simple manual reaction time (RT) to verbal and non-verbal sounds when these stimuli were monaurally presented to 5 to 10 year old children. Seventy-one male and female children, 20 in kindergarten, 25 in second grade, and 26 in fourth grade were studied. All subjects were of average school achievement and were right-handed as ascertained by a handedness inventory. The taped stimuli were the words 'run' and 'jump', the sound 'nur' ('run' in reverse), and a sinusoidal 200 Hz. tone. The order of the stimuli and the ear of presentation were inter-dispersed to avoid attentional set. The children responded to the stimuli by lifting the index fingers of both hands from telegraph keys as soon as they heard the stimuli.

The results of a four-way analysis of variance indicated a statistically significant faster response to stimuli presented to the right than to the left ear. This right ear advantage (REA) occurred for all four stimuli at all grade levels. No age differences or gender differences were found for the ear advantage. In addition, only for the boys, there was a faster

RT with the left hand to all stimulus sounds. The results of the study were discussed in terms of Kinsbourne's attentional model.

To my mother and father

Gussie and Milton Helfgott

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Last, but most important, I thank Myles, my husband of six months, who has endured what must seem to be twenty years of writing and redrafting this thesis. Without his support and love, this labor might have taken twenty years in fact.

I dedicate this dissertation to my beloved parents, who encouraged me throughout my years of schooling and have provided me with the ideals to live up to.

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Introduction

The development of the functions of the two cerebral hemispheres has been the subject of many theoretical discussions (Kinsbourne & Hiscock, 1977; Lenneberg, 1967; Moscovitch, 1977) as well as the basis of numerous empirical studies (see Witelson, 1977). It is possible to use lateral stimulation of the auditory system to investigate hemispheric specialization because of the greater percentage of auditory fibers that connect each ear to the opposite side of the brain than to the same side. Responses to lateral stimulation of the auditory system are often used as indicators of hemispheric functioning, so that responses to right ear stimulation are indicative of left hemisphere function and responses to left ear stimulation imply processing by the right hemisphere. Because of the inference from auditory asymmetry to brain function, the method of laterally stimulating the two ears is frequently used to study hemispheric function.

Most investigations of the development of hemispheric functions with auditory stimulation have focussed on the language functions of the left hemisphere; fewer studies have examined the functions of the right hemisphere. The difficulties in identifying the non-language and language processing differences of the two hemispheres in tasks that involve recognition, memory and complex discrimination, are manifold. Until recently, most studies with young children used tasks of this nature and thereby confounded input, processing and output variables. In studies with adults, numerous attempts have been made to separate response factors from processing differences; (Fry, 1974; Morais & Darwin, 1974; Springer, 1971). However, few studies using children have considered the possible confounding influences of memory and of the type of response on observed ear differences.

The present study investigated lateral differences in reaction time to verbal and non-verbal sounds presented monaurally to 5 to 10 year old children. The rationale for this study stems from the early and ongoing research into lateral differences between the cerebral hemispheres in the adult, as well as from the more recent studies of the developmental course of these differences.

Evidence for the presence of left-right differentiation of the cerebral hemispheres for language function in adults has derived from various sources. Clinical observation was the earliest method used to document cases that showed language to be asymmetrically represented in the two cerebral hemispheres. Dax, in 1836 (cited in Oppenheimer, 1977), observed that right-handed patients who had sustained damage to the left cerebral hemisphere exhibited loss of speech. In 1861, Broca (cited in Oppenheimer, 1977) localized the third frontal convolution of the left hemisphere (in right-handed patients) as the area which, when damaged, resulted in motor speech disturbance. Broca's evidence for the control of speech by the left side of the brain in right-handed people sparked the beginning of the concept of cerebral dominance, i.e., the idea that the hemisphere contralateral to the preferred hand was dominant for language and other cognitive functions.

Soon after the concept of cerebral dominance was advanced, Hughlings Jackson (1864, cited in Searleman, 1977) challenged the assumption of dominance based solely upon the association of aphasia with left hemisphere injury. Jackson argued that left hemisphere superiority for language in right-handed people did not mean that all mental functions are controlled by the left hemisphere. Rather, he claimed that the left hemisphere is specialized for analytic processing, and, that language, by virtue of its analytic nature, is processed more efficiently by the left than by the right hemisphere. The emotional components of language, according to Jackson, are processed in a synthetic or holistic manner by the right hemisphere. Jackson, therefore, not only claimed that the right hemisphere is not mute and subservient to the left, but that there are special functions that the right hemisphere controls. This shift from the concept of absolute hemispheric dominance to that of hemispheric specialization, however, was not acknowledged by neurologists until nearly a century later when the functions of the right hemisphere began to be systematically studied (Kimura, 1961; Milner, 1962; Paterson and Zangwill, 1944; Shankweiler, 1966).

Clinical observation of brain damaged patients continued to be a major source of information about hemispheric processing asymmetries, with right as well as left hemispheric damage being studied. Patients who sustained unilateral brain damage were studied extensively by Milner (1958, 1960), Myer and Yates (1955) and Kimura (1961). Right-handed patients with left-sided injury showed deficits in language skills such as speech (Branch, Milner, Rasmussen, 1964), and learning with retention of verbal material (Myer and Yates, 1955). Right-handed patients who underwent intracarotid sodium amytal testing showed slowed speech when the sodium amytal was injected on the left side, thus implicating the left hemisphere as the mediator of speech (Branch, et al. 1964). In contrast, injury to the right hemisphere was found to be associated with impaired performance on a variety of nonverbal visual tasks. For example, patients with right temporal lobe damage were unable to recognize overlapping nonsense figures and groups of dots presented tachistoscopically (Kimura, 1966). There is also evidence of visual memory deficits specific to non-linguistic stimuli in patients with right-sided lesions. Delayed recall of geometric figures, facial recognition (Milner, 1960) and recognition of nonsense figures (Kimura, 1966), all proved difficult for patients with right-sided lesions. The ability to perform other non-linguistic tasks such as discrimination of timbre and tonal memory on the Seashore Measures of Musical Talents also was deficient in patients with right-sided temporal lobe lesions (Milner, 1962; Shankweiler, 1966).

A second source of evidence for functional specialization of the two cerebral hemispheres in adults derives from behavioral studies of the normal population. Techniques were developed during the 1950's and the 1960's that enabled the demonstration of visual and auditory laterality in normal subjects. Lateral asymmetry in the processing of visual inputs has been found in studies in which visual stimuli have been presented tachistoscopically to the right or the left visual field. Since information reaching each of the peripheral visual fields is relayed to the contralateral occipital cortex, asymmetric hemispheric function can be inferred from asymmetries in the processing of lateral field presentations.

Right-handed normal adults identify words and letters more efficiently when they are presented to the right visual field (left hemisphere) than when presented to the left visual field (Bryden, 1965; Kimura, 1966). On the other hand, a left visual field (right hemisphere) superiority has been reported for various visuo-spatial tasks. For example, Rizzolatti, Umilta, and Berlucchi (1971) found a left visual field (LVF) advantage for facial recognition, and Kimura (1969) demonstrated a LVF advantage for recognition of dot patterns.

Hemispheric differences in auditory processing in the normal adult have been studied with the dichotic stimulation technique. Dichotic stimulation involves the simultaneous presentation of different sounds to the two ears. Kimura adopted this technique for the study of lateral asymmetry from Broadbent (1956), who had first reported differences between the two ears in selective attention when competing sounds were presented. Kimura (1961) showed that right-handed normal adults correctly recalled more digits presented to the right ear than to the left ear. She also hypothesized (based on clinical data of Milner, 1962) a left ear advantage (LEA) for musical and other non-verbal material. When she presented melodic patterns dichotically she found in fact, that melodies presented to the left ear were recalled correctly more often than melodies presented to the right ear. The REA and LEA for linguistic and non-linguistic sounds, respectively, were explained in terms of cerebral specialization and structural organization of the auditory system (Kimura, 1967).

Kimura postulated that stimuli are processed more efficiently if they have direct access, via the crossed sensory pathways,[1] to the hemisphere that specialized in processing them. Therefore, linguistic sounds such as digits are more likely to be correctly recalled when they are presented to the right ear which has direct access to the left hemisphere; non-linguistic sounds such as musical patterns are more likely to be correctly reported when presented to the left ear.

Early dichotic stimulation studies did show that when random sequences of digits were dichotically presented, listeners recalled more digits correctly that were presented to the right ear than to the left (Broadbent & Gregory, 1964; Kimura, 1961). When musical sounds were dichotically presented, they were recalled more accurately when they were presented to the left than to the right ear (Kimura, 1964; Milner, 1962; Shankweiler, 1966). Initially this dual ear asymmetry - a REA for digits and a LEA for musical sounds was interpreted in terms of the meaningfulness of the sounds. The meaningful - meaningless dichotomy was thought, at first, to be a principal factor in determining the ear advantage (Kimura, 1967). The first systematic investigation of phonetic processing without meaning was the nonsense syllable minimal pair study of Shankweiler and Studdert-Kennedy (1967) who dichotically presented single pairs of consonant-vowel syllables (ba, da, ga, pa, ta, ka) and pairs of steady state vowels (i, e, æ , a, u). They found a REA for consonant-vowel syllables, but

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[1] In support of contralateral pathway superiority, electrophysiological measurements in cats recorded larger cortical evoked potentials in the auditory cortex opposite to the click stimulated ear than in cortex on the same side of stimulation (Rosenzweig, 1954).

not for the steady state vowels. These results indicated that the REA does not depend upon the stimuli being meaningful. There is a vast literature which confirms these results (Cutting, 1974; Darwin, 1971; Godfrey, 1974; Karp & Birch, 1969; Kimura and Folb, 1969; Studdert-Kennedy & Shankweiler, 1970; Studdert-Kennedy, Shankweiler, and Pisone, 1972).

This early study (Shankweiler & Studdert-Kennedy, 1967) also indicated that the REA was greater for consonant-vowel pairs that differed on two articulatory features than for pairs differing on a single feature. This result suggested that speech perception may involve the extraction of distinctive features of sounds by the left hemisphere. In a later study (Studdert-Kennedy & Shankweiler, 1970) which investigated in depth the mechanisms for the perception of speech, this hypothesis was confirmed.

Once meaning was eliminated as a major factor for producing a REA, the question of how speech sounds are processed still remained to be answered. Studdert-Kennedy and Shankweiler (1970) proposed that for the processing of speech sounds there is a distinction between the extraction of the auditory parameters of speech and the linguistic interpretation of the sounds. They proposed that the auditory system common to both hemispheres extracts auditory parameters of speech, whereas the left hemisphere is specialized for processing linguistic interpretation of speech.

Because the oral mode is fundamental to spoken language, the articulability of a sound as language is another characteristic of the auditory stimulus that has been investigated in relation to asymmetrical processing. Liberman, Cooper, Shankweiler &

Studdert-Kennedy (1967) have proposed an interdependence of perceptual and productive processes of speech, so that the articulability of sounds of speech is an important aspect of the speech decoding system. The proposed neural mechanism for decoding speech is in the left hemisphere and, therefore, only sounds that can be articulated as speech should be processed by the left hemisphere. To test the hypothesis that only auditory signals that can be articulated are processed by the left hemisphere, Kimura and Folb (1968) dichotically presented trisyllabic nonsense sounds backwards and found that stimulus recognition was better for sounds presented to the right than to the left ear. The investigators explained this REA, which contradicted their hypothesis, by stating that "although these sounds are extremely difficult to reproduce, when one tries to hold them in storage (which is necessary for a recognition task)... one is treating them as though they were sounds that one could reproduce" (page 386). Kimura and Folb did not administer sounds that could not be produced orally and the importance of articulability for language processing remains to be systematically studied.

The contention that the meaningful - meaningless dichotomy is inadequate for describing hemispheric specialization also led to the investigation of the characteristics of non-linguistic sounds that produce LEA. Craig (1979), in a review of studies of lateral differences in the processing of non-linguistic auditory material, discusses various acoustical attributes of non-language sounds. Of the various elements in musical sounds, the major element shown repeatedly to be processed by the right hemisphere is melody (Kimura, 1964, 1967; Spellacy, 1970).

Evidence for the processing of temporal variations of nonverbal sounds by the left hemisphere is contradictory. Halperin, Nachshon, and Carmon, (1973) showed a REA when changing tonal sequences were presented. In contrast, Blechner (1977) showed a LEA for non-speech stimuli with rapidly varying resonance frequencies. One explanation that Blechner offers for the discrepancy is the difference in codability of the stimuli in the two studies. In his study, the stimuli sounded like "chirps" which are not readily codable, whereas other studies may have varied temporal patterns for codable sounds. However, codability is unlikely to be involved since a null or left ear advantage for highly codable vowels has been repeatedly demonstrated (Darwin, 1971; Godfrey, 1974; Studdert-Kennedy & Shankweiler, 1970).

In addition to melodies, pitch contours and temporal variation of acoustic elements of non-verbal sounds, another type of stimulus which has been used to examine lateral differences in the processing of non-linguistic auditory stimuli is environmental sounds such as animal noises, tooth brushing, and water dripping (Curry, 1967; Kimura, 1963). Right-handed adults correctly identify more of these sounds when they are presented to the left ear than when presented to the right ear. The acoustic properties of these varied environmental sounds essential for the production of a LEA are not discussed in these studies.

In summary, it is evident that, based on clinical data from neuropathological populations as well as on experimental studies of both CNS impaired and normal adults, there are functional differences between the two sides of the brain. In adults, there is left hemisphere superiority for linguistic processing and right hemisphere superiority for visuo-spatial, non-linguistic processing. However, the nature and course of development of these functional differences are not clear.

Two theoretical views of the development of functional specialization of the two cerebral hemispheres have emerged. One theory claims hemispheric equipotentiality for language in early ontogeny, and progressive specialization of the two hemispheres from birth through puberty (Lenneberg, 1967). The other theory describes early "built-in" cerebral specialization with no change in hemispheric specialization during language development (Kinsbourne, 1975, 1977).

Lenneberg, the main proponent of the first theory, claims that at birth and during early childhood the two cerebral hemispheres are equipotential for language function. During the course of the child's development, corresponding to the acquisition of language from late infancy through childhood to adolescence, there is an increasing establishment of left hemisphere control over language. Lenneberg's theory is based upon clinical reports of children with unilateral hemispheric lesions. His evidence stems primarily from Basser's (1962) study of thirty cases of children with hemiplegia of early onset (before age 9). Using these data, Lenneberg noted that none of the patients who had sustained unilateral brain damage between three and one half and nine years of age showed permanent speech loss. Lenneberg attributed the fact that these children developed a transitory and non-permanent form of aphasia when the left hemisphere was injured to a concurrent role of the right hemisphere for language. The recovery of language, according to Lenneberg, is due to the right hemisphere's role in language in young children and, therefore, the capacity to sustain language when the left hemisphere is damaged. Lenneberg also noted from Basser's clinical population that, for children below nine years of age, damage to the right side of the brain was as likely to cause aphasia as damage to the left side. Therefore, Lenneberg argued, both hemispheres are involved in language in early development.

Criticism has been leveled against Lenneberg's argument of early bilateral representation of language, based on his interpretation of the clinical data. First, although children recover more quickly and more fully from aphasia than adults, the interpretation of early bilateral representation of language is not the only possible explanation. An alternative interpretation is that although each side of the brain has specific functions, there is greater plasticity of the complete brain in the young child so that it can more easily compensate for functional loss due to structural damage (Isaacson, 1968).

A second point of criticism is that Lenneberg based his conclusions primarily on neuropathological evidence despite the absence of precise anatomical delineation of the brain damage. The morphological limit of brain injury is especially difficult to ascertain in children because diffuse brain damage is more likely to occur in children than in adults (Kinsbourne & Hiscock, 1977; Moscovitch, 1977). Therefore, it is difficult to accept Lenneberg's hemispheric equipotentiality hypothesis since we cannot be sure that the brain damage had not spread to the other side. An example of the probability of bilateral spread of brain damage in children is suggested by Hécaen (1975) in his review of clinical cases. One of Hécaen's patients who sustained a right-sided lesion and demonstrated language impairment was listed as having an etiology of cranial trauma. Hécaen conceded that he could not rule out spread of damage bilaterally in cases of traumatic etiology.

A third criticism of Lenneberg's formulations is based upon a questioning of the adequacy of the behavioral definition of language deficit. Kinsbourne and Hiscock (1977) and others (Moscovitch, 1977; Witelson, 1977) point out some of the problems in the diagnosis of language dysfunction. Language deficit denotes varying disturbances ranging from total mutism to difficulty in reading and writing, or on a linguistic level, from difficulty in phonology to inability to structure sentences (i.e., syntax). Therefore, before one can claim that language is bilaterally represented, it is essential to clarify which language functions are disturbed by damage to each hemisphere. For example, one of the children with a right-sided injury who was described by Hécaen (1976) as having a language deficit had no difficulty other than in writing. Dennis and Whitaker (1977) observed from child pathological cases that, whereas dysarthria was present in equal numbers of right and left-sided hemiplegics, the inability to combine words into sentences was present in many more cases of right-sided than left-sided hemiplegia. In their review of 60 cases of children with brain injury, Kinsbourne and Hiscock (1977) noted that the only evidence of aphasia recorded for many patients was based upon the report in their clinical history that "the child would not talk to the doctor" (pg. 175). The limitations and ambiguities in determining the extent of the lesions in brain-damaged children and the failure to specify the nature of the language dysfunction reported make it difficult to draw definitive conclusions about the development of cerebral functional specialization in the normal child.

Kinsbourne, the foremost proponent of the second theory, does not rely on clinical cases for evidence of the non-developmental theory of cerebral specialization. Kinsbourne (1975, 1977) bases his theory on neuroanatomical evidence and on behavioral studies of normal infants and children. According to Kinsbourne, there is a preprogrammed arrangement for the left hemisphere to be more activated by language stimuli and the right hemisphere to be more activated by non-language stimuli. According to this view, the left hemisphere is specialized for language long before language behavior develops, and this specialization does not change during the course of ontogeny (Kinsbourne and Hiscock, 1977). Although there is evidence for early hemispheric differences from neuroanatomical, electrophysiological and behavioral studies, it is still unclear how specialization of a behavior can occur before any portion of the behavior has emerged.

Early hemispheric differences in structure are indicated from neuroanatomical autopsy studies of newborn infants and fetuses. These studies show an anatomical asymmetry of the two hemispheres, specifically in the area of the planum temporale (Wada, Clark, & Hamm, 1975; Witelson & Pallie, 1973). This area in the left hemisphere is the superior surface of the core of the classical area of Wernicke, whose role in language comprehension is well documented. Witelson & Pallie (1973) found a larger left planum temporale in 11 of 14 brain specimens of infants aged one day to three months who died of other than neurological causes. Wada et al. (1975) reported that morphological asymmetry (i.e., larger left side) was present as early as the 29th gestational week. Although it has been speculated that early anatomical asymmetry is related to early or even later functional differences (Witelson, 1976), whether this relationship does, in fact, exist is open to question. For example, anatomical asymmetry in the region of the temporal lobes has been demonstrated in chimpanzees (Yeni-Komshian & Benson, 1976).

There is also electrophysiological evidence that newborns and older infants respond differentially to speech and non-speech sounds. In several studies with infants, a larger amplitude auditory evoked potential (AEP) has been measured over the left than right temporal lobe region in response to speech stimuli, and a larger amplitude AEP in the right than the left temporal lobe region in response to non-speech stimuli (Molfese, 1977;

Molfese, Freeman & Palermo, 1975; Molfese, Nunez, Seibert, & Ramanaiah, 1976). However, the relationship between these reported lateral differences in auditory evoked potentials and the development of functional cerebral specialization is unclear.

In addition to the finding of early neuroanatomical and electrophysiological differences, early behavioral asymmetries have been demonstrated in studies of the neonate. Lateral differences in the direction of both head and eye turning to lateralized stimulation of different modalities has been consistently observed. The normal newborn infant is asymmetric in its response to simple auditory stimuli (Hammer & Turkewitz, 1975; Turkewitz, Birch, Moreau, Cornwall, Levy, 1966), being more responsive to white noise stimulation of the right ear than of the left ear. The newborn also shows lateral differences in response to tactile stimulation. When a soft brush is applied to the perioral region of the two day old infant, the characteristic head turning response occurs more reliably when the stimulus is presented to the infant's right side (Moreau, Helfgott, Weinstein, & Milner, 1978). When visual targets are laterally presented to infants, they spend more time viewing targets on the right than equivalent targets on the left (Wickelgren, 1967).

The results of the studies mentioned above indicate that there are early structural electrophysiological and behavioral asymmetries. Other investigations, aimed at determining the ability of infants to process speech or speech-like sounds, have measured behavioral responses (such as high amplitude sucking (HAS) and head turning) to the presentation of speech and non-speech stimuli (Eimas & Miller, 1980; Eimas, Siqueland, Jusczyk and Vigorito, 1971; Fodor, Garrett & Brill, 1975). Eimas, et al. (1971) used the habituation and dishabituation of the HAS to show that one to four month old infants could discriminate the synthetic speech sounds /ba/ and /pa/ which differed in voice onset time, and that discrimination was reliably better across than within adult phonetic categories. Fodor, et al. (1975) demonstrated with a conditioned head turning paradigm that infants 14 to 18 weeks of age were able to discriminate between natural speech consonant - vowel syllables that differed in the initial consonants /p/ and /k/.

In addition to these studies which imply the existence of a processing mechanism particularly applicable to speech sounds in young infants, there are studies which have attempted to relate a speech processing mechanism to left hemisphere function in young infants (Entus, 1975; Glanville, Best, & Levinson, 1977). Entus (1975) combined the dichotic listening procedure with the HAS paradigm and reported that infants between the ages of 22 and 140 days displayed asymmetric responses to speech and non-speech sounds. Greater recovery of the HAS response was reported to changes in speech stimuli presented to the right ear and to changes in non-speech stimuli presented to the left ear. Glanville et al. (1977) found the same direction of auditory asymmetry when they used cardiac habituation as a response to a dichotic listening task. In their study with 3 month old infants they reported greater response recovery when a novel speech syllable was presented to the right than the left ear, and greater response recovery when a novel musical note was presented to the left than right ear. These studies of young infants suggest that prelinguistic infants have some capacity for processing language sounds. Although it is unclear what mechanisms (auditory and/or phonetic) are involved in processing at this early age, it is certain that some level of language processing is present long before the child can articulate speech.

In addition to the results of studies of newborn infants, an abundant source of information on early asymmetries of function derives from investigations of children aged 3 to 10 years. Study of the specialized functions of the left and right hemispheres in young children has involved tachistoscopic presentations of visual stimuli, dichaptic presentation of tactile stimuli, and dichotic presentation of sounds. The present study involves auditory stimulation and, therefore, only those developmental investigations which examined lateral differences in the processing of auditory inputs will be discussed in detail.

Developmental studies of functional asymmetry which involve the visual modality in relation to linguistic function have used children 7 years and older. One reason for this is that in order for the child to be able to respond to linguistic stimuli presented visually he/she has to be a proficient reader. The linguistic stimuli that were used in these studies were three and four letter words (Miller & Turner, 1973; Yeni-Komshian, Isenberg and Goldberg, 1975), letters of the alphabet (Broman, 1978; Reynolds & Jeeves, 1978), and numerals (Yeni-Komshian et al, 1975).

The results of the studies in which linguistic stimuli were visually presented to the two visual fields are inconsistent. In the Miller and Turner (1973) study, 8, 10, and 12 year old children had to recall verbally four and five letter familiar words shown horizontally via tachistoscopic presentation. Only the 10 and 12 year old children reported more words correctly from the right visual field than from the left. The 8 year old children showed no lateral differences in their responses. Yeni-Komshian et al. (1975), presented Arabic numerals and words (names of numerals) tachistoscopically to 10 to 13 year old children and found no differences between the left and right visual fields in accuracy of verbal report. On the other hand, Reynolds and Jeeves (1978) presented alphabetic letters tachistoscopically to 7, 8, and 14 year old children and found a right visual field advantage. One major difference between the Reynolds and Jeeves study and the other studies is the response measure used. Yeni-Komshian et al. (1975) and Miller and Turner (1973) measured the number of stimuli that were correctly reported verbally whereas Reynolds and Jeeves (1978) measured manual reaction time to the detection of the stimulus.

Although not as numerous as the investigations that used visually-presented linguistic stimuli, some experiments have examined the processing of visually presented non-linguistic stimuli in children (Broman, 1978; Carey & Diamond, 1977; Carey, Diamond, & Woods, 1980). The only non-linguistic visual stimuli that have been used are photographs of faces. Leehy (1976, unpublished report cited by Broman, 1978) presented photographs of faces tachistoscopically to the left and right visual fields of 8, 10, and 12 year old children and found a LVF advantage in the accuracy of recognition only in children 10 years and older. Broman (1978) also presented facial photographs tachistoscopically to 7, 10, and 13 year old children and found a LVF superiority for all ages. However, the response measure was choice manual reaction time and not accuracy of verbal recognition. Once again, the reaction time measure revealed differences, especially in the younger children, that were not shown with accuracy and recall measures.

Other investigations of the development of functional specialization of the two hemispheres involve the somatosensory system. The technique most commonly used to study asymmetry in the somatosensory system is the dichaptic task developed by Witelson (1974). This task involves the presentation of pairs of tactuospatial (nonsense) patterns to the right and left hands simultaneously. Witelson presented pairs of nonsense shapes and alphabet letter forms dichaptically to 47 right-handed 6 to 14 year old children. The children palpated the shapes and responded by pointing to the correct stimulus form from a visual display of several shapes. For all age groups Witelson found more accurate visual recognition of nonsense forms palpated with the left hand than of those palpated with the right hand. These results support the view that right hemisphere specialization for at least some aspects of tactuospatial matching is present by six years of age.

Although functional asymmetry has been investigated in the visual and somatosensory systems, the oral characteristic of speech accounts for the more frequent empirical attention to the auditory modality in developmental studies of hemispheric specialization for language and non-language functions. Both dichotic and monaural techniques have been used to examine the ontogeny of lateral differences in processing of auditory inputs.

Most studies of lateral differences in auditory processing of language and nonlanguage material have demonstrated early auditory asymmetry. Kimura (1963) was the first to adopt the dichotic stimulation technique (see page 4) for use with children. In her first study of dichotic listening in children, 1 to 3 pairs of digits were presented dichotically to 145 children, 4 to 9 years old, and the children were asked to report verbally what they heard in any order. She found that for each age group, digits arriving at the right ear were more accurately reported than digits arriving at the left ear. The results suggest that left cerebral superiority for language is established at least as early as age 4.

Other studies using verbal report as the response to dichotic stimulation also showed early asymmetry. Nagafuchi (1970) presented two and three syllable words to 3 to 6 year old children and his results indicated a REA for children as young as three years. Similarly, Kinsbourne and Hiscock (1977) found a REA for digits in 3 to 12 year old children. Geffner and Hochberg (1971) examined the relation between socioeconomic background and lateral differences in response to dichotically presented linguistic stimuli and found a REA to digits in the four to seven year old middle socio-economic group. However, for the children in the low socio-economic group there was no REA until age seven. Ingram (1975) presented words dichotically to 84 right-handed children 3 to 5 years of age and measured a nonverbal response (pointing to pictures). She also found a REA for children as young as 3 years; but since right and left-handed pointing was not counterbalanced, response laterality was not controlled.

Instead of using digit pairs, words or letters, Berlin, Hughes, Lowe-Bell, and Berlin (1973) employed nonsense consonant-vowel syllables (pa/ba/ta/da/ka/ga/) phonetically matched so that the only differences between pairs of stimuli were in places of articulation, in voicing or in both. The nonsense syllables were presented dichotically to 5 to 7 and 13 year old children. The task for the five year olds was verbal report and the task for the older children was written report. A REA was found for all ages and there were no age differences in the magnitude of the REA. Hynd and Obruzut (1977) also used pairs of consonant vowel syllables in their study with 5 to 12 year old children. Their results demonstrated the same REA as had been shown in studies in which digit strings were used. The REA was present at 5 years of age and did not increase with increase in age.

Most developmental studies of lateral differences in auditory processing have used linguistic material; relatively fewer studies have examined the development of asymmetries in the processing of non-linguistic material. Knox and Kimura (1970) studied ear differences in response to non-verbal sounds by presenting environmental sounds dichotically to 80 right-handed 5 to 8 year old children. The environmental sounds were complex auditory sounds, such as: snoring, tooth brushing, water dripping, ticking clock, galloping horse, train whistle, and farm animal sounds. The investigators found a LEA to the environmental sounds in children as young as five years.

One other type of study which attempted to investigate the functions of the right hemisphere in young children used monaural presentation of Morse Code patterns of sounds (Bakker, 1967, 1968). Bakker conducted a series of studies in which Morse Code patterns of sound, generated by a buzzer, were monaurally presented to 6 to 11 year old children. The response measure was the manual reproduction of the sound patterns with a key. Bakker found a LEA for all ages; he interpreted this as an early right hemisphere specialization for this task. Morse Code patterns should involve sequential processing and it is therefore unclear why the children demonstrated a LEA. In fact, adults who are naive in the use of Morse Code showed a REA for patterns up to 7 elements in length (Papcun, Krashen, Terbeek, Remington, & Harshman, 1974). When longer patterns were used the naive adults did show a LEA. Perhaps the task for the young children (i.e., manual reproduction of the patterns) and the task for the adults when they were presented with 13 element patterns were tasks that did not involve left hemisphere sequential processing but rather some right hemisphere processing mechanism. Although this explanation is post hoc, it illustrates the difficulty of predicting ear advantages for non-linguistic tasks.

The studies described above have demonstrated lateral differences in the processing of linguistic and non-linguistic auditory stimuli as early as 3 and 5 years of age; they have also shown that neither the magnitude nor the direction of these differences changes from age 3 to age 13. On the other hand, a few studies have demonstrated lateral differences only for older children and an increase in the magnitude of these lateral differences with age. Satz, Bakker, Teunissen, Goebel and Van der Vlugt (1975) presented four digit pairs per trial dichotically to 198 right-handed 5 to 11 hear old children. The children were required to recall as many digits as possible in any order. Satz et al. found a significant REA only for children 9 to 11 years old. The task in this study, however, was different from that in other studies in that the recall of four pairs of digits which had been presented at a rate of two per second proved difficult even for the older children. Therefore, the memory load may have reduced the lateral asymmetry for the younger children.

Another study which demonstrated a developmental increase in asymmetry was conducted by Bryden and Allard (1976). Nonsense consonant - vowel syllables were presented dichotically to 7 to 12 year old children, and the children had to recall as many consonant - vowel syllables as possible. Bryden et al. found a REA for all ages in terms of accuracy scores. However, when they substracted a right ear starting bias (i.e., trials in which recall was started only with items from the right ear) from the accuracy scores they found that a greater proportion of 12 year olds than 7 year olds showed right ear superiority. Bryden and Allard explain the discrepancy between the responses of the younger and older subjects by noting that the 7 year olds showed the REA because of a starting bias, and the 12 year olds showed the REA "because of a more basic perceptual difference between inputs to the two ears" (p. 396). Of course, the question of the basis of the starting bias in the 7 year olds remains unanswered.

It should be noted that although these two studies demonstrated age differences in ear asymmetry, they also are subject to certain experimental criticisms. In the Satz et al. study the effects of short term memory were confounded with lateral processing differences when long lists of digits were presented. In the Bryden and Allard experiment, the order of recall confounded lateral processing of the linguistic stimuli for the younger children.

In order to examine the development of lateral differences in processing of auditory inputs in 5 to 10 year old children, many factors including memory load must be controlled. There is evidence from adult studies, beginning with that of Shankweiler and Studdert-Kennedy (1967), that the laterality effect is not dependent on memory processing, i.e., single syllable pairs have been shown to produce ear advantages. Studies with children, however, usually involved the presentation of several stimulus pairs per trial (Bryden, 1970; Geffner & Hochberg, 1971; Hynd & Obrzut, 1977: Kimura, 1963; Knox & Kimura, 1970; Satz et al., 1975; Schulman-Galambos, 1977). It is important to study empirically whether memory load is an important variable for the lateral differences reported in studies with young children.

Another important factor which may have influenced the lateral differences that have been reported in many dichotic stimulation studies is attention. Kinsbourne (1970, 1973) proposes an attention model to explain the greater recall and recognition of digits presented to the right than the left ear. He contends that an expectancy set for a particular class of input (linguistic or non-linguistic) induces activation of one hemisphere and concomitant suppression of the opposite hemisphere. Thus, an expectancy for verbal material arouses the left hemisphere and directs attention towards the right ear. The converse occurs for non-linguistic material.

Hiscock and Kinsbourne (1977, 1980) studied the effect of selective attention on ear advantages in children. They presented digits dichotically to 3 to 5 year old children who were instructed to attend to only one ear on a dichotic trial and to report the digits at the designated ear. A REA was found for the total number of digits reported, regardless of which ear was designated as the attended ear. Thus, Hiscock and Kinsbourne found an effect similar to that reported by Kirstein and Shankweiler (1969) with adults, namely, a larger proportion of intrusion errors from the right ear when the children were attending to the left ear than vice versa.

One way of ascertaining the role of attention on lateral differences is to present stimuli that will prime each hemisphere (e.g. words to prime the left and tones to prime the right hemisphere) interspersed within each block of trials. The interspersion of the two types of stimuli should prevent an expectancy set based on the linguistic or nonlinguistic nature of the stimulus (Kinsbourne, 1973).

Although many studies have investigated lateral differences in the infant and the child, and it is clear that lateral asymmetry exists early in life, the variables controlling these differences are uncertain. Variables such as memory, attention, task difficulty, and response mode have typically not been controlled.

The present study attempted to measure lateral differences in young children with a task similar to that used in behavioral studies of speech perception with infants (Best et al., 1977; Entus, 1975) in that it did not require linguistic processing. The task was simply to respond, by lifting both index fingers off keys when any sound was heard. Linguistic and nonlinguistic sounds were presented monaurally in an unpredictable sequence. Thus, while habituation of behavior, either of sucking or of heart rate, was measured in the infant studies, the present study measured simple manual reaction time (RT). The finding of a right and a left ear advantage to linguistic and nonlinguistic stimuli, respectively, in terms of simple reaction time would demonstrate that ear differences occur even when variables such as those mentioned above have been controlled.

CHAPTER 2

METHODS

Subjects.

Seventy-one children were studied at the following three grade levels: Kindergarten, Second and Fourth Grades. There were 20 children (7 girls and 13 boys) in the Kindergarten Group (mean age = 5.5 years, range = 5 years, 0 months to 6 years, 5 months). There were 25 children (15 girls and 10 boys) in the Second Grade Group (mean age = 7 years, 5 months, range = 6 years, 11 months to 8 years, 5 months). There were 26 children (14 girls and 12 boys) in the Fourth Grade Group (mean age = 9 years, 8 months, range = 9 years, 0 months to 11 years, 2 months). All of the children attended a New York City elementary public school in a middle income school district in Queens County. Permission to conduct the study was granted by the District Superintendent, the Principal of the school and the Office of Educational Evaluation of the Board of Education of the City of New York (Appendix A). Written informed consent for the child to participate in the study was obtained from each parent (Appendix B).

The following criteria were used for the selection of subjects:

(1) Average or better school achievement. For Second and Fourth graders, the reading grade level score on the New York City Reading Test, used by the school as the measure of school achievement, was adopted for this study. For Kindergarten child-

ren, school achievement was ascertained by the child's teacher.

(2) Normal hearing. All subjects heard within the normal range as determined by performance on an audiometric test which had either been administered within one year prior to the study (recorded in school medical records) or by the experimenter before the testing session. During the audiometric screening test administered by the experimenter, tones of 1,000, 2,000, and 4,000 Hz were presented at a hearing level of 20 dB. and 500 and 250 Hz tones were presented at 25 dB.[1]

(3) Right-Handedness. Hand preference was ascertained by performance on a five-item performance inventory which was administered to each child. The five items were: writing name, throwing a ball, eating with a spoon, eating with a fork, and combing hair. The hand used in each of these activities was recorded. Only those children who performed all five activities with their right hand were included in the study.

(4) Successful completion of twelve practice trials.

Children who did not meet all four criteria were eliminated. Two Kindergarteners and two Fourth

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[1]Dr. M. Mazor, clinical audiologist at the Speech and Hearing Center at Queens College, established this audiometric test as the relevant screening task.

graders were eliminated because they failed the audiometric screening test. Three Kindergarteners, one Second grader and one Fourth grader were eliminated because, although they wrote their names with the right hand, they did not accomplish the other four tasks in the handedness inventory with the right hand. Three Kindergarteners were eliminated because of unsuccessful completion of the 12 practice trials. Therefore, from a population of 83 children, experimental data were collected for 71 subjects.

Stimuli.

Four auditory stimuli were taped: two word and two non-word sounds. The two words were 'RUN' and 'JUMP', and the two non-word stimuli were the word 'RUN' in reverse, (i.e., 'NUR') and the pure sinusoidal 200 Hz tone produced by an auditory oscillator. The duration of each stimulus was 400 msec. The two verbal stimuli, 'RUN' and 'JUMP', were selected because they are monosyllabic words which are familiar to 5 to 10 year old children. The tone was used because it ia a nonverbal sound. The sound 'RUN' backwards was selected because it is a sound that is not as easily articulated, and less frequently articulated as a speech sound than 'RUN' and 'JUMP'. The sound of 'RUN' reversed was difficult to articulate because when 'RUN' was taped to match the duration of 'JUMP' the 'N' of 'RUN' was extended and therefore sounded like an aspirated 'H' as in 'HNUR'. The sound 'HN' does not appear as the beginning of a word in

English and therefore is a sound that is not frequently articulated as speech by English speaking persons.

The stimulus tape was made in a sound attenuated room in the following manner: The words 'RUN' and 'JUMP' were recorded from the natural speech of a female speaker, the sound 'HNUR' was taken from the recording of 'RUN' played backward, and the 200 Hz. tone was produced by an auditory oscillator. A master tape of the 4 stimuli was recorded on one channel of a dual channel tape recorder (Ampex PR-10). This master tape which had a recording of each stimulus once was then designed to form a loop. The stimulus sounds were then re-recorded via a second tape recorder (Ampex PR-10) from the master tape loop onto the experimental tape. Each of the four stimuli was recorded 23 times, for a total of 92 trials. The stimuli were recorded on one track of the recording tape so that for each trial presentation a switch was activated in order to stimulate only one ear at a time.

Apparatus.

The experimental tape was presented on a reel-to-reel Akai 4000 DS tape recorder at an intensity of 54 dB. (re 0.0002 dynes/cm^2) measured at the output of the earphones with a Bruel and Kjaer sound level meter. This relatively low intensity level was used because of the results of Doehring's (1972) study which indicated that higher intensity tones could stimulate the contralateral ear through bone conduction. The stimuli were presented via matched Maico earphones.

A .05 volt 50 Hz. square wave pulse which identified the beginning of each stimulus presentation was recorded on the second tract of the tape. This pulse was fed into a relay system connected to two electronic clock counters (Lafayette model 54419). The electronic clock counters, triggered by the onset of the stimulus and the placement of the child's hands' in the appropriate position on the response keys, permitted the reaction times to be recorded for both hands.

Two Morse Code keys, fastened to two separate 4-1/2 inch wooden planks, were clamped to the table top, one at the child's right and one at his/her left. Although the respective tensions of the two keys were equated, the keys were reversed for half of the children in order to avoid any possible differences due to equipment. The appropriate side of space was always maintained, so that each child responded with the left hand on a key to his/her left and the right hand on a key to his/her right side.

Experimental Procedure.

Each child was tested individually in a quiet room in the school building. The child was seated at a table and the handedness inventory (described above) was administered. Once it was determined that the child performed all five behaviors with his/her right hand, the child was seated at a second table. Two Morse Code keys were placed on the table ten inches apart, one in front of the right hand and the other in front of the left hand. The experimental procedure was then explained to each child in an informal way, so that he/she would feel free to ask questions. The experimenter indicated which finger is the index finger and told each child to place the index finger of each hand on the corresponding key. The child was told that he/she would hear different words and sounds through earphones and as soon as the sounds were heard he/she was to remove his/her fingers from both keys and then replace them so as to be ready for the next sound. A set of matched Maico earphones was then fitted on the child and the tape started.

The instructions were repeated at the beginning of the tape so as to accustom the child to the earphones. The following instructions were heard through the earphones: "You are going to hear four different sounds. As soon as you hear the sound or word, quickly pick up your fingers and then place them down again on the black circles (keys). Are you ready to start? Good - now put your fingers down, one on each circle. Get ready, set, and listen." The instructions were presented to the left ear for half of the children in each age (grade) group and to the right ear for the other half to counterbalance any possible effect of instructional language set on response.

Following the instructions, the child was administered 12 practice trials, the first 8 of which consisted of presentation of each of the four stimuli in random order once to each ear. The remaining 4 practice trials consisted of presentation of each of the four stimuli once in random order, to either the left or the right ear. After the practice trials, 80 test trials were given. The 80 trials consisted of each of the stimuli randomly presented ten times to each ear, with a total of 40 presentations to the right ear intermixed with 40 to the left ear. The same tape was used for all children; however, the order of ear presentation was changed for half the subjects in each age group. All stimuli that were presented to the right ear were switched to the left ear and vice versa for half the children. The 80 trials were presented in two blocks of 40 trials, with a five minute rest period between blocks. The earphones were reversed after 40 trials for all subjects and the response keys were reversed for half the subjects in each age group to control for any differences due to equipment.

The order of presentation of the four stimuli was randomized over the 40 trial blocks with the following two constraints: 1) no stimulus occurred more than three times consecutively, and 2) no type of stimulus (word and nonword) occurred more than three times consecutively. The order of ear presentation was also randomized with the following constraint: Each of the two stimulus types (word and nonword) was not presented to the same ear for more than three consecutive trials. The order of ear presentation was controlled by the experimenter who manipulated a silent switch. The ear stimulated and the order of presentation of stimuli were randomized so as to avoid the establishment of "set" or bias for ear and/or type of stimulus.

The interstimulus interval was varied to prevent the child from anticipating the stimulus sounds. The varied interval which was measured from the end of one stimulus to the beginning of the next stimulus, varied randomly from 3.0 to 4.5 seconds.

Response Measure.

The response was bimanual reaction time, measured in milliseconds by two clock counters from the onset of stimulation to the release of the response keys. The reaction times were recorded by the experimenter from the clock counters for each hand on each trial. Bimanual reaction times were measured in order to enable examination of the effect of presenting the stimulus ipsilateral vs. contralateral to the side of response. This issue, i.e., stimulus response compatibility, has been examined in studies of adults who responded bimanually to auditory stimuli (Provins & Jeeves, 1975) but has not yet been explored in auditory laterality studies with children.

Each of the 71 children made a total of 160 responses, two responses (one with each hand) to each of the 80 stimulus presentations.

Statistical Design and Analyses.

The raw reaction time (RT) scores were normalized by the use of geometric means. This transformation potentially eliminates undue weight of extreme scores, i.e., reduces skewness, and also reduces the relationship between the RT mean and the variance of the RT (Hamsher & Benton, 1977; Mueller, 1949).

The geometric means were computed for the 10 trials for each child for the following:

1)	RH-RE-RUN	5)	RH-LE-RUN	9)	LH-LE-RUN	13)	LH-RE-RUN
2)	RH-RE-JUMP	6)	RH-LE-JUMP	10)	LH-LE-JUMP	14)	LH-RE-JUMP
3)	RH-RE-NUR	7)	RH-LE-NUR	11)	LH-LE-NUR	15)	LH-RE-NUR
4)	RH-RE-TONE	8)	RH-LE-TONE	12)	LH-LE-TONE	16)	LH-RE-TONE

(RH indicates right hand, RE right ear, LH left hand, LE left ear). These means were averaged arithmetically across subjects to provide group mean reaction time.

The transformed RT data were subjected to a four-way analysis of variance: Stimulus by Grade by Ear by Hand, (4x3x2x2). This analysis consisted of three repeated, within subject factors (Hand and Ear at two levels each, and Stimulus at four levels) and one non-repeated, between subject factor (Grade at three levels). In order to study the effect of gender a second analysis of variance (ANOVA) was performed. This second ANOVA was a five-way analysis, Stimulus by Grade by Gender by Ear by Hand (4x3x2x2x2). It consisted of three repeated within subject factors (Hand and Ear at two levels each, and Stimulus at four levels), and two non-repeated, between subject factors (Grade at three levels and Gender at two levels) (Kirk, 1968).

CHAPTER 3

RESULTS

The results of the four-way analysis of variance (ANOVA) indicated several statistically significant main effects as well as some statistically significant interactions. These results, described below, are presented in Table 1.

Grade Level Differences in Reaction Time

According to the ANOVA (Table 1) the main effect of grade was highly significant ($p < .002$). This indicates that there was a statistically significant difference in RT across the three grade levels. The mean RTs[1] for the children in each grade are presented in Table 2, which shows that RT decreased with increase in grade level from Kindergarten to the Fourth grade. A Tukey Honestly Significant Difference (HSD) Test (Kirk, 1968) was done in order to determine whether the significant decrease in RT occurred only from Kindergarten to Fourth grade or if the decrease in RT was significant from each grade to the next higher grade. As indicated in Table 3, the RT of the children in each grade differed significantly from that of children in each other grade; Fourth graders responded significantly faster than both Second graders and Kindergarteners, and Second graders responded significantly faster than Kindergarteners.

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[1]The group mean RTs presented in the tables are arithmetic means based on the individual geometric means.

Table 1

Summary of Four-Way Analysis of Variance

Source of Variance	Sum of Squares	d.f.	Mean Square	F	P
Grade	2,156,954.00	2	1,078,477.00	6.92	.002
Ear	22,401.12	1	22,401.12	9.67	.003
Stimulus	6,153,728.00	3	2,051,242.00	317.53	.001
Hand	4,446.01	1	4,446.01	5.51	.022
Grade X Ear	3,617.06	2	1,808.53	.78	ns
Grade X Stimulus	200,302.00	6	33,383.66	5.17	.001
Grade X Hand	1,199.70	2	599.85	.75	ns
Ear X Stimulus	5,627.94	3	1,875.98	.67	ns
Ear X Hand	160.56	1	160.56	1.42	ns
Stimulus X Hand	659.08	3	219.69	1.00	ns
Grade X Ear X Stimulus	15,789.37	6	2,631.56	.94	ns
Grade X Stimulus X Hand	1,844.34	6	307.39	1.40	ns
Grade X Ear X Hand	99.37	2	49.68	.44	ns
Ear X Stimulus X Hand	1,524.78	3	508.26	2.92	.001
Grade X Ear X Stimulus X Hand	1,293.84	6	215.64	1.24	ns
Error Grade	10,600,092.00	68	155,883.68		
Error Ear	157,493.87	68	2,316.39		
Error Stimulus	54,906.53	68	807.44		
Error Hand	1,317,839.00	204	6,459.99		
Error Grade X Stimulus	1,317,839.00	204	6,459.00		
Error Grade X Ear X Stimulus X Hand	35,548.80	204	174.24		

Table 2

Reaction Time (msec.) of Children in

Three Grade Levels

Grade	n	Mean	SD
Kindergarten	20	711.0	144.43
Second	25	666.4	120.97
Fourth	26	604.8	108.26
Total	71	655.0	136.87

Table 3

Tukey Analysis for Differences

Between Means

		Differences Between Mean RT for All Grades			
		Grade	Four	Two	Kdg.
		Mean RT	604.8	664.4	711.0
Grade	Four				
Mean RT	604.8		---	60*	107*
Grade	Two				
Mean RT	664.4			---	47*
Grade	Kdg.				
Mean RT	711.0				---

* $p < .01$; Tukey test value required to reach the .01 level of signigicance is 46.1.

Ear Differences in Reaction Time

Children in all three grades detected the stimuli faster when they were presented to the right ear than when presented to the left ear (Table 4). The more rapid RT to right than to left ear stimulation was highly significant, as evidenced by the statistically significant main effect for ear (Table 1).

To determine if the magnitude of the ear difference in RT varied according to grade (age), the mean RTs to stimulation of the right and left ears by children in each of the three grades were calculated. Inspection of Table 4 shows that RT to stimulation of the right ear was faster than to stimulation of the left ear for each of the three grade (age) levels. It can also be seen in Table 4 that the magnitude of ear differences in RT decreased slightly with increase in age; however, this decrease in RT was not statistically significant, (i.e., the grade by ear interaction was not statistically significant; Table 1).

In order to determine if the children detected each of four stimuli faster when it was presented to the right, as opposed to the left ear, the RTs to each stimulus were calculated. As indicated in Table 5, the RT to each stimulus was faster when the sound was presented to the right than when presented to the left ear. Although the difference between the RTs to right and left ear stimulation appears to vary among the four stimuli, i.e., the RT difference between right and left ear stimulation for 'JUMP' is 3.4 msec. and the difference for 'NUR' is 14 msec., the magnitude of the differences among the four stimuli

Table 4

Reaction Time (msec.) to Stimulation of the Right and Left Ears for Three Grade Levels

Grade	n		Left Ear	Right Ear
Kindergarten	20	mean	717.9	704.1
		s d	149.25	139.58
Second	25	mean	668.6	660.5
		s d	127.95	133.02
Fourth	26	mean	605.6	600.7
		s d	115.00	118.94
Total	71	mean	659.5	650.9
		s d	137.39	136.35

NOTE: The standard deviations in the table are derived from repeated measures on the same subjects. Therefore, despite fairly large standard deviations, the small difference between ears is statistically significant. This is also true for the analysis of stimulus and hand differences in Tables 5 and 8, respectively.

Table 5

Reaction Time (msec.) to Each Stimulus

According to Ear Stimulated

	Ear Stimulated				
	Left Ear		Right Ear		Total
	Mean	s d	Mean	s d	Mean
Tone	752.7	132.74	746.6	130.03	749.6
Run	680.1	105.55	669.4	103.98	674.7
Nur	657.8	116.23	643.8	119.03	650.8
Jump	547.2	108.85	543.8	108.26	545.5
Total	659.5	137.39	650.9	136.35	

was not found to be statistically significant (see non-significant stimulus by ear interaction, Table 1).

Stimulus Differences in Reaction Time

It was just noted that the magnitude of the ear differences did not vary significantly as a function of stimulus. However, analysis of the total RTs to the four stimuli, independent of ear stimulated, did reveal signficant differences among the four sounds. The RT to 'JUMP' was the fastest, the RT to 'NUR' was faster than to 'RUN', and in turn the RT to 'RUN' was faster than to the 'tone' (Table 5). This difference in RT among the four stimuli was highly significant (Table 1). To determine which of the four stimuli contributed to the significant main effect for stimulus, a Tukey HSD test was performed. As indicated in Table 6, there were significant differences among the RTs to each stimulus.

In addition to the differences that were found for the RTs of all the children to the four stimuli, there were differences among the three grade (age) levels in their RT to each stimulus. The RTs of children in each grade differed significantly from each other for the detection of each of the stimulus sounds (see significant interaction of stimulus by grade, Table 1).

Table 6

Tukey Analysis for Differences Among the Mean RTs to Each of the Four Stimuli

		Differences Between Mean RT for All Stimuli			
	Stimulus	JUMP	NUR	RUN	TONE
	Mean RT	545.6	650.8	674.7	749.6
Stimulus	JUMP				
Mean RT	545.6	--	105.2*	129.1*	204*
Stimulus	NUR				
Mean RT	650.8		--	23.9*	98.8*
Stimulus	RUN				
Mean RT	674.7			--	74.9*
Stimulus	TONE				
Mean RT	749.6				--

* $p < .01$; Tukey test value required to reach the .01 level of significance is 20.7.

Figure 1 indicates that the children in all three grades showed the same pattern of RT to the four stimuli, with the slowest RT to the 'tone' and the fastest RT to 'JUMP'. Although the order of RTs to the stimuli (from fastest to slowest) is the same for all grades, the relative differences between the RTs to each stimulus are similar for only the second and fourth graders. The kindergarteners showed a disproportionately long RT to the 'tone' and a small difference between RTs to 'RUN' and 'NUR'. Table 7 shows the mean RT for each stimulus according to grade. The disproportionately long RT of the kindergarten group to tone is 840 msec. which is 95 msec. longer than the RT of the kindergarteners to any other stimulus. The difference between the kindergarten group's responses to 'NUR' and 'RUN' is only 5 msec., which is 26 msec. less than the smallest difference between the other two groups to any stimulus.

<u>Hand Difference in Reaction Time</u>

As Table 8 shows, the RT of the left hand was faster than the RT of the right hand for each of the grade levels. This hand difference in RT was statistically significant (Table 1). The faster reaction time with the left hand was independent of the ear stimulated, as evidenced by the non-significant interaction of hand and ear, and independent of stimulus, as evidenced by the non-significant interaction of hand and stimulus (Table 1). Thus, for each of the four stimuli, and for both right and left ear stimulation, all grade (age) levels showed faster RTs with the left hand (an analysis of gender differences below indicates that the hand difference is based on the RTs of the boys).

Figure 1

Reaction Time to Four Stimuli by Children in Each

of Three Grade Levels

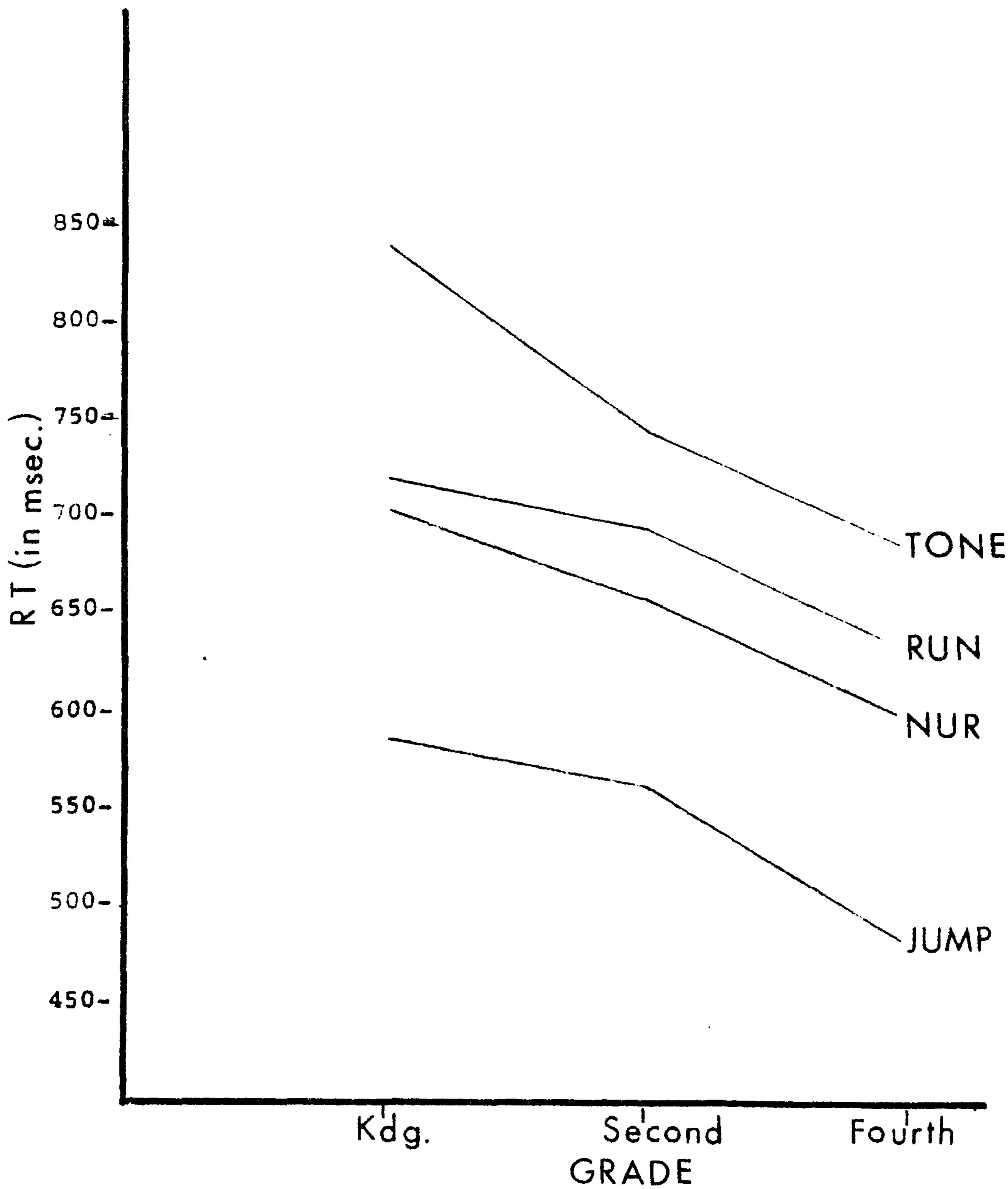

Table 7

Reaction Time (msec.) to Four Stimuli
by Children
in the Three Grade Levels

Grade	n	Stimulus	Mean	s d
Kdg.	20	JUMP	588.7	112.33
Second	25	JUMP	561.9	105.07
Fourth	26	JUMP	496.6	88.65
Total	71	JUMP	545.5	108.38
Kdg.	20	NUR	704.9	111.80
Second	25	NUR	660.2	114.85
Fourth	26	NUR	600.2	103.85
Total	71	NUR	650.8	117.59
Kdg.	20	RUN	710.2	102.13
Second	25	RUN	691.4	110.02
Fourth	26	RUN	631.5	85.40
Total	71	RUN	674.7	104.60
Kdg.	20	TONE	840.3	128.79
Second	25	TONE	744.9	119.57
Fourth	26	TONE	684.5	100.70
Total	71	TONE	749.6	131.20

Table 8

Reaction Time (msec.)

for Right and Left Hands

for Three Grade Levels

Grade	n	Response Hand			
		Left		Right	
		Mean	s d	Mean	s d
Kdg.	20	710.1	143.97	711.9	145.35
Second	25	661.2	132.16	668.0	128.87
Fourth	26	601.5	117.42	604.9	116.57
Total	71	653.1	137.46	657.3	136.39

The significant interaction ($p < .001$, Table 1) among response hand, ear stimulated, and stimulus are graphically depicted in Figure 2. Table 9 shows that for 'RUN', 'NUR', and the 'tone', the order of RT from fastest to slowest was right ear (RE) left hand (LH), RERH, LELH, LERH. The RT pattern to 'JUMP' differed from that to the other stimuli. For the word 'JUMP', the RT of the LELH was less than the RT for RERH. The differences between the RT to 'JUMP' and the other three stimuli contributed to the statistically significant three-way interaction.

Gender Differences in Reaction Time

The five-way analysis of variance failed to reveal a significant main effect for gender (Table 10). The mean RTs for the girls and boys in each grade are presented in Table 11 which shows that the girls in Kindergarten and Second Grade had faster RTs than the boys in these grades, and the boys in the Fourth Grade had faster RTs than the Fourth Grade girls. These differences, however, were not statistically significant (see non-significant interaction of grade by gender, Table 10).

Examination of the interactions of gender with grade, with ear, with stimulus, and with hand, indicated only one statisically significant interaction, namely, gender by hand ($p < .01$, Table 10). As can be seen in Table 12, the difference in RT between the right and left hands of the girls was 0.4 msec. whereas for the boys, the hand difference was 8.0 msec. The near symmetric RTs of the hands of the girls, and the asymmetric RTs of the hands of the boys accounts for the statistically significant gender by hand interaction.

Figure 2

Interaction of Ear by Hand by Stimulus

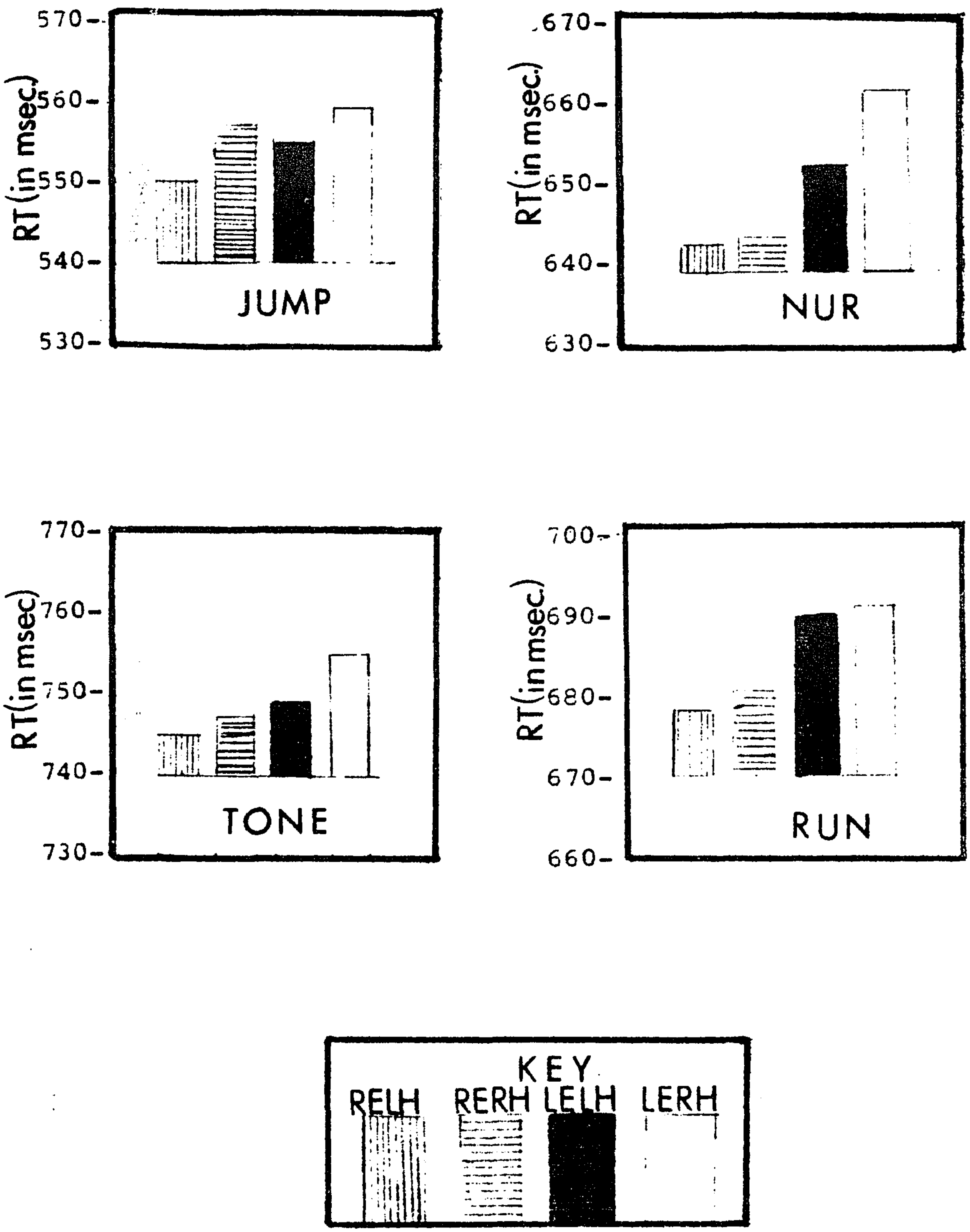

TABLE 9

Reaction Time (msec.) to Each Stimulus According to Ear Stimulated and Response Hand

Stimulus	Ear Stimulated		Response Hand		Mean	SD
	Left	Right	Left	Right		
RUN	L		L		679.6	111.63
RUN	L			R	680.5	99.40
JUMP	L		L		545.3	108.90
JUMP	L			R	549.2	109.55
NUR	L		L		653.6	114.25
NUR	L			R	662.1	118.62
TONE	L		L		749.5	131.05
TONE	L			R	755.9	135.27
RUN		R	L		668.1	105.30
RUN		R		R	670.8	103.37
JUMP		R	L		540.2	109.11
JUMP		R		R	547.4	108.07
NUR		R	L		643.2	120.41
NUR		R		R	644.5	118.48
TONE		R	L		745.4	131.13
TONE		R		R	747.7	129.85

Table 10

Summary of Five-Way Analysis of Variance

Source of Variance	Sum of Squares	d.f.	Mean Square	F	P
Grade	2,036,830.0	2	1,018,415.0	6.36	.003
Gender	14,567.0	1	14,567.0	.09	ns
Ear	19,436.9	1	19,436.9	8.45	.005
Stimulus	5,825,110.0	3	1,941,703.0	295.70	.001
Hand	3,755.8	1	3,755.8	4.93	.03
Grade X Gender	175,455.0	2	87,727.5	.55	ns
Ear X Gender	6,343.4	1	6,343.4	2.76	ns
Stimulus X Gender	10,595.0	3	3,531.6	.54	ns
Hand X Gender	5,356.5	1	5,356.5	7.01	.01

Table 11

Reaction Time (msec.)

of Girls and Boys

in Three Grade Levels

Gender	Grade	n	Mean	SD
Girls	Kindergarten	7	698.8	144.01
Girls	Second	15	652.6	116.09
Girls	Fourth	14	615.4	117.00
Girls	Total	36	647.1	125.86
Boys	Kindergarten	13	717.6	144.58
Boys	Second	10	682.6	147.90
Boys	Fourth	12	589.0	115.39
Boys	Total	35	663.5	147.01

Table 12

Reaction Time (msec.)

for Right and Left Hands

for Boys and Girls

Gender	n		Response Hand		Total
			Left	Right	
Boys	35	mean	659.5	667.5	663.5
		s d	146.21	147.96	147.01
Girls	36	mean	646.9	647.3	647.1
		s d	128.33	123.56	125.86
Total	71	mean	653.1	657.3	
		s d	137.46	136.39	

CHAPTER 4

DISCUSSION

The present study found that 5 to 10 year old children responded differently to right and left ear stimulation when speech sounds or a tone were presented monaurally. The lateral difference involved faster reaction time (RT) to sounds presented to the right ear than to sounds presented to the left ear. Since it has been established that ear asymmetry reflects hemispheric asymmetry (Mountcastle, 1962), with auditory fibers from each ear directed primarily to the contralateral hemisphere (Guyton, 1972), this right ear advantage (REA) in reaction time points to a left hemisphere superiority in the simple detection of both linguistic and nonlinguistic sounds in the absence of a language processing task.

The present finding of a REA in 5 to 10 year old children is in accord with the findings of a number of studies, several of which have reported a REA in children as young as three or four years (Geffner & Dorman, 1976; Hiscock & Kinsbourne, 1980; Nagafuchi, 1970). In the present study, there was no evidence of age difference in either the direction or the magnitude of auditory asymmetry to either linguistic or nonlinguistic auditory stimuli. Thus, the data support those developmental studies which found no age differences in REA (Berlin et al., 1973; Hiscock & Kinsbourne, 1977; Kimura, 1963, 1967; Knox & Kimura, 1970).

The results of the present study add to those of previous investigations of the development of lateral asymmetry because they demonstrate a lateral difference in the time it takes to respond to a sound, whereas results of other studies showed a difference in the recognition, recall, and the verbal identification of the sounds. Most studies examining auditory asymmetry in children have involved dichotic stimulation and either recognition or recall tasks. For example, Kimura (1963) presented triads of digits dichotically to 4 to 9 year olds and measured the number of digits recalled. Bryden (1970) did the same with seven to nine year old children, whereas, Satz, Bakker, Teunissen, Goebel and Van Der Vlugt (1975) presented quartets of digits to 6 to 11 year olds. Berlin, Hughes, Lowe-Bell and Berlin (1973) presented pairs of CV syllables dichotically to 5 to 13 year olds and measured the correct recognition of the syllable pairs from written items (oral report for the 5 year olds). Geffner and Dorman (1976) presented single pairs of CV syllables dichotically to four year olds and measured oral report of the syllable pairs. All these investigations used dichotic stimulation and response tasks that involved memory and/or verbal recognition, and the results all indicated better performance by children for verbal material presented to the right ear. The present investigation augmented the study of auditory asymmetry in children to include a measure of temporal processing, namely, reaction time. We presented stimuli monaurally and measured simple manual reaction time. Therefore, we have shown that in a simple reaction time task with no competing auditory stimulation, no memory demands, and no verbal recognition requirement, there is a time advantage for stimuli presented to the right ear.

The finding of a REA in 5 to 10 year old children for monaurally presented words (e.g. 'RUN', 'JUMP') for a task that did not involve linguistic processing, together with demonstrations that infants are more responsive to speech presented to the right than to the left ear (Entus, 1975; Glanville et al., 1977) suggests a left hemisphere language mechanism primed to respond to speech without interpretive processing. Although this mechanism is not understood, it may be that the left hemisphere is automatically engaged by some acoustic property of speech that remains to be defined. However, the demonstrated REA for the non-verbal stimuli, 'TONE' and 'RUN' backward (HNUR) seems at first glance to contradict this hypothesis. Two points must therefore be made. First, the children may have responded to 'HNUR' as a speech sound and second, an attentional bias to the right may have occurred.

Regarding the first point, although the syllable, 'HNUR' is not an English word and is therefore less frequently, if ever, articulated than common words such as 'RUN and 'JUMP', it is a phonetically possible sound. Therefore, it may have sounded like speech and could have been responded to as such by the 5 to 10 year old children. In fact, when the children were asked after the test session, what they had heard, most replied "run, jump, beeping sound, and ha no". Some children even said they heard the colloquial negative, 'nope'. Therefore, it appears that young children not only attempt to articulate nonsense sounds, as was reported by Kimura and Folb (1968) for adults, but they may hear meaningless sounds as meaningful words. Therefore, it is possible that the children responded faster when 'HNUR' was presented to the right than to the left ear because they responded to it as a speech sound.

The second point follows from the argument that, if 'HNUR' was responded to as a verbal stimulus, a biasing effect could have occurred over the course of testing, with three verbal sounds mixed with only one nonverbal tone. Thus, it is possible that the REA for the 'TONE' occurred because the left hemisphere was primed by the three verbal stimuli. This is precisely what Kinsbourne (1973) would predict from his attentional model of behavioral asymmetries. According to this model, an individual will attend to the side of space opposite the cerebral hemisphere that is stimulated. Therefore "the left hemisphere, when engaged in its specialized (i.e., linguistic) activity, whether anticipatory or ongoing, generates a right-sided selective orientation" (Kinsbourne, et al., 1977, pg. 182). Thus, observed ear asymmetries are affected by the linguistic or non-linguistic nature of the input, since attention to the right or left is related to cerebral specialization of function, so that language stimuli direct attention to the right side, whereas non-language stimuli, processed by the right hemisphere, direct attention to the left side.

Evidence from studies with adults have indicated that involuntary attention may affect ear advantages (Dick, Rosenberg, & Karp, 1977; Haydon & Spellacy, 1973; Kirstein & Shankweiler, 1969; Provins & Jeeves, 1975; Simon, 1967; Treisman & Geffen, 1968). When subjects in these studies were required to respond to verbal stimuli, attention was directed to the right. For example, during a verbal shadowing task, information from the unattended right ear is more likely to intrude than information from the unattended left ear (Treisman & Geffen, 1968). Kirstein and Shankweiler (1969) also found interference based on attentional set when subjects were attending to verbal stimuli in a standard consonant - vowel syllable test. More recently, in a study with adults, Studdert-Kennedy and Kerr (1981) reported that when consonant vowel syllables are presented randomly mixed with pitch contours, the usual ear advantages (REA and LEA respectively) are significantly reduced, or even reversed. Thus, the REA for the tone in the present study may have resulted from an attentional bias to the right because of the greater number of verbal (three) than nonverbal (one) stimuli.

However, it should be noted that some studies have shown a faster reaction time to nonverbal stimuli (tones) presented to the right ear when the side of stimulation was unpredictable (as was the case in the present study). For example, Simon (1967) presented tones monaurally to adults, who were either informed or naive as to which ear would be stimulated. There were no ear differences when the subjects were advised where to attend. However, when they did not know the side to be stimulated, there was a significant 4 msec. faster reaction time to the detection of the tone presented to the right ear. Simon explained the REA as an expectancy phenomenon. "When uncertain as to which ear will be stimulated, subjects tend to tune in with their right ear and therefore react faster on the trials where the stimulus source corresponds to their expectancy" (p. 54).

Haydon and Spellacy (1973) also demonstrated a REA in simple RT to tones that were monaurally presented under conditions of ear uncertainty. These investigators argued, as did Simon, that attentional set contributed to the ear preference. A REA in RT to monaurally presented tones was also demonstrated by Provins and Jeeves (1975) and by Dick et al. (1977). In all of these studies, as in the present one, the ear to be stimulated was not known to the subject before each trial and the subjects responded faster to tones presented to the right than to the left ear. Therefore, the finding of a REA for the 'TONE' in the present study of 5 to 10 year old children not only confirms the results of Simon (1967) and other investigators with adult subjects, but also constitutes the first empirical demonstration of such an effect in children. Whereas it is reasonable to argue, as Simon does, that there may be a lateral expectancy bias favoring the right ear, the basis of this postulated bias is unknown.

In addition to studying ear asymmetry, the present study also examined hand differences in RT as well as the relationship between responding hand and stimulated ear (stimulus-response compatibility). Since there was no evidence of an interaction between ear and hand, it is clear that the REA was independent of the hand used to respond. There was, however, a difference between the girls and the boys in reaction times with their right and left hands. The boys responded more rapidly with their left than with their right hand; there was no difference in RT between the two hands of the girls. The left hand superiority for the boys is not easily understood since there are conflicting reports concerning the hemispheric control of the motor response involved in this task. Lawrence and Kuypers (1968) showed that there is ipsilateral as well as contralateral motor control of an extremity; however, the ipsilateral control is limited mainly to the proximal musculature. In the present study, the responses were performed by the distal musculature (i.e., lifting of finger from key) and therefore should be controlled by contralateral motor cortex. However, it has also been demonstrated that the distal musculature may be differentially controlled by the ipsilateral or contralateral hemispheres depending upon the type of movement that is involved. For example, Kimura and Vanderwolf (1970) found that for isolated flexion of a single finger or pair of fingers, normal right-handed adults do better with their left than right hands. These authors proposed that the greater ipsilateral than contralateral representation might account for better left finger control. Also, Denckla (1973) found that 5 to 7 year old children responded faster with the right hand for repetitive finger movements but equally fast with both hands for successive finger movements. Annett (1970) showed that for a peg moving task, albeit more complex than simple finger lifting, boys were faster than girls with their left hand. Until now, no developmental study has examined bimanual reaction time to auditory stimuli and, therefore, there are no studies with which to compare our results.

Most studies with adults in which manual reaction time to monaural stimulation has been examined have found no differences between the left and right hands. Aitkins (1976) and Provins and Jeeves (1975) presented tones monaurally and found no hand differences in reaction time. In Simon's study (1967), although there were no statistically significant hand differences, there was a trend toward faster reaction time with the left than with the right hand. It has been demonstrated (Kelso, Soutard, & Goodman, 1979) that when adults respond bimanually to easy tasks, they initiate movements virtually simultaneously. Therefore, the absence of a hand difference in reaction time of the 5 to 10 year old girls (but not the boys) in the present study corroborates the results obtained in studies with adults.

Finally, the present investigation examined gender differences in ear asymmetry in children. There were no differences in the ear asymmetry between the girls and the boys; a right ear advantage was found for both girls and boys at all three grade levels. The absence of a gender difference in ear asymmetry is in agreement with findings obtained in most dichotic listening studies with children (Berlin, Hughes et al., 1977; Geffner & Hochberg, 1971; Hiscock & Kinsbourne, 1977; Knox & Kimura, 1970; Satz et al., 1975: Schulman-Galambos, 1977). Those investigations showing earlier left himisphere specialization for girls than for boys and earlier right hemisphere specialization for boys than for girls (e.g., Witelson 1976) have all used tactuospatial rather than auditory stimuli.

Although there is no evidence for gender differences in developmental studies of asymmetry in the auditory system, the early studies by Kimura (1963, 1967) are sometimes cited as showing such differences. However, Kimura did not find gender differences in asymmetry to either verbal or non-verbal sounds; rather, she found a gender difference in overall accuracy. A REA for digit repetition (1963) was demonstrated for four year old girls and boys; however, the scores for girls showed a greater overall accuracy than the scores for the boys. For environmental sounds, Kimura (1967) found that ear asymmetry (a LEA) occurred at the same age for girls and boys (five years); however, there was greater accuracy of response to environmental sounds for the boys than the girls.

In summary, the present finding of a faster simple RT to both linguistic and non-linguistic auditory stimuli presented to the right than to the left ear in 5 to 10 year old children demonstrates that differences in response to monaural stimulation can be measured in the absence of a linguistic processing task. Evidently, the left hemisphere is predisposed to respond more rapidly to some as yet undefined acoustic properties of speech.

APPENDIX A

Letters from the Office of Educational Evaluation and the Bureau of Child Guidance granting permission to conduct the study at a New York City Public School.

BOARD OF EDUCATION
OF THE CITY OF NEW YORK

BUREAU OF CHILD GUIDANCE

Headquarters

116 West 32nd Street, New York, New York 10001

594-4720

JAMES N. RINALDI
Director

VERA S. PASTER, Ph.D.
Assistant Director

DOROTHY S. LEE, Ph.D.
Assistant Director

INGRAM COHEN, M.D.
Chief School Psychiatrist

PAULINE C. ZBOCHKA, Ph.D
Chief School Psychiatric Social Worker

RACHEL M. LAUER, Ph.D
Chief School Psychologist

September 3, 1976

Ms. Elayne Helfgott
Queens College
65-30 Kissena Boulevard
Flushing, N.Y. 11367

Dear Ms. Helfgott:

I am enclosing an application form for approval to do research. Please have the Authorized Faculty Sponsor, District Superintendent and Principal sign the form. Mr. Rinaldi, Director, and I have already signed it.

Submit the completed form with your outline to The Office of Educational Evaluation and you will hear directly from them when your research topic is approved.

Sincerely yours,

Rachel M. Lauer (PS)

Rachel M. Lauer, Ph.D.
Chief School Psychologist

RML:ps
enc.

BUREAU OF CHILD GUIDANCE

APPLICATION FORM

S T U D E N T   R E S E A R C H

University: City University of New York   Date of Application:

Name of Student: Elayne Helfgott   September 2, 1976

Field of Specialization: Neuropsychology

Research Topic: Development of lateral differences in reaction time and eye orientation to verbal and nonverbal auditory stimuli in young children.

Research is for M.A. ___ Ph.D. ✓ Ed.D. ___ Other(specify)___

All applications must be submitted with signed approval of faculty sponsor and THREE Copies of Outline.

Approved by	Date Received	Date Transmitted	Signature
Authoirzed Faculty Sponsor	9/14/76	9/14/76	[signature]
BCG Research and Development Unit			
Chief Psychologist or Chief Social Worker	9/2/76	9/2/76	[signature]
BCG Director	9/2/76	9/2/76	[signature]
DISTRICT ~~Associate~~ Superintendent	9/16/76	9/16/76	[signature]
~~Superintendent~~ ~~BCG Office~~ PRINCIPAL	A. W. [illegible] for H.B. Gillam	9/14/76	9/14/76

Returned to BCG Date__________ Approved_______ Disapproved_______

Comments:

Parental approval necessary for each child participating in this evaluation [illegible]

BOARD OF EDUCATION OF THE CITY OF NEW YORK
OFFICE OF EDUCATIONAL EVALUATION
110 LIVINGSTON STREET, BROOKLYN, N. Y. 11201

ANTHONY J. POLEMENI, PH.D.
DIRECTOR

RICHARD T. TURNER, PH.D.
ASST. ADMIN. DIRECTOR

September 27, 1976

Ms. Elayne Helfgott
Queens College of the City University of N.Y.
65-30 Kissena Boulevard
Flushing, New York 11367

Dear Ms. Helfgott:

I am happy to inform you that your proposed study entitled,"DEVELOPMENT OF LATERAL DIFFERENCES IN REACTION TIME AND EYE ORIENTATION TO VERBAL AND NON VERBAL AUDITORY STIMULI IN YOUNG CHILDREN" has been approved by the Office of Educational Evaluation, with the following conditions:

1. Before involving any child in your study, you must obtain written parental consent. (I have enclosed a form which you may follow in drawing up your own Parental Permission Form).

2. Your report of the study should not include identification of any school or school personnel. A code system should be used.

3. You must make it very clear to your prospective respondents that their cooperation is on a purely voluntary basis.

Whenever your report is ready, I should be interested in receiving a copy.

Best wishes in this endeavor.

Sincerely yours,

Anthony J. Polemeni

AJP:JA:lb
Encl:

Anthony J. Polemeni
Director

P.S. You may duplicate this letter in any quantity you need in order to inform cooperating principals and community superintendents that you have received approval from the Office of Educational Evaluation.

APPENDIX B

Letter from principal of Public School granting permission to examine the records of kindergarten, second, and fourth grade students.

LUCRETIA MOTT SCHOOL
PUBLIC SCHOOL 215Q
535 BRIAR PLACE
FAR ROCKAWAY, NEW YORK 11691

HERBERT B. TILLEM PRINCIPAL
ARNOLD R. WITTENSTEIN ASSISTANT PRINCIPAL

Oct. 12, 1977

Dear Teachers:

Ms. Elayne Helfgott is a doctoral candidate in psychology at City University. She has permission to conduct her thesis research here at P.S. 215.

Her topic is the development of laterality.

Please permit her to go through the children's cumulative reports. She can do this in your room, or take the case and do the research in the main office.

She will select some youngsters who meet certain criteria. These children will be given parental consent forms . If they are returned signed, Ms. Helfgott will administer a 35 minute testing session to each child individually. It will be primarily a hearing test during which the child's behavior is observed.

Thank you for your cooperation.

Very truly yours,

Herbert B. Tillem
Principal

APPENDIX C

Copy of parental permission form, which was required before child could participate in the study.

Board of Education of the City of New York

Public School 215
535 Briar Place
Far Rockaway, New York 11691

Mr. H. Tillen - Principal

I hereby allow my child to participate in a study conducted by Elayne Helfgott, a doctoral student of Queens College, under the supervision of Dr. T. Moreau child psychologist of the Psychology Department of Queens College. The study will consist of the normal child's response to different sounds heard through earphones. Each child will be observed for 35 minutes at P.S. 215 during the regular school day.

____
Parent Signature

____
Date

Name of child ____________________

Date of birth ____________________

Class __________

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