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LATERALITY EFFECTS: IMMEDIATE OR EMERGING?

by

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ABSTRACT

An experiment was designed to investigate if late emerging ear asymmetries are a result of repeated exposure to single classes of stimuli during the course of a dichotic task. Pairs of sounds were presented dichotically followed by four binaural choices from which the initial dichotic targets had to be identified. Subjects were randomly assigned to one of three conditions: dichotic trials containing speech sounds only, trials with emotional nonverbal sounds, or a random combination of both. A significant right ear advantage (REA) was found during the first block of trials in the speech trials. No significant left ear advantages (LEA) were found in any condition throughout the study. The mixed trials, which exhibited no global ear advantage, showed the highest overall accuracy of any group. The laterality results suggested that ear advantages were not sufficiently established in this experiment to permit a conclusion regarding the time course of developing asymmetries for different classes of stimuli. As well, a response position analysis of accuracy at the four binaural choices suggested that memory components influenced in particular the emotional trials. Taken together, the results challenge the assumption that ear advantages represent instantaneous asymmetries. Under divided attention conditions, preferred modes of processing characterizing hemispheric specialization develop over time.

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INTRODUCTION

Originally used to examine limitations in information processing (Cherry, 1957; Broadbent, 1954, 1957), dichotic listening has become a classic tool for investigating cerebral function in normal individuals. In the dichotic listening paradigm, subjects are presented with two different signals simultaneously, one at each ear, and are asked to identify the dichotic targets in some manner. Dichotic investigations using verbal material in the 1950s and 1960s (Cherry, 1953; Broadbent, 1958; Moray, 1959; Treisman, 1964) revealed that attention was severely limited when divided between two competing channels of auditory verbal input. These studies in particular generated theories regarding the focus of the "bottleneck" in information processing, the point at which separate channels merge to a serial system which handles one channel at a time. Variations in the dichotic paradigm were used to investigate the basis upon which selection of one message over another is made. Treisman (1960) found that it was easier to shadow an attended message when the two passages were read by speakers of different gender, or if the passages were in different languages (Treisman, 1964). In general, selection was facilitated under dichotic conditions when the two messages could be distinguished on the basis of some stimulus characteristic.

The success of dichotic listening in characterizing attentional resources led to its utility as a non-invasive tool for inferring cerebral function. Kimura's (1961a, 1961b) original studies were germane to validating the use of the dichotic paradigm to study perceptual asymmetry. Kimura (1961a) presented dichotic digit sequences to unilateral temporal lobe and frontal lobe patients. Patients with unilateral temporal lobectomies exhibited impaired recognition of digits arriving at the ear contralateral to the removal. Both pre- and postoperatively, overall accuracy was impaired to the greatest extent in left temporal lobe patients. Having established the importance of the temporal lobes in dichotic tasks, Kimura (1961b) then went on to investigate speech lateralization in a small group of normal controls and patients with epileptogenic lesions. The control subjects (right handers) showed a significant right ear effect on the recall of digits. Subjects with left hemisphere speech were more accurate on right ear performance; conversely, subjects with right hemisphere speech were more accurate on the left ear. Kimura concluded from this study that recall of verbal material was better on the ear contralateral to the speech hemisphere.

Kimura (1964) demonstrated that not all stimuli produced the right ear advantage (REA) characteristic of her dichotic digits task. Kimura's (1964) subjects showed a left ear advantage (LEA) for the perception of dichotically presented baroque chamber music. These data were consistent with Milner's (1962) earlier report that scores on the Seashore Measures of Musical talents were depressed by right temporal lobectomy but not left temporal lobectomy. By proposing different roles for the right and left hemisphere in verbal and nonverbal perception, Kimura's work suggested that the two cerebral hemispheres were differentially specialized.

A structural model was proposed by Kimura to explain these original findings. Information is transmitted through the ascending auditory pathways from each ear to both ipsilateral and contralateral auditory cortices. The anatomy of the auditory system insures that each hemisphere receives a greater amount of information from the contralateral ear (Rosenweig, 1951). Crossed pathways seem to have more fibers and faster transmission speeds than ipsilateral ones. (Majkowski, Bochenek, Bochenek, Knapik-Fijalkowska, & Kopec, 1971). According to this model, then, input from the right ear has more direct access to the left hemisphere. Under dichotic conditions, simultaneous activation of left and right ear pathways creates an inhibition, or occlusion, of ipsilateral connections, enhancing a difference between the competitive inputs. Implicit in Kimura's model was the understanding that input to a hemisphere not specialized to process the incoming information must transverse an indirect path from the ear to the designated processing hemisphere across the corpus callosum. When subjects attempt to recognize left ear input from a dichotically presented speech pair, they may be doing so from a "degraded" transcallosal signal (Studdert-Kennedy, 1975).

Since Kimura's original findings, a great deal of research has been conducted to discover what types of stimuli are lateralized under dichotic conditions, and what conclusions may be drawn about the common properties of different classes of stimuli. Of particular interest has been the REA attributed to verbal stimuli and its implication for the role of the left hemisphere in language processing. A seminal paper by Studdert-Kennedy and Shankweiler (1970) investigated the use of single pairs of consonant-vowel-consonant (CVC) syllables which contrasted in only one phone (initial stop consonant, final stop consonant, or vowel). The syllables were formed by pairing each of the six stop consonants /b,d,g,p,t,k/ with each of the six vowels. A robust right ear effect was found for initial stops and, to a lesser degree, terminal consonants. Vowels were not consistently lateralized. From this study, Studdert-Kennedy and Shankweiler (1970) assigned to the language dominant hemisphere the role of extracting, or decoding, that part of the signal which was linguistic: "... the separation and sorting of a complex of auditory parameters into phonological features" (p. 590).

Other researchers made explicit what was implicit in the Studdert-Kennedy and Shankweiler conclusion. The critical features for identifying stop consonants are the initial bursts of energy and change of frequency from the onset of the consonant to the steady state which follows in the vowel of the CVC syllable (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Repp (1978) used synthetic speech stimuli to vary voice onset time, which he concluded had a large effect in producing the REA. Dwyer, Blumstein, and Ryalls (1982) found that the presence of abrupt onsets, not transition information, critically determined lateralized processing in CV pairs. As well, performance on dichotic tasks using stop consonants appears to be selectively influenced by unilateral brain injury. Oscar-Berman, Zurif, and Blumstein (1975) found that patients with unilateral hemisphere damage identified more CV syllables heard in the ear ipsilateral to the damage, and that the left brain-damaged group was inferior to that of normal subjects.

These results suggest that the left hemisphere may be specialized for detecting the fine temporal differences that are inherent in the speech signal. Moreover, the consistent right ear effects seen with the CV pairs suggests that this process of extracting linguistic information from the signal is dependent upon stimuli that exhibit a high degree of categorical perception. Perception is categorical when subjects can discriminate among stimuli to the extent of assigning different labels to them. Stop consonants differing in their distinctive features (i.e., voicing or place of articulation) are good candidates in this regard, because the listener must select one stimulus over another on the basis of a specific acoustical feature for which the stimuli are paired. To date, the use of stop consonant-vowels pairs has popularized the single response dichotic listening paradigm in regard to speech stimuli.

It was Divenyi and Efron's (1979) contention that right ear effects in general represent the processing of temporal information in dichotic sounds, whether speech or nonspeech. Thus, a REA becomes manifest only when the subject is listening to sounds that vary in the time domain. In this light, speech is but one special case of this larger class of signals. The REA accompanying certain types of nonspeech signals may reflect left temporal lobe's special role in the processing of temporal information. Halperin, Nachshon, and Carmon (1973), for example, reported that ear superiority shifted from left to right as a function of the increase in the number of frequency transitions presented in a dichotic sequence of tones. Stimuli with two alterations or more produced a REA; a LEA was found for stimuli with no changes. Papcun et al. (1974) found a REA when Morse code letters were dichotically presented to naive subjects. The researchers concluded that perception of stimuli associated with sequential analysis or segmental subparts recruits left hemisphere involvement.

The left hemisphere's superiority in temporal discrimination has been additionally confirmed with visual as well as somatosensory stimuli. A study by Efron (1963) established that the "point in the central nervous system" where temporal discrimination is made is in the hemisphere dominant for speech. Efron intended to test the hypothesis that judgments of temporal order of two brief tactile stimuli would be mediated by the left hemisphere in normal right handed subjects. In one set of trials, Efron delivered mild electric shock to the same finger of the right and left hand of each subjects. The presentations to the right and left sides were separated by various intervals. Efron also directed brief light flashes to the nasal retina of the right and left eye. Subjects were required to report when the stimuli were perceived as simultaneous. Stimuli were perceived as simultaneous when a 2 - 6 msec. delay separated delivery. It appeared that sensory messages received by a non-dominant hemisphere needed to transfer to the dominant hemisphere via a pathway reflecting a 2 -6 msec delay.

The research evidence suggests, then, that if the left hemisphere acts as a sequential processor, it is not the stimulus configuration per se, but the manner in which the stimulus is processed, that differentiates left from right hemisphere functioning. There is scant evidence that the right hemisphere can process temporal information as well as the left hemisphere. In general, the profile characterizing the right hemisphere has been more elusive.

Since Kimura's original findings proposing a verbal-nonverbal dichotomy for the two hemispheres, dichotic listening studies have expanded the notion that the two hemispheres handle information in basically different ways. A simple example of this principle comes from the study by Papcun et al. (1974) previously discussed. A REA was found with naive subjects using Morse code signals; a LEA was found for subjects who were professional Morse code operators. The authors concluded that Morse code operators who were more proficient at dealing with the signal did not need to segment the signal into its subparts in order to process it. Thus, the subjects exhibiting a LEA on this task may have been processing the signal in a more "holistic" manner.

The concept of the right hemisphere as a holistic processor has been poorly understood, although the label has been a popular one to encompass diverse research results. Much of the original impetus for the holistic label comes from laterality studies of facial recognition, thought to typify right hemisphere processing (DeRenzi & Spinnler, 1966). Studies of split brain patients (Gazzaniga & LeDoux, 1978) engaged in visuo-constructive tasks necessitating spatial skills have also elaborated an understanding of the type of tasks the right hemisphere may perform better than the left. Dichotic listening studies yielding left ear effects suggest at least that the two hemispheres may go about their tasks in different ways.

A group of dichotic listening studies investigated the LEA underlying the perception of musical stimuli. Shankweiler (1966) used Kimura's (1964) instrumental chamber music pairs with a group of temporal lobe patients. In this paradigm, 4 second musical excerpts were paired in which the instrument was the same and pitch range was similar, leaving melodic pattern as the primary cue. Presentation of the dichotic targets was followed by 4 binaural alternatives, from which the subject was to choose the two targets initially presented. Kimura found a LEA on this task for normal subjects. Shankweiler found that right temporal lobectomy significantly impaired performance on the left ear. He also noted that patients who were better on one ear on the melodies task exhibited an opposite ear proficiency for the digits task.

Gordon (1970, 1978) used this two response paradigm to investigate right hemisphere involvement is the processing of music. Gordon (1970) used pairs of chords as well as pairs of melodies, and found a significant LEA for the chords test only. Gordon hypothesized that his subjects used rhythmic cues for recognizing the melodies and not the pitch changes used in discriminating the chords. In a follow-up study (1978), Gordon elaborated that the important cue for identification of melody in his study was probably rhythm, which could in turn be characterized as right ear dominance dependent on temporal changes within the stimuli.

While musical stimuli in general seem to produce left ear effects, the musical components of temporal sequencing and rhythm may favor a left hemisphere involvement. The relative predominance of the rhythmic and pitch factors in a melody could determine the side and degree of lateralization in a given melody. Music may be a special class of nonverbal stimuli whose components are difficult to dissociate successfully using dichotic listening. Gordon's explanation of his findings seems clever, but it also underscores the problems associated with an inferential process such as dichotic listening. Even Gordon could not precisely define how his listeners separated the pitch patterns from the temporal ones in his melodic chords.

Left ear advantages have been reported for nonverbal auditory material other than music. Curry's (1967) subjects showed a LEA for dichotically presented environmental sounds (i.e., toilet flushing, car starting). King and Kimura (1972) and Mahoney and Sainsbury (1987) reported a LEA for vocal nonspeech sounds such as crying, laughing, and coughing. In particular, the LEA seen in dichotic studies employing stimuli of an emotional nature supports an intriguing role for the right hemisphere in the lateralization of affective processes.

There is much evidence suggesting that the right hemisphere plays a special role in the expression and recognition of emotion. In normal right handed subjects, right hemisphere activation occurs when answering emotion-related questions (Schwartz, Davidson, and Maer, 1975) and during stress (Tucker, et al., 1977). Left visual field advantages are obtained for identifying emotional expressions of human faces (Suberi & McKeever, 1977; Ley &

Bryden, 1979; Safer, 1981). One of the earliest dichotic listening studies to investigate the recognition of emotional stimuli was conducted by Haggard and Parkinson (1971). Subjects were asked to identify the verbal content and emotional value of sentences that were dichotically presented with continuous speech babble. Six sentences were read in one of four emotional tones: angry, bored, happy, and distressed. A small LEA was found for judging the emotional intonation of the sentence; no ear effect was found for identifying the content. On this basis of their findings, Haggard and Parkinson suggested that the direction of ear superiority was influenced not by the sound characteristics of the stimuli per se but rather by the nature of the task.

Although King and Kimura (1972) found a LEA for vocal nonverbal sounds such as crying, laughing, sighing, etc., they did not discuss the relationship of the LEA to the emotionality of their stimuli. In a similar experiment, Carmon and Nachshon (1973) used nonverbal dichotic stimuli: crying, shrieking, and laughing of a child, of an adult male and of an adult female. Subjects were required to match the right ear stimulus and the left ear stimulus to one of nine cartoons depicting three characters in each of the emotional states represented by the dichotic sounds. A LEA was found for seven of the nine stimuli used; a slight REA was found for identification of a child's shriek and an adult male's laughter. Carmon and Nachshon felt that they could not extrapolate from their results the crucial factors underlying the left ear superiority for nonverbal emotional sounds; however, they speculated that the LEA could be explained in reference to a right hemisphere dominance for emotional vocalizations.

Ley and Bryden (1982) conducted a study reminiscent of the emotionally intoned sentences of Haggard and Parkinson (1971). Sentences read in happy, sad, angry, and neutral voices were paired with monotone sentences of similar semantic content. Subjects were required to monitor one ear and report both emotional tone and content of the target sentence on a multiple choice recognition sheet. A LEA was found for almost every subject for identifying the emotional tone of voice; a simultaneous REA was found for recognizing the verbal content of the sentences. Ley and Bryden attributed these results to differential lateralization of emotional functions, suggesting that "... independent parallel processing occurs in the two hemispheres for the preferred components (emotional or verbal) of a composite stimulus" (Ley & Bryden, 1982, p. 7). However, with the exception of Goodglass and Calderon (1977), who studied parallel processing of verbal and tonal material under dichotic conditions, demonstrations of simultaneous ear effects for different aspects of the same stimulus are rare in dichotic listening studies. In general, dichotic listening studies imply a right hemisphere involvement in the perception of emotional stimuli.

In summary, the dichotic listening research has contributed to an understanding of the differential specialization of the two hemispheres. Dichotic research has consistently replicated Kimura's (1961a) original results of a REA for speech material, suggesting that the direction of this right ear effect in right handed subjects is related to speech lateralization. Moreover, the use of stop consonant pairs has produced a reliability which has popularized their value for investigating the mechanisms underlying the right ear advantage. The LEA found in dichotic investigations of music, environmental sounds, and vocal nonspeech sounds has been less consistent, but nonetheless points towards a right hemisphere involvement. Moreover, laterality investigations through the visual system have substantiated these hemispheric profiles. In general, visual studies support a right visual field superiority for words and letters, and a left visual field advantage for nonverbal language tasks (see Bryden, 1982).

The different specializations proposed for the two hemispheres are not, however, sufficient explanation for the asymmetrical ear effects of dichotic listening paradigms. Close scrutiny of the methodology employed in various dichotic tasks suggests alternatives to the anatomico-functional evaluation first offered in Kimura's research (1961a, 1961b, 1967). According to this model, ear effects are a consequence of the structural invariance of the auditory (or visual) system: stimuli transmitted directly to the hemisphere specialized for processing them are at an advantage. One could predict that certain classes of stimuli, or specific characteristics of the stimulus, would necessarily lead to a laterality effect.

Rebuttals to a structural model have highlighted several problems. In dichotic listening, the question was raised if "direct access" implied that subjects had a tendency to start their reports with the preferred ear, thus creating a "starting ear" bias. According to Inglis (1962), greater accuracy would occur for the ear with which subjects initiated their reports. Monitoring procedures asking subjects to report one ear first, however, confirmed that report bias was not sufficient to explain emergent ear advantages (Blumstein, et al., 1975). The issue of report bias in itself has been an important methodological one which has been addressed through careful experimental design (Bryden, 1982; Whitaker, 1985).

A second question arising from the structural approach is whether dichotic competition is necessary for lateralization, since Kimura's model states that ascending ipsilateral input will be inhibited by competing information, thus creating an ear advantage. Monaural ear effects have been obtained in many studies (see review by Henry, 1979), but there is some question as to whether these monaural effects are quantitatively and/or qualitatively different than dichotic ones. However, work with split brain patients gives strong evidence that dichotic competition does induce occlusion: these patients perform equally well with both ears on monaural identification of digits or CV syllables, but dichotic performance reveals a massive left ear loss (Milner, Taylor, & Sperry, 1978; Sparks & Geshwind, 1968).

Most importantly, a structural model cannot take into account the changes in ear advantages which follow from task demands. For example, a structural model would predict that speech stimuli should invariably produce a REA. However, in the study by Spellacy and Blumstein (1970), vowels produced a right ear effect when embedded in other speech signals, but a left ear effect when the stimuli were presented in random order with nonspeech stimuli. Klatzky and Atkinson (1971) asked subjects to memorize sets of letters. Subjects performed more proficiently with right visual field presentations when asked to judge if the first letter of the name of a picture was in the initial set. When asked if a certain letter was in the memorized set, left visual field presentations were more accurate. The researchers interpreted their data in keeping with the nature of the task and not the stimulus configuration. The first task involved language functions, whereas the second task required matching the shape of the stimulus to the memorized set. Studies of this nature imply that it is not the stimulus per se which determines the direction of the effect, but rather the manner in which the stimulus is processed.

Many laterality studies are more compatible with an attentional, rather than a purely structural, model of perceptual asymmetry. Kinsbourne (1970, 1973) advanced the view that perceptual advantages depend on the balance of activation or arousal of the two hemispheres. In this selective attention model, each hemisphere serves the contralateral side of space. Activation of one hemisphere turns attention to the opposite side, while inhibiting activation of the other hemisphere. In comparison to the structural model, then, hemispheric asymmetries develop not because of direct access but because the stimulus, or the expectation of a stimulus, directs attention to the field contralateral to the primed hemisphere, facilitating perception of material presented to that field (Kinsbourne, 1975).

Implicit in this model is a type of priming mechanism. Asymmetries are material-dependent in the sense that verbal and non-verbal tasks are assumed to differentially prime the hemisphere specialized to process the information. In addition, expectancy for a certain class of material will make the designated processing hemisphere more receptive to incoming information in general, thus enhancing a perceptual advantage. The research of Spellacy and Blumstein (1970) may be interpreted in this light. Expectation of a language or non-language set was manipulated by presenting in random series, with the CVC test stimuli, dichotic pairs of real words or pairs of melodies and sound effects. The test stimuli generated a right ear effect when embedded in other speech signals, but a left ear effect when presented with nonspeech sounds. Thus, using Kinsbourne's approach, asymmetries may be predicted when an attentional set is induced by the nature of the task, rather than from structural dependency.

Kinsbourne (1970) himself suggested an experimental test of the above prediction. If one were to intermingle in separate dichotic trials material known to yield a left ear advantage with that which yields a right ear advantage, the perceptual laterality should be reduced, since the possibility of priming the system with a certain type of material is curtailed. Research using mixed lists has not emerged clearly in favour of Kinsbourne's hypothesis, however.

Dee and Hannay (1973) randomly intermixed CVC trigrams with complex visual forms and presented them to subjects in either the right or left visual field. A left visual field superiority was found for the task. These researchers concluded that the effect of randomly intermixing verbal and nonverbal stimuli may be characterized by shifts towards a common coding strategy. Because a subject can neither switch sets to accommodate different types of stimuli, nor develop an expectancy based on one class of stimuli, a predominant processing mode will be established if there is a compatibility in the stimuli. Whereas the form stimuli used in their experiment could not be processed easily in the left hemisphere, the CVC trigrams were amenable to right hemisphere visuo-spatial processing, consistent with the preferred mode of processing established with exposure to the forms.

There have also been reports of concurrent left and right laterality effects with mixed lists. Kallman (1978) presented subjects with dichotic pairs of musical and speech sounds randomly intermixed. Reaction time measures favored the right ear in response to speech targets; there was a trend favoring the left ear in the faster detection of musical targets. The significant interaction between stimulus types and ears was interpreted by Kallman to mean that an attentional explanation based on expectancy alone could not justify fully the ear asymmetries. Goodglass and Calderon (1977) mixed their presentation in a somewhat different manner. Subjects were presented with spoken numbers superimposed on piano notes in each ear and, in a second condition, competing digits sung to competing tonal patterns. Independent right ear superiority for the verbal component and left ear superiority for the tones emerged, supporting the view that independent parallel processing takes place in the two hemispheres for their preferred components of a complex stimulus. The researchers found their data incompatible with Kinsbourne's model, which cannot explain simultaneous opposite perceptual asymmetries.

Using Kinsbourne's attentional perspective, concurrent activity intended to activate one hemisphere should be able to create shifts in laterality patterns of subjects engaged in dual-task conditions. This is, in fact, what Kinsbourne (1970) investigated initially. He found that subjects who were required to remember a concurrent verbal memory load of six words while performing a gap detection task exhibited a right visual field advantage, whereas previously there had been no advantage. Subsequent studies by Hellige and Cox (1976) and Hellige, Cox, and Litvac (1979) also concluded that concurrent verbal memory loads can influence laterality patterns. Subjects in the Hellige and Cox (1976) study were required to recognize complex polygon forms presented to the right or left visual fields. A left visual field (right hemisphere) advantage was observed in a no memory load condition; however, when subjects were required to concurrently remember 2 or 4 words, this perceptual asymmetry was reversed. Following a direct access model, one could not account for this shift in laterality. In contrast, according to Kinsbourne, maintaining verbal material in memory should serve to activate the left hemisphere, improving performance in the space contralateral to the more activated of the two hemispheres.

However, Hellige et al. (1979) were encouraged to re-evaluate Kinsbourne's attentional model in keeping with additional findings to the above study. In a concurrent memory load condition increased to 6 words, form recognition accuracy for the polygons increased, resulting in a left visual field advantage. This incremented condition seemed to interfere with left hemisphere performance. At this stage, the researchers concluded that the "...laterality shift may be qualitatively different when a considerable amount of verbal processing is required than when verbal processing requirements are not demanding" (Hellige et al., 1979, p.253).

Next, Hellige et al.(1979)investigated a task where the concurrent memory load was nonverbal, and the laterality task was one of tachistoscopic word recognition. The nonverbal memory task neither decreased overall word recognition nor changed the magnitude of the observed right visual field (left hemisphere) advantage. In an analogous dichotic listening experiment, Hellige and Wong (1983) found that a right ear advantage for recognition of CV syllables was decreased with a concurrent verbal memory load, but with a nonverbal concurrent load, no effect on right or left ear recognition was evidenced.

Taken together, the work by Hellige and colleagues pointed to the possibility that when both the laterality task and concurrent memory load are verbal, recognition performance of the left hemisphere deteriorates relative to right hemisphere. From this, Hellige et al. postulated that the left hemisphere functions as a "limited capacity information processing system," which could be influenced separately from the right hemisphere. Concurrent verbal activity, then, might selectively interfere with processing in the left hemisphere, depending on the amount of processing required and the difficulty of the task. In other words, concurrent activity does not necessarily prime one hemisphere to make it more receptive to incoming stimuli.

Hellige et al.'s (1979) re-evaluation of the attentional model makes sense if a concurrent task is indeed separable from an ongoing laterality task. In their research, no attempt was made to address the issue that the data represented some type of interactive processing between the two contiguous tasks. In this sense, the researchers failed to speculate on the the level of processing which might be necessary to maintain items in memory during the laterality task. Under dual task conditions, laterality patterns may emerge, or fail to emerge, not because of memory load per se, but rather because of the types or levels of processing inherent in concurrent task situations.

The levels of processing approach was originally introduced by Craik and Lockhart (1972). The basic premise is that stimuli can be processed at different levels. In the case of verbal stimuli, it can be processed at a pre-categorical, acoustic level (Crowder, 1973), a linguistic level which codes the stimulus into categorical, phonetic features, or a semantic level. Deeper processing leads to a more persistent memory trace. The degree of retention of a stimulus will depend on the extent of processing expended on a task. According to Craik and Lockhart (1972):

> ... speed of analysis does not necessarily predict retention. Retention is a function of depth, and various factors, such as the amount of attention devoted to a stimulus, its compatibility with the analyzing structures, and the processing time available, will determine the depth to which it is processed... (pp.676-677).

It is the nature of the encoding process, then, and not the attributes of the stimuli per se, that is the main determinant of retention of stimulus information.

The research by Moscovitch and colleagues exemplifies a depth of processing approach to interpreting laterality effects (Moscovitch, Scullion, & Christie, 1976; Klein, Moscovitch, & Vigna, 1976; Moscovitch & Klein, 1980). These researchers have proposed that lateralization is in actuality a late, or deep, stage of processing. Early processes at the sensory level are not lateralized since they can be handled equally well by either hemisphere. In a study by Moscovitch et al.(1976), no perceptual asymmetry was found when target faces were presented closely in time to comparison faces. With short interstimulus intervals in the range of 50 msec., subjects were forced to respond to the task on the basis of physical features only, preventing depth of processing. With longer time intervals between the two stimuli, subjects were able to process the target face to some depth. When the interstimulus interval between the target and comparison faces was lengthened, a left field advantage was observed.

The research by Studdert-Kennedy (1970) and Crowder (1973) involving speech perception lends support to

Moscovitch's interpretation. These researchers have implied that all acoustic signals undergo a common low level processing. The right ear advantage on dichotic tests using stop consonant stimuli emerges when the left hemisphere extracts linguistic information from these earlier stages of analysis. The stop consonants in particular show a high degree of categorical perception in that they allow the listener to distinguish them on the basis of their distinctive features. This categorical nature of the stimuli characterizes the higher order type of processing necessary to recruit specialized hemispheric involvement. In this sense, a similar process would apply to the right hemisphere in extracting higher order, nonlinguistic information from music, for example.

Moscovitch et al.'s (1976) study of face recognition reiterates the basic claim that asymmetries are determined not by stimulus configuration but rather by the cognitive operation specific to processing the stimulus. Depth of processing is necessary to engage the appropriate cognitive operation:

> Hemispheric differences emerge at a later stage of processing concerned with integrating sensory features into relational or categorical features that will reflect the specialized processing capacities of each hemisphere (Moscovitch & Klein, 1980, p.591).

A point of contention with Moscovitch's model of laterality as depth of processing has been whether asymmetries are indeed restricted to later stages of processing (see Cohen, 1972). Nonetheless, this model is attractive from the perspective of being able explain results incompatible with a purely structural model, such as simultaneous or reversed asymmetries, which seem to plague many of the results of dichotic listening experiments.

That the two hemispheres are specialized to process different types of information does not seem to be in doubt; the points of departure among the three models centers around the mechanisms which underlie perceptual advantages. In the structural model, perception is best for stimuli with the most direct access to the hemisphere specialized for processing it. In Kinsbourne's attentional model, hemispheric priming by a stimulus or by expectation of a stimulus biases attention to the field contralateral to the primed hemisphere, facilitating perception of stimuli presented to that field. In the information processing model suggested by Moscovitch et al. (1976), asymmetries emerge only as the stimulus is represented in terms of higher order, categorical processes which characterize later stages of processing.

In theory, both Kimura's and Kinsbourne's models of laterality have held that asymmetry is due to enhanced perception. A strict interpretation of a structural model of laterality does not leave room for attentional variables of the type proposed by Kinsbourne. In reality, however, it has never been clearly established how to delimit the contributions of attention to the perceptual process. Perception usually refers to the cognition resulting from the activity of the cells in various regions of the neocortex beyond primary sensory cortex. As such, perception is an analysis of sensory integration that results in the recognition of particular phenomena. Attention is generally agreed to be a selection process by which an organism deals more effectively with one type of sensory stimulus at the expense of other stimuli also stimulating the system. Under divided attention conditions, when a subject must attend to several stimuli simultaneously, it is extremely difficult to interpret the relative contributions of perception versus attention to the total perceptual process.

Naantanen (1982) has suggested that there must be a bias in the sensory system toward an attended stimulus that enhances perception. The basis for this bias could be either a stimulus characteristic or stimulus meaning at different levels of neural processing. Naantanen proposed that this bias begins to develop *after* the first presentation of the stimulus as a result of selective rehearsal of the task-relevant features. One implication of this research is that depending on the task, it may take longer in some cases to learn to ignore task-irrelevant features. Naanaten's work has been largely in the realm of electrophysiological recordings, and at present there is no way to employ his methodology with cognitive studies of divided attention to test his hypotheses. Nonetheless, his research suggests that there may be neurophysiological mechanisms involved in attention which are in keeping with structural models of laterality.

An issue raised by Hirst (1986) is whether attention is an actual mechanism or a reflection of the limits of the brain's resources. If it is a mechanism, then Hirst proposes that it should eventually be possible to locate the areas of the brain responsible for attentional effects. On the other hand, if attention reflects processing capacity, then attention will be dissociable from perception. It is unlikely that cognitive paradigms will be able to address these concerns in the future without recourse to a neurobiological approach to the study of attention.

The phenomenon of memory also poses a challenge to a full understanding of laterality effects. In general, the distinction between memory and perception has been poorly understood. Implicit in the depth of processing model of laterality is a sense that the later stages of processing may involve some memory component. A study by Dee and Fontenot (1973) has been instructive in suggesting that left visual field advantages arise from differences in memory rather than purely perceptual processes. The researchers presented forms of high complexity and low association value to the left and right visual fields. After a variable delay of 0, 5, 10, or 20 seconds, the subject was required to indicate whether a new form was the same, or different from, an initial figure. A right hemisphere superiority emerged only at longer retention intervals.

That memory may contribute to laterality effects attributed to right hemisphere functioning, such as facial recognition, has been borne out in research by Milner (1968) in studies of patients with right temporal lobectomies. Milner found that immediate recognition of unfamiliar photographed faces in her patients was normal, although impaired after a 2 minute delay. Milner felt her patients were exhibiting a mnemonic rather than a perceptual disorder. As discussed earlier, a study by Moscovitch et al. (1976) using normal subjects showed that a left visual field superiority was apparent when interstimulus intervals between target and comparison faces was long enough to permit depth of processing. At short interstimulus intervals, no asymmetry was apparent.

Spatial recognition, and in particular facial recognition, are thought to typify the processing style attributed to the right hemisphere (Levy, Trevarthen, & Sperry, 1972). Perhaps the right hemisphere accrues an advantage with the retention of stimuli that are primarily low in "verbalness" only after a time delay. This is not because the right hemisphere is more holistic or less analytical but because the left hemisphere is less efficient at processing the information, and less competent at encoding complex visual stimuli. Thus, the left hemisphere's short term recognition of complex visual material may not lead to the formation of long term memories. If the nature of the material committed to long term memory characterizes the different processing modes of each hemisphere, then one could expect a memory component to contribute to laterality effects.

Regardless of the model used to explain laterality effects, all perspectives share the view of asymmetry as a preferred mode of processing which improves performance for one perceptual field relative to the other. Thus, although the end result may be a complicated interaction of perception, attention, and memory, the development of asymmetry in any task necessarily implicates cerebral specialization. If ear advantages in dichotic listening are a direct reflection of hemispheric dominance, dichotic listening tasks might be expected to produce results that are reasonably invariant with respect to the direction, if not the magnitude, of an ear advantage.

In a replication of a study by King and Kimura (1972), Mahoney and Sainsbury (1987) suggested that attentional mechanisms help to determine the magnitude of an ear effect. Mahoney and Sainsbury (1987) presented subjects with human, nonspeech sounds in a dichotic forced choice recognition task. Subjects were asked to verbally identify a dichotic pair of targets from an array of 4 binaural alternatives. The researchers found that under divided attention conditions, a LEA developed in the latter half of the experimental trials. When subjects were required to monitor either the left or right ear, there was no significant ear by block interaction. While consistent with the direction of effect found in King and Kimura's work (1972), the Mahoney and Sainsbury study also hypothesized a role for attention in establishing the rate of development of laterality effects seen in this paradigm with human nonspeech sounds. The underlying assumption is that asymmetries do not occur instantaneously under divided attention conditions but rather develop over time as a result of deployment of attention.

Late occurring performance asymmetries have been rarely reported for verbal and nonverbal stimuli (Perl & Haggard, 1975; Sidtis & Bryden, 1978; Mahoney & Sainsbury, 1987). Results of this research have not clarified whether fluctuations in response patterns over trials were specific to the stimulus material and/or the chosen paradigm. The present study used the two-response paradigm employed by Mahoney and Sainsbury (1987) to investigate if repeated exposure to a specific class of stimuli (i.e., speech, emotional sounds) is necessary to establish the late emerging perceptual asymmetry found in Mahoney and Sainsbury's results. Neurologically intact subjects, both males and females, were presented with dichotic pairs which were identified verbally from 4 binaural alternatives. In keeping with Mahoney and Sainsbury's data, one would predict that under divided attention conditions, the direction of an ear effect should reflect the hemispheric specialization accompanying the specific category of stimuli, but that an ear advantage would emerge only after repeated exposure to the stimuli. Different pairs of emotional stimuli should render a late emerging LEA; by comparison, subjects exposed to speech sounds only in this two-response paradigm should show a late emerging REA.

The idea that asymmetries take time to develop under certain conditions is suggestive of a priming mechanism which facilitates performance. According to Kinsbourne, this type of priming should result in a gradient of improved performance over the course of the trials. If a late emerging effect represents an "attentional set" induced through repeated exposure to stimuli, subjects exposed to dichotic trials of mixed classes of stimuli should exhibit no ear advantage. As well, since laterality reflects a preferred mode of processing which improves performance, one could also predict that the mixed runs should be more difficult, leading to lower ear accuracy scores than in the pure trials containing a single class of stimuli.

METHOD

Design: Subjects were randomly assigned to one of three conditions: speech sounds, emotional nonverbal sounds, or a combination of both. Each condition was considered a separate mixed factorial design. The independent variables were sex (male and female), ear (left and right ear), and block (block one and block two). The total number of trials were divided in half to form blocks one and two. Correct performance on the first half of the trials was summed to form block 1; correct performance on the latter half comprised block 2. Sex was the between subject variable. Ear and block were within subject variables. The dependent variable was the number of correct responses on the dichotic listening task.

Stimuli and Apparatus: Speech stimuli employed in this experiment were consonant-vowel combinations/ba/,/pa/,/da/, /ta/,/ga/,/ka/. The speech stimuli were spoken by an adult, male, professional broadcaster and recorded on a metal (Type IV pure iron particle) cassette tape. The human, emotional nonspeech sounds were recorded from a BBC sound effects album (Waaser,1976) onto a master cassette tape. Emotional stimuli included adult laughs, baby cries, adult sobs, moans, and coughs.

To generate dichotic tapes using segments from the above master tapes, samples of stimuli were digitized via an analog-to-digital converter (ADV11-C) on a VAX computer

(11/730) with ILS processing. The signals were low-pass filtered at 4800Hz using a Wavetek Dual Hi/Lo Filter (model #852), and sampled at 10,000 samples/sec. The resulting file for each sample was then displayed on the computer terminal. Each speech segment was edited to 250 msec, emotional stimuli to 1400 msec. All segments were then transferred to new files which were equated for overall intensity. The mean decibel level was 46.6 dB (speech = 47.1, emotional stimuli = 46.5). The prepared stimuli were then stored on disks on a PDP 11/23+ computer in a separate file for each stimulus set and each channel.

The DICHOT program of Procter, Ponton,and Jamieson (1986), was used to execute simultaneous two-channel output. Recording levels of the two channels were calibrated and equated for intensity. Order of stimulus presentation was then entered manually into the computer, as well as values for interstimulus interval (ISI = 1.25 sec) and intertrial interval (ITI = 12 sec). Order of report was controlled by having the left ear dichotic response represent the first correct response position on one half of the trials, while the right ear dichotic stimuli represented the first correct response position on the remaining trials. No two consecutive trials had the same correct response positions.

Stimuli were then processed through a digital-to-analog converter (AAV11-C) at a sampling rate of 10,000 samples/sec/channel, low pass filtered at 4800Hz, amplified through a Crown D-75 amplifier, and recorded on a two channel Revox B710 MK11 microcomputer cassette tape deck. The final dichotic tapes were recorded on metal cassette tapes. A dichotic tape consisted of six practice trials, followed by two blocks of experimental trials. Each trial consisted of a dichotic pair of sounds followed by four successive binaural sounds, two of which were identical to the dichotic targets. Two tapes were made for each condition, each with a different order of trial presentation.

The speech tapes consisted of twelve experimental trials, with six trials in each block. Dichotic pairs were chosen which differed on the basis of one distinctive feature, either voicing or place of articulation. Speech blocks were balanced so that pairs equally represented these two categories within each block of trials. The emotion tapes consisted of ten experimental trials. All sounds in a given trial were from the same category (i.e., moans), to minimize verbal labelling of the sounds. Block presentation was designed such that the first five trials (block 1) represented each of the five emotional stimulus categories. Similarly, the last five trials (block 2) represented one trial from each of these categories. The mixed tapes consisted of twenty-two experimental trials. Each block contained the six speech trials (used in the speech tapes) and the five emotional trials (used in the emotional tape presentation), randomly intermixed. Table 1 outlines sample trial presentations, from Tape A, for each condition.

TABLE 1

Dichotic Trial Presentation for Tape A for Each Condition

TRIALS	CONDITION		
	Speech	Emotion	Mixed
Practice	6 trials	6 trials	6 trials
Block 1	1. V	1. Moan	1. Laugh
	2. P	2. Laugh	2. P
	3. P	3. Cry	3. V
	4. V	4. Cough	4. Sob
	5. V	5. Sob	5. V
	6. P		6. Cough
			7. P
			8. V
			9. Cry
			10. Moan
			11. P
Block 2	7. P	6. Cry	12. Cry
	8. V	7. Laugh	13. V
	9. P	8. Moan	14. P
	10. V	9. Sob	15. Moan
	11. P	10. Cough	16. P
	12. V		17. Cough
			18. V
			19. Laugh
			20. Sob
			21. P
			22. V

V = Voiced/Voiceless Dichotic Pair
P = Place of Articulation Pair

The stimulus tape was played to the subjects with a Sony Stereo Cassette Deck TC-AX22 ,a Sony integrated stereo amplifier TA-AX22, and AKG (K240) stereo headphones. Sound pressure level was adjusted to 70dB across the headphones. By reversing headphone orientation, one half of the subjects heard channel 1 on the left ear, while the remaining subjects heard channel 1 on the right ear.

Subjects: Seventy-two (36 males and 36 females) undergraduate students enrolled at the University of Calgary volunteered to participate in this experiment. Subjects were each paid $3.00. The mean age of the subjects was 24.86 years (males = 23.42, sd = 3.85; females = 26.31, sd =5.45). The criteria for selection were dextrality and an auditory threshold of 20dB or less with no more than a 5dB threshold difference between the left and the right ears. The overall performance of all subjects included in the analysis was above 50% accuracy. Bilingual subjects were rejected, as were professional musicians, since research suggests that specialized linguistic or musical skills may affect perceptual asymmetry (Bever & Chiarello,1974; Papcun et al., 1974; Mohr & Costa, 1985).

Handedness was assessed with Bryden's (1977) Simplified Hand Preference Questionnaire. When scored, this questionnaire provides a laterality quotient (lq) ranging from -1 to +1, with negative scores indicating left handedness, positive scores right handedness. The mean lq from the handedness questionnaire was +.96 (males= +.96, sd= .08; females =+.97, sd = .09). Auditory thresholds were measured for each ear separately with a Maico #39 audiometer.

Procedure (see Mahoney, 1985):

Subjects who indicated right handedness on the questionnaire and subjectively reported normal hearing were tested individually in a sound proof booth (Controlled Acoustical Environments No. 11631). The following instructions were given to the subjects:

> "You are going to hear two different sounds at exactly the same time, one in your left ear and one in your right ear. Listen carefully to both of them. Following this, you will hear four other sounds, presented one at a time. Two of these four sounds will be exactly the same as the first two sounds which were initially presented together. I would like you to tell me, by number, which two of those four other sounds are the same as the first two sounds that were presented together."

The subject was then given an example of the format for each trial. Subjects were required to indicate by number the dichotic targets. If uncertain, they were instructed to guess. Subjects were expected to provide answers in numerical sequence and to respond only after they had heard all four binaural sounds. After procedural questions were answered, the subject was placed under the headphones in one of the two headphone positions, and the six practice trials began. While in the soundproof booth, the subjects communicated with the experimenter through a Fanon intercom. Verbal answers provided by the subjects were recorded manually by the experimenter. Following the six practice trials, subjects were given the opportunity to ask questions. The experimental trials began when all procedural questions were answered. After the experimental trials, the hearing of each subject was tested with a Maico #39 audiometer. The frequency range tested was 125Hz to 6000Hz.

RESULTS

All inferential statistics were computed with Biomedical Computer Programs-P series (BMDP) software programs (Dixon, 1985). The programs were univariate and multivariate programs which generated repeated measures analyses of variance (ANOVA). For all within subject effects with more than one degree of freedom, the Greenhouse-Geisser probabilities were employed to establish significance. ANOVA Tables are presented in Appendix A, Tables 1 through 15.

A criticism of early dichotic studies was that they failed to specify the sex of the subject or to report whether sex differences were observed (see McGlone,1980). For this reason, sex was included as a between subject variable in the present study to address this methodological issue. However, researchers (Harshman & Remington, 1974; Lake & Bryden, 1976; McGlone, 1980; Harshman, Hampson, & Berenbaum, 1983)) have cautioned that perhaps only large scale dichotic studies can reliably uncover significant ear by sex asymmetry.

Preliminary Analyses:

For each condition, a three-way mixed factorial ANOVA was conducted on the total correct response scores to assess the influence of headphone position and order of presentation on the laterality data. Headphone position (channel 1 on left ear versus channel 1 on right ear) and trial presentation (Tape A versus Tape B) served as between subject variables; ear (left versus right) served as the within subject variable. The main effects of headphone position and order of trial presentation were nonsignificant, as were possible interactions. Results of this analysis indicated that in all conditions, neither headphone position nor order of presentation was a nuisance variable (Keppel, 1982) in the laterality data.

To evaluate the possibility that response patterns resulted from a response bias created by the subjects' monitoring a preferred ear, order of report was assessed by a two-way mixed factorial ANOVA in which sex served as the between variable and ear of first correct response served as the within variable. For all three conditions, main effects of ear and sex were nonsignificant; interactions between sex and ear were nonsignificant as well. This analysis indicated that subjects reported the right ear first as often as they reported the left ear first.

Stimulus Type Analyses:

Each condition was composed of different categories of dichotic stimuli within experimental runs. For this reason, stimulus type analyses were conducted separately on each condition. No significant effects were apparent to suggest that some types of stimuli were more accurately recognized than others within their respective conditions.

In the speech condition, the stimuli were composed of dichotic pairs differing in either voicing or place of articulation. Divenyi and Efron (1979) reported differences between these two categories in terms of magnitude of a REA. To evaluate possible differences, a three-way mixed ANOVA was conducted in which sex was the between subject variable; the within subject variables were ear (left versus right) and dichotic pairs differing in either voicing or place of articulation. Main effects of sex and pairing were nonsignificant as were all possible interactions. However, the main effect of ear was significant ($F = 5.76$; $df = 1,22$; $p < .05$). Inspection of cell means in Table 2 indicates that subjects more accurately identified the speech stimuli with their right ear than with their left, regardless of the distinctive pairing of the dichotic speech sounds. This result is in keeping with the predicted REA for speech stimuli.

TABLE 2

Cell Means and Standard Deviations for the Ear Effect in Speech Stimuli Types

Distinctive Feature	Left Ear	Right Ear
Voicing	4.63 (1.04)	5.13 (.81)
Place of Articulation	4.38 (1.24)	5.04 (.82)

To determine if some types of emotional sounds were more accurately identified than others, emotional stimulus type was evaluated with a three-way mixed ANOVA. Sex served as the between subject variable. Ear (left and right) and stimulus type (cough, laugh, moan, adult sob, baby cry) served as within subject variables. All main effects and interactions were nonsignificant, indicating that emotional sounds were identified equally well for both ears.

TABLE 3

Mean Number of Correct Responses and Standard Deviations for the Left and Right Ears for Each Emotional Stimulus Category

	Stimulus Category				
	Cough	Laugh	Moan	Sob	Cry
Left Ear	1.58(.41)	1.25(.74)	1.50(.47)	1.29(.70)	1.25(.65)
RightEar	1.58(.40)	1.37(.71)	1.50(.35)	1.42(.61)	1.42(.61)

A three-way mixed ANOVA was conducted on proportion of correct responses in the mixed condition to determine whether subjects were more accurate in identifying speech versus emotion trials. Sex was the between subject variable. Ear (left or right) and class of stimuli (emotion versus speech) were the within subject variables. Main effects of sex, class, and ear were nonsignificant; the interaction of ear by sex proved to be significant ($F = 16.67$; $df = 1,22$; $p < .001$). Simple main effects analysis on the ear by sex interaction suggested a significant difference between left and right ears for males ($F = 15.74$; $df = 1,22$; $p < .001$). Perusal of means in Table 4 suggests that females had equivalent ear performance, whereas right ear scores were more accurate than left ear scores for males. However, the analysis of interest here is whether subjects in general treated the emotional stimuli differently than the speech stimuli under mixed conditions. Results would indicate that speech and emotion stimuli were not differentially identified.

TABLE 4

Proportion of Correct Responses and Standard Deviations for Ear by Sex Interaction for Males and Females in Stimulus Type Analysis in the Mixed Condition

	Left Ear	Right Ear
Males	.749 (.10)	.860 (.095)
Females	.841 (.12)	.811 (.142)

<u>Overall Accuracy:</u>

Correct response totals were tabulated for all conditions. Inspection of Table 5 reveals that overall accuracy was highest for the stimuli in the mixed condition at 81.5%, followed closely by the speech stimuli condition at 79.86%, and the emotional stimuli trials at 70.84%. In general, then, subjects were most proficient at the dichotic task in the mixed condition, and least proficient with the emotion stimuli. Performance is equivalent between left and right ears in the emotion and mixed condition, but the speech stimuli exhibit more of a disparity between left and right ear accuracy, suggesting a REA for the speech stimuli.

TABLE 5

Percentage of Overall Ear Accuracy for All Conditions

Stimuli	Left Ear	Right Ear	OVERALL
Speech	75.00	84.72	79.86
Emotion	69.17	72.50	70.84
Mixed	80.00	83.46	81.50

Overall ear accuracy was also assessed separately for the speech and emotion stimuli comprising the mixed trials. Table 6 compares ear accuracy in the pure trials to their counterpart in the mixed trials. Under mixed conditions, both left and right ears maintained or improved accuracy relative to the pure trials. The right ear advantage indicated in the speech trials, denoted in the preceding table, disappears under mixed conditions because the left ear improves its performance.

TABLE 6

Percentage of Overall Ear Accuracy for Pure Speech and Emotion Stimuli Trials Compared to Mixed Trials

	Left Ear		Right Ear	
	Single /	Mixed	Single /	Mixed
Speech	75.00 /	82.30	84.72 /	84.62
Emotion	69.17 /	76.67	72.50 /	82.08

Table 7 summarizes overall ear accuracy scores in each condition according to sex. Perusal of the accuracy values suggests generally equivalent performance within conditions for both males and females.

TABLE 7

Percentage of Overall Ear Accuracy for Males and Females in All Conditions

Stimuli	Males	Females	OVERALL
SPEECH			
Left Ear	78.20	71.53	75.00
Right Ear	86.81	82.63	84.72
EMOTION			
Left Ear	70.00	68.33	69.17
Right Ear	78.83	69.17	72.50
MIXED			
Left Ear	74.99	84.09	79.54
Right Ear	83.36	80.58	83.46

In summary, the results of the overall accuracy scores reflect highest ear accuracy for the mixed trials, with right ear performance higher than left ear performance in the speech trials. This right ear advantage diminished under mixed conditions.

Laterality Analyses for Individual Subjects:

Laterality analyses included calculation of ear advantages for individual subjects according to a difference score and according to Hawles' (1969) *e* index. To determine the percentage of subjects exhibiting right or left ear advantages, individual difference scores (correct right ear responses - left ear responses) were first calculated for each subject in each condition. Table 8 summarizes the correct response data in terms of percentage of male and female subjects exhibiting right or left ear advantages (REA, LEA). In the speech condition, 58.33% of all subjects showed a right ear advantage (REA); 25% showed a left ear advantage (LEA), and 16.67% revealed no ear advantage. In the emotion condition, 50% of subjects showed a REA, 33.33% exhibited a LEA, and 16.67% had no ear advantage. Under mixed conditions, 54.17% of subjects exhibited a REA, 37.5% showed a LEA, and 8.33% showed no ear advantage. Perusal of the overall percentage reveals that the distribution of subjects according to ear advantage is similar in all conditions, although the speech condition contains the highest proportion of subjects with a right ear advantage.

A methodological issue which surrounds the measurement of ear advantage in dichotic listening is the preferred laterality index. Some researchers have argued that by nature laterality measures are within subjects designs and as such, performance cannot be compared directly between subjects who operate at different performance levels

(Marshall, et al., 1975; Bryden & Sprott, 1981; Lauter, 1982). In response to these considerations, Hawles' (1969, but see Repp, 1977) e index has been recommended to measure individual performance in a two-response paradigm. Hawles' approach expresses the observed lateral difference in the two-response paradigm as a proportion of the maximum possible difference that occurs at the subject's level of accuracy. If a subject scores below 50% accuracy, e is calculated by right ear minus left ear responses/total correct response; over 50%, e becomes right ear minus left ear/total errors. In light of the above consideration, Hawles' (1969) laterality index e (right ear correct responses minus left ear responses/total errors) was calculated for individual subjects in all conditions.

TABLE 8

Percentage of Subjects Exhibiting Ear Advantages (EA) for All Conditions

Stimuli	Males	Females	OVERALL
SPEECH			
REA	58.33	58.33	58.33
LEA	25.00	25.00	25.00
No EA	16.67	16.67	16.67
EMOTION			
REA	50.00	50.00	50.00
LEA	25.00	41.67	33.33
No EA	25.00	8.33	16.67
MIXED			
REA	83.33	25.00	54.17
LEA	8.33	66.67	37.50
No EA	8.33	8.33	8.33

Figure 1 depicts the distribution of scores generated from the calculation of e for each subject. The percentage of subjects showing right and left ear advantages is consistent with the above table. In other words, whether the ear advantage was calculated by e or with a simple difference score, the percentage of subjects exhibiting right and left ear advantages was comparable between these two indices.

Using a difference score, ear advantages (EA) were calculated to determine the percentage of subjects who reversed ear advantage between block 1 and 2. A subject was considered to have reversed EA if block 1 showed more correct right than left ear scores, and block 2 the opposite (or vice versa). Using this measure, 41.67% of subjects in the speech condition exhibited changes between block 1 and block 2 (males = 41.67%, females 41.67%). In the emotion condition as well, 41.67% reversed ear accuracy (male = 33.33%; females = 50%). In the mixed condition, 33.33% of both males and females showed changes in EA. Considering the criticisms made by Repp (1978) and Speaks et al. (1982) regarding the unreliability of dichotic listening tasks in general, this is an important observation. One cannot assume a subject's overall performance is representative of his profile during the course of the task. Hence, looking at trial-by-trial response patterns in some systematic fashion may be an important addition to understanding how asymmetry develops under certain conditions.

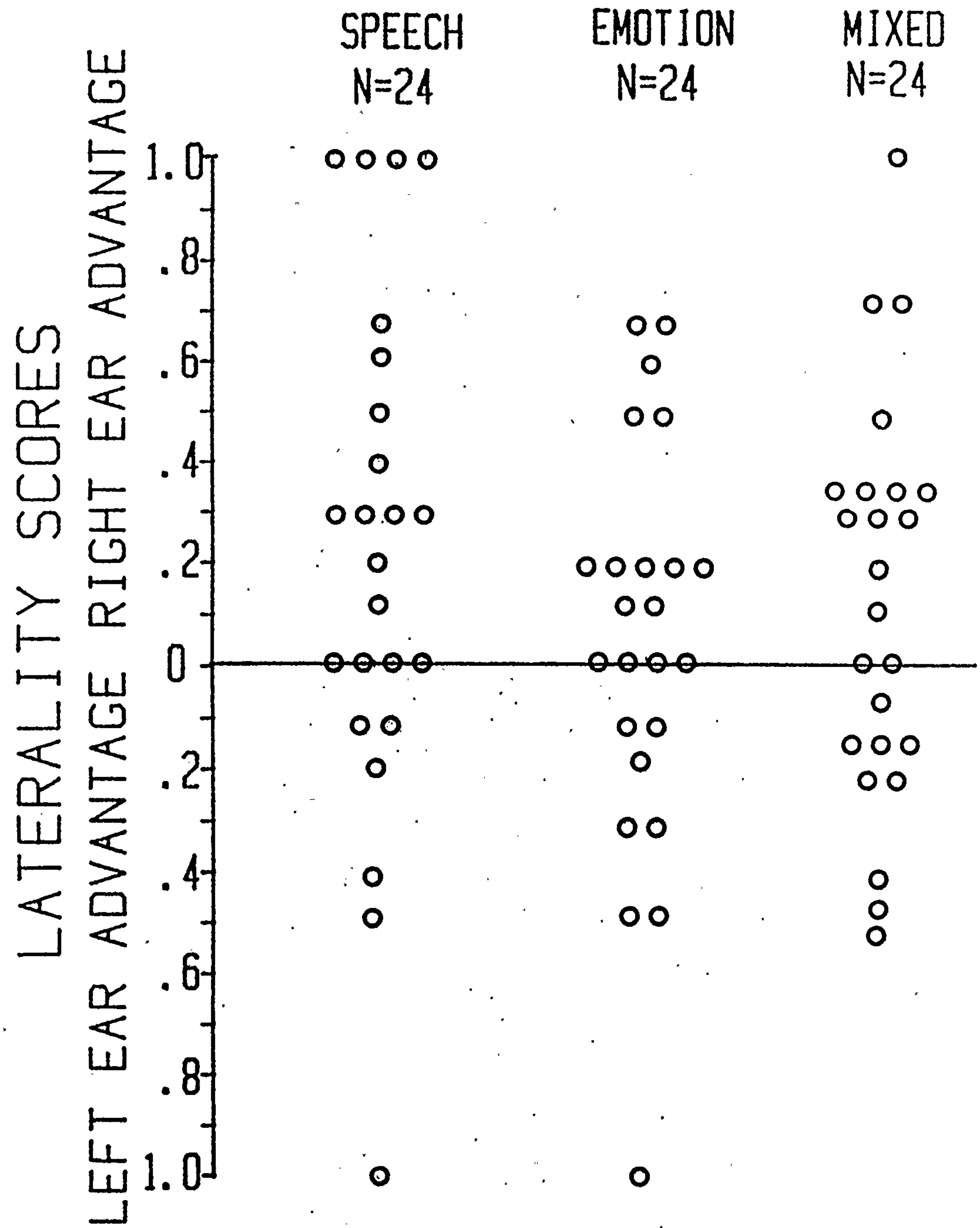

Figure 1: Laterality Index e in Speech, Emotion, and Mixed Conditions. Laterality scores are right ear responses minus left ear responses divided by total number of errors. Each circle represents a subject.

Correct Response Analyses for Grouped Subjects:

Correct responses for all trials in each condition were tabulated, and then the data were grouped into blocks to determine if response patterns differed across trials. Figure 2 (a,b,c) depicts correct response scores for individual trials. To determine if response patterns differed across trials, data were grouped into two equal blocks. In the speech condition, for example, correct responses on trials 1 to 6 were summed to form the first block; responses on trials 7 to 12 formed block 2. Blocked correct response data were subjected to a three-way mixed ANOVA. Sex was the between subject variable. Ear (left versus right) and block (block 1 and block 2) were within subject variables. This analysis yielded a significant main effect of ear ($F = 5.76$; df = 1,22; $p < .05$), and a significant ear by block interaction ($F = 11.00$; df = 1,22; $p < .01$). All other main effects and interactions were nonsignificant. Simple main effects analysis on the ear by block interaction supported a significant difference within block 1 ($F = 17.02$; df = 1,22; $p < .001$). Means for the ear by block interaction are presented in Table 9.

TABLE 9

Cell Means and Standard Deviations for the Ear by Block Interaction of Speech Stimuli Condition

	Block 1	Block 2
Left Ear	4.167 (1.38)	4.833 (1.09)
Right Ear	5.500 (0.49)	4.667 (1.07)

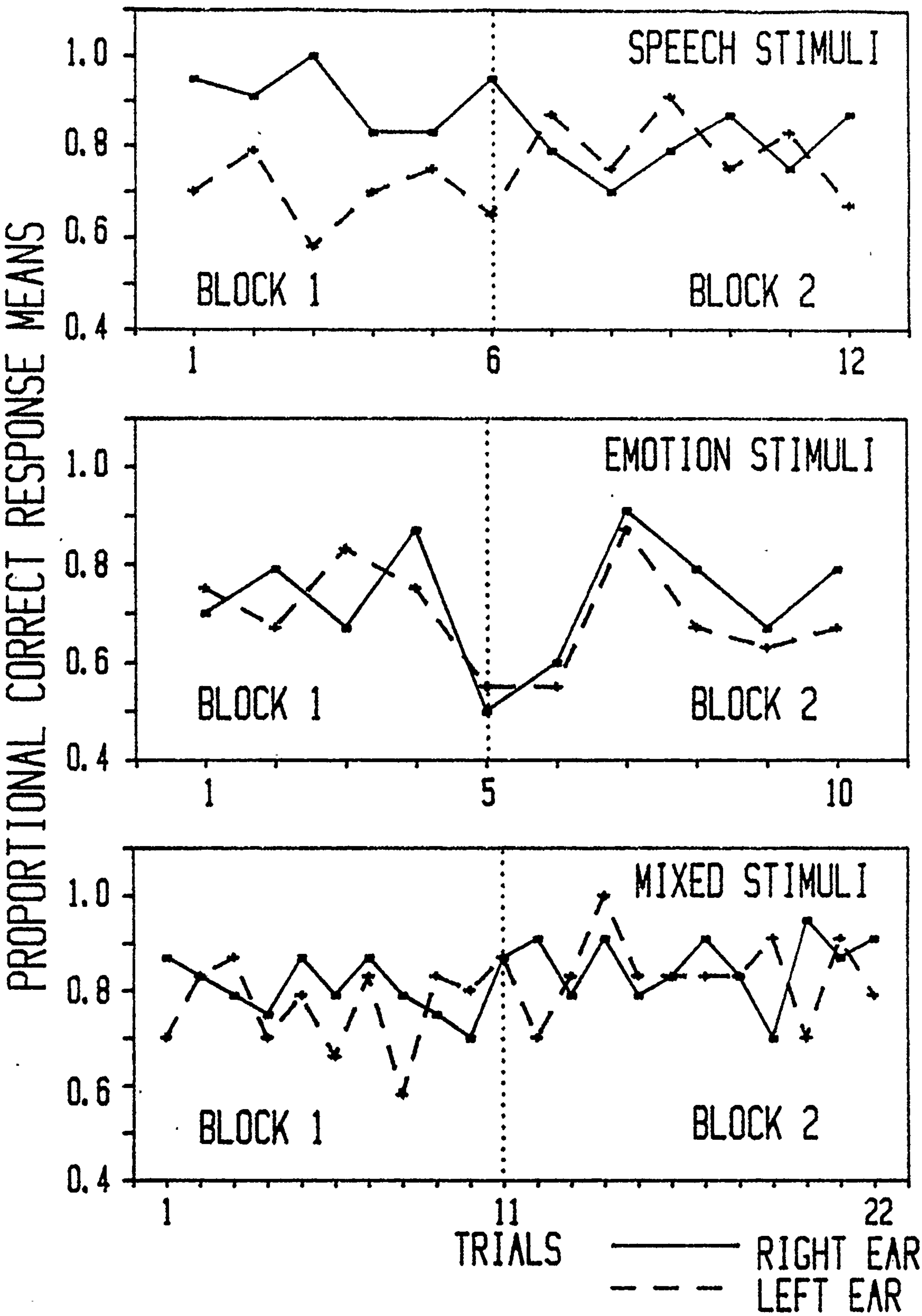

Figure 2 a,b,c: Ear X Trial Correct Response Scores for All Conditions. Each set of trials is divided into two equal blocks.

Figure 3a illustrates the decline in right ear performance between block 1 and block 2. Student Newman-Keuls post hoc comparisons indicated that the decline in right ear performance between block 1 and block 2 was significant ($p < .05$); the increase in left ear performance was not.

The emotion trials were analyzed in similar fashion with a three-way mixed ANOVA. Main effects of sex, block, and ear were nonsignificant. The ear by block by sex interaction proved to be significant ($F = 6.62$; $df = 1,22$; $p < .05$). Simple main effects analyses of this triple interaction revealed that right ear accuracy differed from left ear accuracy for males in block 2 ($F = 5.54$; $df = 1,22$; $p < .05$). Inspection of cell means in Table 10 highlights that right ear accuracy was higher than that of the left ear for males in block 2.

TABLE 10

Cell Means and Standard Deviations for the Ear by Block by Sex Interaction of Emotion Stimuli

	Left Ear	Right Ear
Males: Block 1	3.917 (.996)	3.417 (1.08)
Males: Block 2	3.083 (1.31)	4.167 (0.73)
Females: Block 1	3.083 (1.08)	3.667 (1.07)
Females: Block 2	3.750 (0.86)	3.250 (1.21)

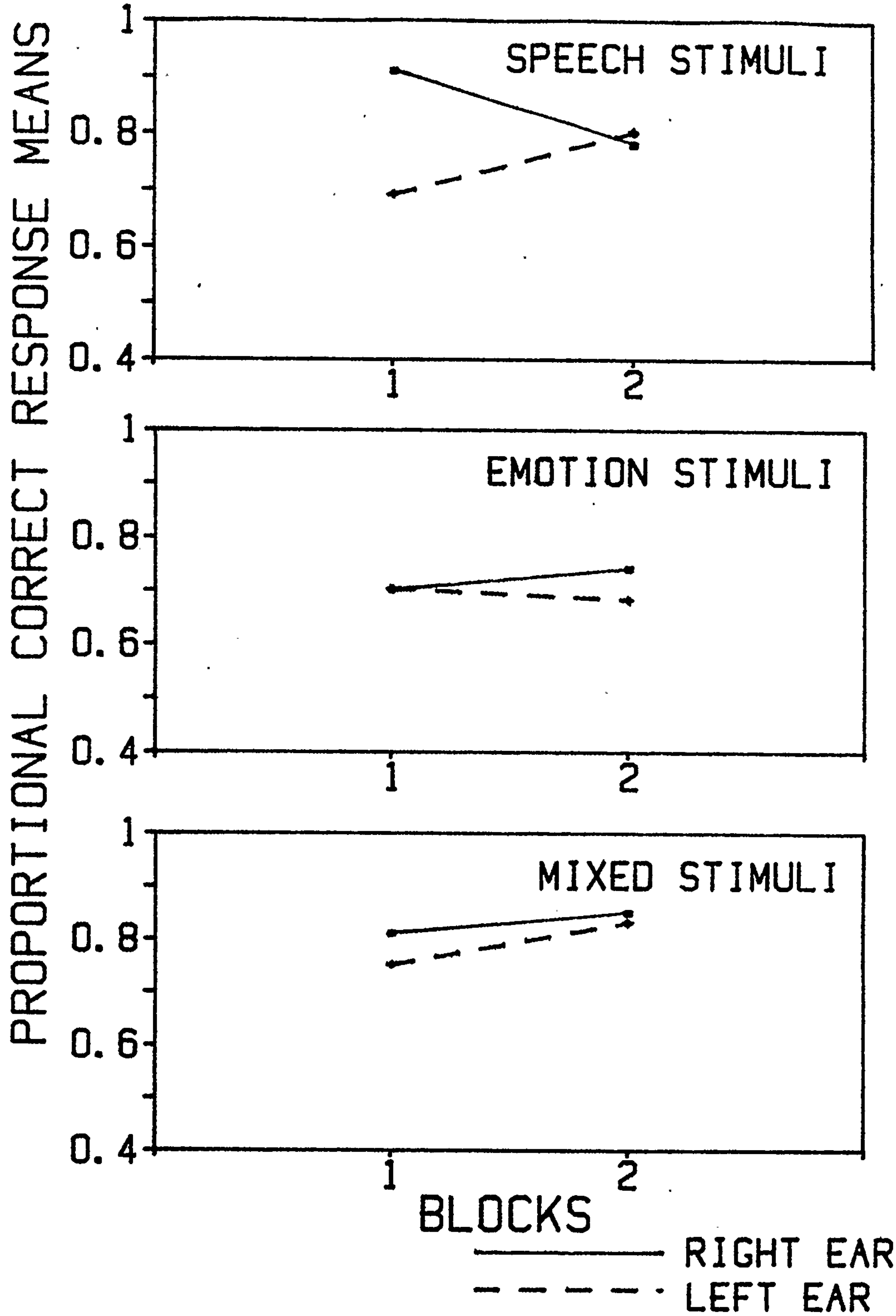

Figure 3 a,b,c: Ear X Block Correct Response Scores for All Conditions. Right ear performance was significantly more accurate than left ear performance in Block 1 in the speech condition.

Figure 4 (a,b) illustrates contrasting profiles for males and females. At block 2, males exhibited a significant REA; females, by comparison, were more accurate with the left ear. Using student Newman-Keuls post hoc tests, both right and left ear changes across blocks were significant for males ($p < .05$), whereas only the left ear increase from block 1 to 2 was significant for females ($p < .05$). This latter profile of static right ear performance coupled with left ear performance which becomes increasingly accurate over trials is consistent with the response pattern seen in the Mahoney and Sainsbury (1987) findings for all subjects. Figure 3b depicts ear accuracy with the sex differences collapsed.

When the correct response data in the mixed condition were evaluated with a three-way mixed ANOVA, significant results emerged in the main effect of block ($F = 7.30$; $df = 1,22$; $p < .05$), the ear by sex interaction ($F = 12.76$; $df = 1,22$; $p < .05$), and the ear by block by sex interaction ($F = 7.17$; $df = 1,22$; $p < .05$). Analyses of the simple main effects of the triple interaction showed that for males, there was a significant difference between left and right ear performance in block 1 ($F = 16.18$; $df = 1,22$; $p < .05$). Right ear performance was significantly higher than left ear in block 1. Cell means for the ear by block by sex interaction are recorded in Table 11.

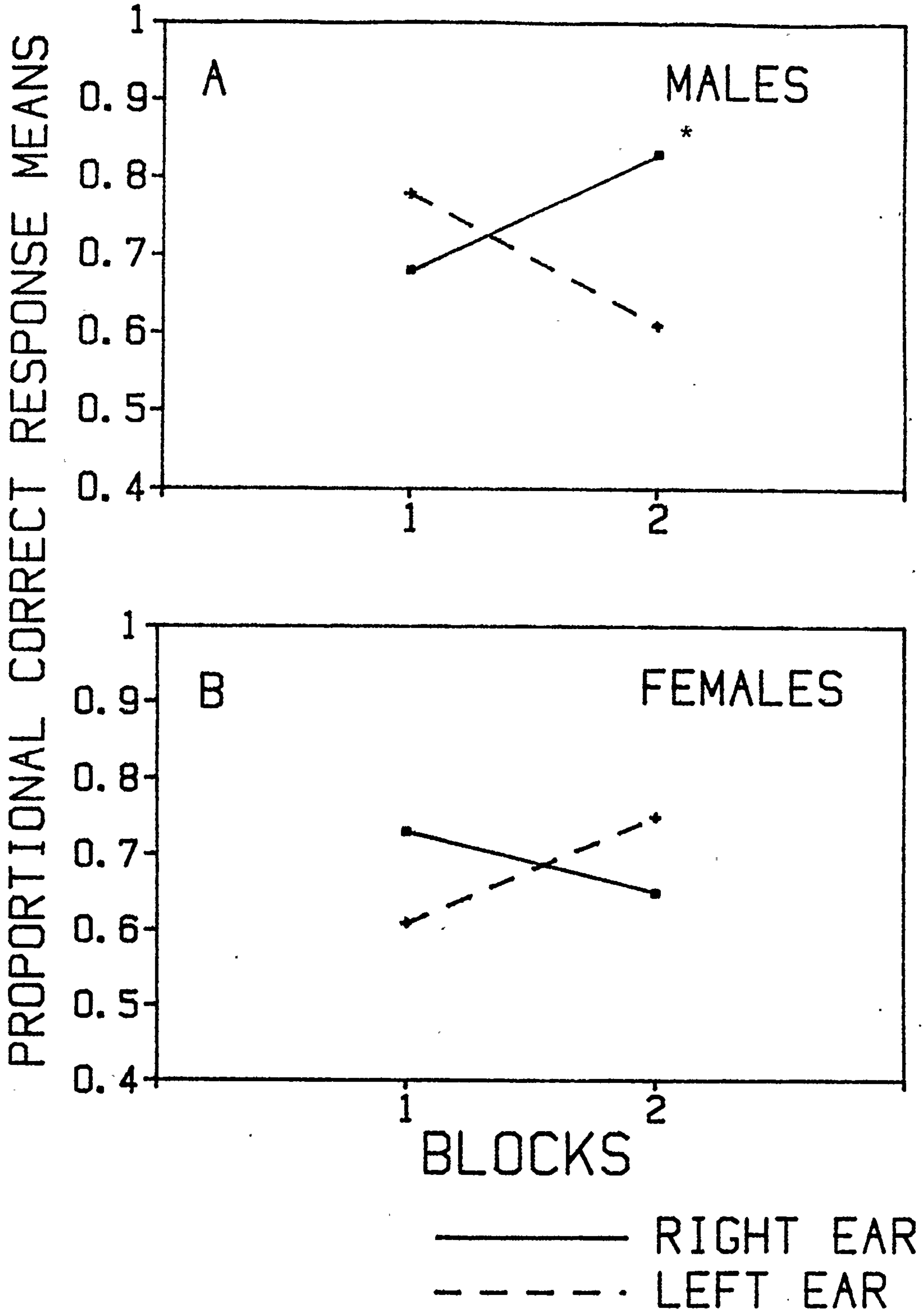

Figure 4 a,b: Ear X Block X Sex Correct Response Scores for Emotion Condition. Right ear performance differed from left ear for males in Block 2. *($p < .05$)

TABLE 11

Cell Means and Standard Deviations for the
Ear by Block by Sex Interaction of Mixed Stimuli

		Left Ear	Right Ear
Males:	Block 1	7.50 (1.44)	9.67 (0.77)
Males:	Block 2	9.00 (1.20)	9.33 (1.30)
Females:	Block 1	9.08 (1.72)	8.17 (2.02)
Females:	Block 2	9.42 (0.79)	9.58 (1.44)

Figure 5 (a,b) depicts the response profiles for males versus females in the mixed condition. At block 2, both males and females exhibit comparable performance with both ears. Newman-Keuls post hoc tests substantiated that for males, the increase in left ear performance from the first to the second block was significant ($p < .01$). For females, the increase in right ear performance was significant ($p < .05$). Figure 3c depicts ear by block response patterns.

The major findings from the correct response analyses are, first of all, a REA in the speech trials. While consistent with the original hypothesis predicting the direction of the effect, the ear advantage emerged in the first, not second, block of trials. In the emotion condition, there was a significant REA for males in block 2. With mixed trials, there was a REA for males in block 1. Neither of these results was predicted. For the emotion stimuli in particular, males and females exhibited contrasting patterns over the course of the dichotic task.

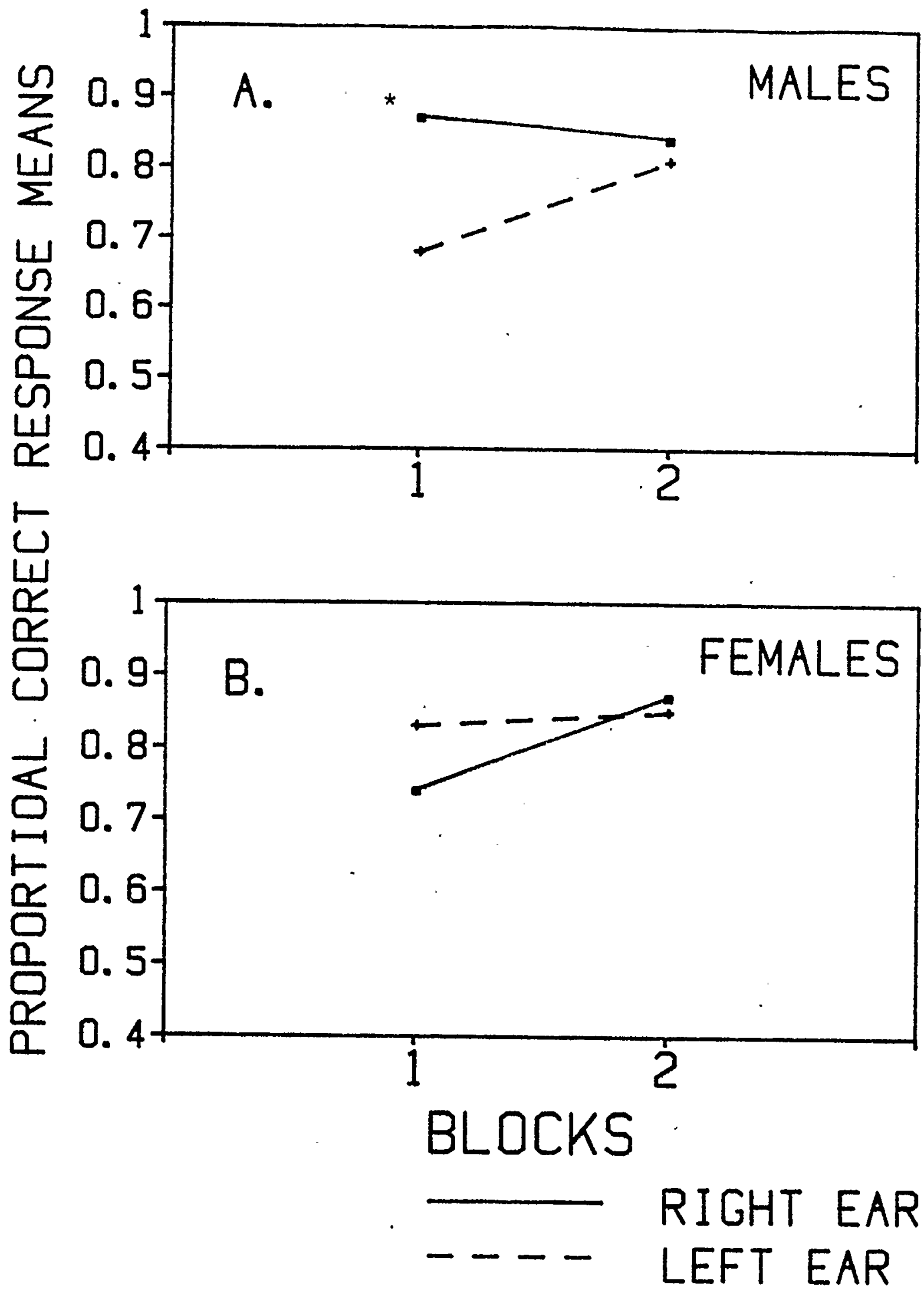

Figure 5 a,b: Ear X Block X Sex Correct Response Scores for Mixed Condition. Right ear performance differed from left ear for males in Block 1. *(p. < .05)

Response Position Analyses:

The effect of memory load on ear effects has been a particular concern with the use of the forced choice paradigm requiring a subject choose two responses from four choices. In terms of how much the subject is required to remember, this paradigm contrasts to the one response design where the subject is expected to identify one target from two choices. A study by Yeni-Komshian and Gordon (1974) concluded that right ear effects differed as a function of the duration of the time subjects were asked to retain dichotically presented stimuli prior to recall.

Response position analyses using proportion of correct responses were conducted to determine if the length of time that the dichotic sounds were held in short term memory differentially influenced performance on the task. Sex was the between subject variable. Response position(1 through 4) was the within subject variable. Neither main effect of position nor sex by position interaction were significant in the speech condition.

With the emotion stimuli, the sex by position interaction was nonsignificant. However, the effect of position was highly significant ($F = 10.67$; $df = 3,66$; Greenhouse-Geisser $p. < .0001$). Using Student Neuman-Keuls post hoc tests, significant comparisons emerged between position 1 and position 3, position 2 and position 3, and position 3 and position 4 ($p. < .01$). From Figure 6 it can be seen that with the emotion stimuli, subjects were most

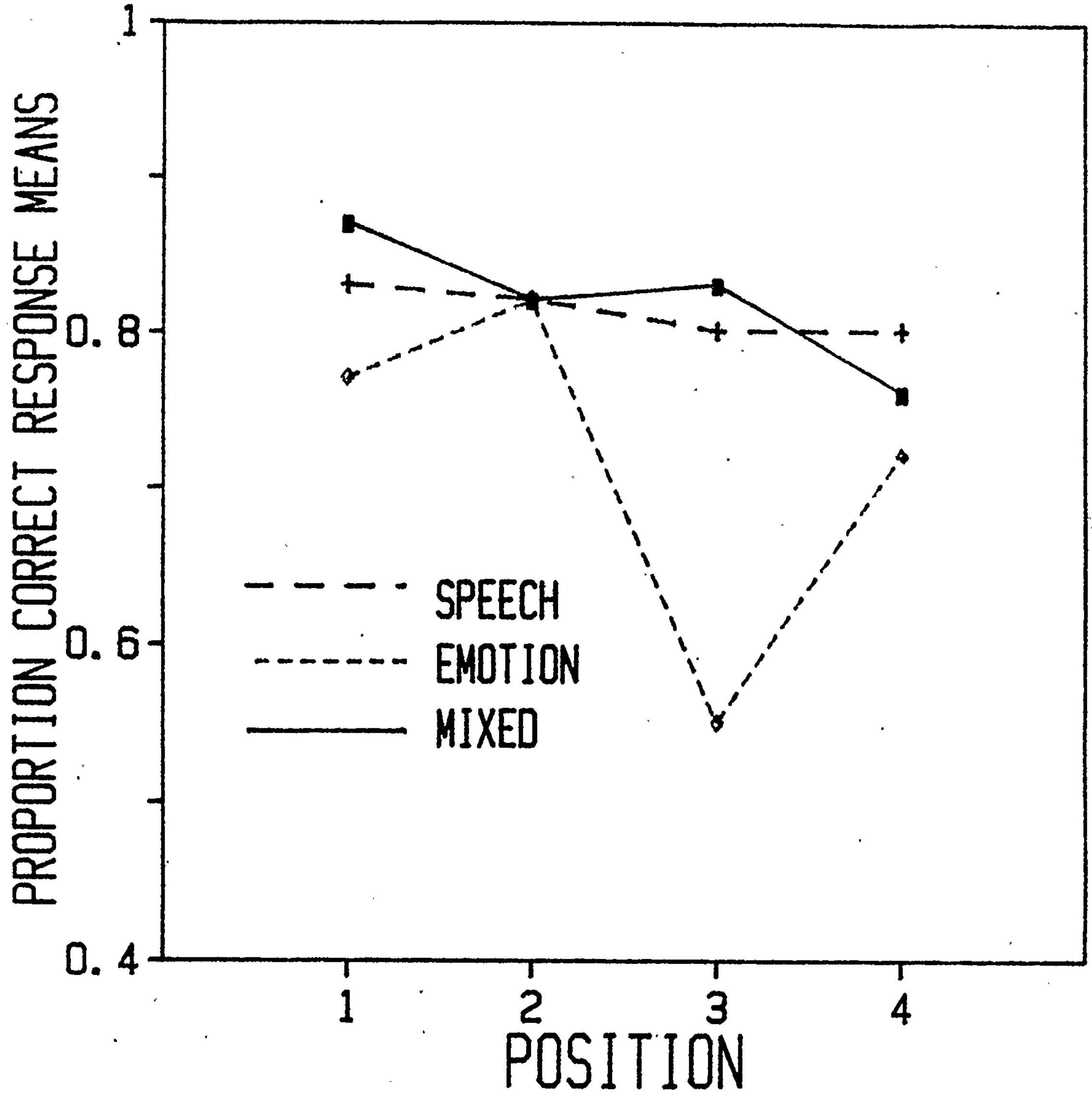

Figure 6: Proportion Correct Response Scores for Each Position in Each Condition. There is a highly significant effect of position in the Emotion trials and a significant effect of position in the Mixed trials.

accurate when the correct response was in position 2, and least accurate with the correct answer in position 3. However, response position was counterbalanced across ear and headphone position. Therefore, the effect of position should have equally affected performance on the right and left ears. Ear by response position means in Table 12 supports this interpretation.

TABLE 12

Proportional Means and Standard Deviations for the Response Position Effect of Emotion Stimuli

	Response Position			
	1	2	3	4
Left Ear	.783(.215)	.801(.188)	.517(.199)	.667(.174)
Right Ear	.750(.211)	.825(.155)	.583(.217)	.768(.183)

A similar position analysis on the mixed condition resulted in a significant effect of position ($F = 3.56$; $df = 3,66$; Greenhouse-Geisser $p. < .05$). Newman-Keuls comparisons were significant between position 1 and position 2, and between position 1 and position 4 ($p. < .05$). Figure 6 illustrates that in this mixed condition, subjects were most accurate in position 1 and least accurate in position 4. Table 13 presents the mean number of correct responses for the left and right ears; the effect of position is here demonstrated to have equally affected the left and the right ears. In both the emotion and the mixed stimuli conditions, then, the amount of time the binaural stimuli were held in memory prior to matching them to the target dichotic sounds, influenced performance on the dichotic listening task. This is an important finding which shall be used to evaluate the two-response paradigm in the forthcoming discussion.

TABLE 13

Proportional Means and Standard Deviations for the Response Position Effect of Mixed Stimuli

	Response Position			
	1	2	3	4
Left Ear	.864(.120)	.788(.221)	.818(.107)	.736(.140)
Right Ear	.887(.087)	.810(.105)	.850(.135)	.792(.106)

DISCUSSION

Mahoney and Sainsbury (1987) hypothesized that under divided attention conditions, laterality effects take time to develop. If this is true, then the performance under mixed conditions suggests that preferred modes of processing were not sufficiently established in this experiment to make generalizations about asymmetry. Under mixed conditions, subjects were more accurate overall (81.5%) than either in the speech group (79.86%) or the emotion trials (70.84%). If anything, the mixed group should have proved a more difficult task than the pure trials. Thus, while one would have predicted that the mixed presentation may have prevented development of laterality, one cannot argue that the mixed trials should have been an easier task.

In comparing overall ear accuracy of the mixed trials to their counterparts in the pure trials, both left and right ears maintained or improved accuracy relative to the pure trials. The REA seen in the pure speech trials disappears under mixed conditions, not because the right ear gets worse, but because the left ear gets better. As long as performance in the pure trials is equivalent to the mixed condition, one cannot assume that preferred modes of processing in the pure trials were disrupted in any way by embedding them in the mixed condition.

In this light, the response profiles of the speech trials is illustrative. The REA seen in the speech trials is statistically substantiated in the main effect of ear in the stimulus type analysis as well as the correct response analysis. However, when the correct responses for the speech trials were analyzed according to blocks, the REA was found in the first, not the second, block of trials. The decline in right ear accuracy from the first to the second block indicates that the significant ear advantage initially seen was not maintained throughout the task. As illustrated in Figure 3a, at block 2, right and left ears reached equivalent performance.

The REA seen with the use of dichotic stop consonant pairs in the research by Studdert-Kennedy (1970) and Crowder (1973) suggested that right ear effects reflect the left hemisphere's extracting meaningful linguistic information from these speech signals. This is precisely the type, or level, of processing proposed by Moscovitch and Klein (1980) to describe the categorical perception that lies at the base of specialized hemispheric involvement. However, without a consistent effect of right ear accuracy which continues into the later response trials, one cannot assume that the initial REA best qualifies as a meaningful laterality effect.

This does not imply that the left hemisphere is not involved in processing the CV pairs. It is possible that the disappearance of the ear effect in the second block of trials is related to the manner in which subjects deploy attention in this paradigm when exposed to speech stimuli. If left hemisphere processing is really established for these CV pairs, though, the REA should not disappear. Its decline suggests that a late emerging REA would be a more valid measure of laterality effects than an effect seen at the outset of a dichotic run.

The above considerations apply as well to evaluating the laterality effects in the emotion stimuli trials. In the trials using the nonverbal emotional sounds, a late emerging LEA was expected. In contrast to the predicted hypothesis, a REA was found for males in block 2. Of particular interest are the results depicted in Figure 4 (a,b). Males and females exhibited contrasting ear profiles on this task. For example, both right and left ear changes across blocks were significant for males, with left ear accuracy decreasing over blocks. For females, there was a significant increase in left ear performance from block 1 to block 2. Although females did not show a significant LEA in the second block of trials, the post hoc analysis suggest a trend consistent with the Mahoney and Sainsbury (1987) findings: that is, while right ear performance remained consistent, the left ear was increasing in accuracy. These results are not incompatible with Kimura's (1972) earlier findings of a LEA for females on this two-response paradigm task using emotional, nonverbal sounds.

It is difficult to know if these data represent real gender differences related to functional cerebral organization. Certainly there is research suggesting that males and females may perform differently on dichotic tasks for a number of reasons. Research based on verbal stimulus presentations has hypothesized that females show more symmetrical performance than males (see McGlone, 1980). Research investigating emotional perception has been less clear in regards to differences between males and females. For example, Graves et al.(1981) concluded that males were more accurate than females in identifying emotional versus nonemotional words when they were presented to the left visual field. By comparison, Strauss (1983) found no sex differences on this type of task.

Auditory tasks using nonverbal stimuli have not been as rigorously investigated as verbal ones for sex differences in laterality. King (1970) reported that a LEA for the perception of hummed melodic patterns and vocal nonspeech sounds did not vary according to sex. Hatta and Ayentani (1985) found a sex difference in females showing a higher sensitivity to evaluating negative emotional tones of unknown speech. Mahoney and Sainsbury (1987) did not find significant sex differences in their study.

The possibility exists that sex differences in laterality experiments occur because men and women approach the same task in different ways. Task demands may recruit biases towards certain processing modes, with differential strategies varying with the subject's sex. Arguments along this line have been invoked to suggest that females are especially biased towards a verbal problem solving mode. Thus, Kimura (1969) was able to conclude that failure of her female subjects to show a left visual field superiority on a dot localization task reflected that females approach the task as a verbal problem rather than a visuo-spatial one. In a set of experiments by Bryden (1979), differences between males and females emerged with varying sets of instructions to the same task. Bryden's general conclusion was that sex differences disappeared under more stringent control of attentional strategies. However, Richards and French (1987) wisely caution that it is tempting to produce post hoc explanations on the basis of task demands when studies of hemispheric function yield results opposite to those predicted; yet a simple strategies model has not been precisely defined. The underlying issue is likely to remain unresolved: "Strategies might be expected to vary both between subjects, in terms of preferred mode of processing, and within subjects, depending on a variety of factors such as instructions and stimulus context" (p. 163).

Given the above considerations, it is purely speculative to suggest that females approached the task of identifying nonverbal emotional sounds differently than males. However, the response patterns for males and females in dealing with emotional sounds contrasts strikingly with the other two conditions. Under mixed conditions, for example, right and left ear performance becomes equivalent in block 2 for males and females (see Figure 5 a,b). In essence, the differences between male and female performance is indistinguishable at this point. Perhaps with more trials in this paradigm, females would develop a significant LEA in block 2 of the emotion trials in comparison to the REA shown by males. In this case, one could argue that the LEA reflects a right hemisphere processing of nonverbal emotional sounds which varies according to sex. Alternately, one could argue from the data that the speed with which females develop the LEA associated with emotional sounds in this paradigm differs from that of males in that females develop a LEA sooner. With only 10 experimental trials comprising the entire task, it is impossible to assess whether block 2 is an adequate representation of optimal performance level for either males or females, or whether it indeed represents the preferred mode of processing for the stimuli under discussion. The only way to address this issue directly is to create a dichotic task with more blocks of trials, giving potential asymmetry more time to develop.

The mixed group would have proved particularly interesting with additional trials. There is some indication that a trend towards a REA could have been established in this group. Although the main effect of ear failed to reach significance (p. = .067), the percentage of subjects exhibiting a REA (54.17%) was very close to the proportion in the speech trials (58.33%). As Figure 5 (a,b) illustrates, at block 2, both males and females were more accurate at the right than left ear, although not significantly so. A "coding shift" hypothesis proposed by

Dee and Hannay (1973), earlier discussed, could have accommodated a right ear advantage. The results of the mixed data might propose that subjects were more likely to encode the emotional sounds in a manner consistent with left hemisphere processing. However, once again, more blocks of trials are necessary to observe if an ear advantage would have been successfully established in this mixed group.

The number of dichotic trials to include in an experimental run has been a key issue in research seeking to establish reliability of dichotic listening in general. The data from this study point out that up to 41.67% of subjects changed ear advantages between blocks 1 and 2 in any one condition, serving to call into question the stability of performance throughout the task. Blumstein, Goodglass, and Tartter (1975) initially noted these types of reversals and suggested that subjects on the deviant side were more likely reverse ear advantages on retesting. However, the underlying reasons for these fluctuations in response patterns may be more complicated than this original explanation.

Speaks et al. (1982) have emphasized that dichotic runs composed of too few trials may be characterized by unreliable ear advantages. In fact, these researchers found that approximately six listening blocks (180 trials) of CV pairs were required to achieve a split-half reliability coefficient of +0.90. Lauter (1982) has additionally proposed that relative ear advantages for different stimuli may differ from absolute ear advantages for individuals. In some cases, then, pre-screening of subjects must be conducted so that only individuals who show stable ear advantages for the stimuli in question are included in the study. Wexler and Hawles (1983) have gone a step further to use subjects in their studies with ear differences great enough to meet a statistical significance criterion in line with neurological data. In all of these cases, however, lengthening the dichotic runs has been a prime candidate for stabilizing ear advantages. Thus, a serious criticism of this task is that it may not have given subjects adequate exposure to the dichotic pairs to allow development of asymmetry.

Taken together, then, the results of this experiment strongly suggest that a laterality effect had not yet developed in any condition. The number of exposures to the dichotic pairs comprising the experimental trials may be the major attenuating factor. One cannot assume, however, that asymmetries develop in a similar manner regardless of the class of stimuli. For example, in this study, response profiles for the speech trials differs from the emotion trials. Figure 3(a,b) depicts that in the speech trials, right and left ear performance is disparate in block 1, but similar in block 2. The emotion stimuli show a contrasting profile, with both ears exhibiting basically equivalent performance in block 1, but differing in the second block. The possibility exists that the effects associated with nonverbal emotional sounds in this paradigm are qualitatively different than the laterality effects obtained with speech sounds.

One way in which the speech trials compare with the emotional trials qualitatively is in the acoustic characteristics of the stimuli. The speech sounds were paired specifically to differ on one distinctive feature only; the right ear effect can be assumed to result from decoding the stimuli according to a pre-specified classification. The emotional sounds, however, can be identified on the basis of temporal and/or spectral patterns. As long as the acoustical characteristics are not precisely defined, it is difficult to ascertain how they contribute to ear effects associated with nonverbal emotional sounds.

Closely aligned with this line of thought is the fact that the emotional sounds may be more complex "packages" than the CV combinations. One could argue that in addition to their acoustic complexity, the emotional sounds carry an additional semantic component not inherent in the speech stimuli. Thus, the type of processing necessary to see a laterality effect in the emotion trials might be qualitatively different than the categorical perception represented in the speech sounds. Under divided attention conditions, the course of developing asymmetries may reflect these differences specific to each class of stimuli. It may take longer for subjects to learn to attend to the emotional sounds than the speech sounds under dichotic conditions, because they are more acoustically and semantically complex.

The extent to which memory components may have contributed to the absence of laterality effects in the data is unclear, but the response position analyses suggest that the issue needs to be addressed. When each of the four response positions was analyzed for each condition, a highly significant effect ($p < .001$) of position emerged in the emotion trials, and a significant effect ($p < .05$) was found for the mixed condition. The only condition without a position effect was the speech trials. As illustrated in Figure 6, the response pattern for the emotion trials in particular differs from the other conditions; there is a severe drop in accuracy at position 3.

There are several ways in which to interpret this data. The research by Yeni-Komshian and Gordon (1974) would suggest that the length of time the dichotic sounds were held in memory differentially influenced performance on the dichotic task. However, one cannot assume that length of time is the only critical factor in producing these results. Subjects were also listening to stimuli differing from the speech sounds in terms of their complexity. Since the profile for the emotion trials differs dramatically from the other two conditions in terms of response position accuracy, it seems likely that these results reflect an interaction of the stimuli with memory constraints imposed by the paradigm itself.

In the paradigm used in this experiment, the subject is asked to make successive discriminations of 4 binaural choices. Not only does information have to be integrated over events, but also the value of non-targets has to be remembered in the total binaural array according to some dimension, for example, pitch, duration, or intensity. Successive discriminations of this type differ from simultaneous discrimination involving a single response in that the former places a greater load on memory. According to Parasuraman (1979), with weak or difficult signals, the processing resources that must be consistently allocated for successive discrimination may not meet the needs for stable performance. This is especially true when the processing demands of memory load are combined with a high stimulus presentation rate. Time pressure, which is inherent in the structure of the task, increases processing demands.

It may be that the rate of presentation of the binaural choices was inappropriate for emotion trials in particular. Why an interstimulus interval should have affected this set of trials so profoundly is unclear. However, left visual field studies reviewed earlier (see Dee & Fontenot, 1983; Moscovitch, et al.,1976) have hinted at the possibility that left visual field superiorities are dependent to some extent on hemispheric differences in memory rather than purely perceptual processes. There have been no dichotic listening studies systematically investigating the possibility that the left ear effect seen with auditory stimuli is dependent upon an optimum interstimulus interval analogous to the time delays in the above studies. The studies of King and Kimura (1972) and Mahoney and Sainsbury (1987) both used interstimulus intervals of 5 seconds; Gordon's study with musical stimuli also used an ISI in this range. Spellacy (1970) found that a LEA was shown in the recognition of musical stimuli was optimum following a 5 second interval. From this latter study, Spreen, Spellacy, and Reid (1970) went on to conclude that ear differences for music and tonal patterns was optimum at intervals of 1- 5 seconds. If mnemonic hemispheric differences play a part in right hemisphere laterality, then a 1250 msec. interstimulus interval may have prevented the depth of processing needed to establish a right hemisphere preference for the emotional sounds.

It is possible that the serious decrement in accuracy in the emotion trials at position 3, and the recovery at position 4, represents serial position effects of the type used as evidence of primacy and recency effects (Atkinson & Shiffrin, 1968). Many accounts of primacy and recency effects have been generated, but the most common is that initial items in a series receive more rehearsals and are thus better registered in memory. Items arriving first have less competition for available space, and final items can survive on encoding which is basically acoustic, or phonemic (rather than semantic), which gives rise to good immediate recall for items in final positions. If one accepts Craik and Lockhart's (1972) levels of processing model, variables such as rate of presentation highly affect long term retention but have little effect on operations used for short term storage. Although a strict interpretation of performance accuracy as serial position effects is unwarranted due to the small number of trials, this discussion does point out that dichotic listening paradigms using longer interstimulus intervals may be significantly different than those employing shorter ones. Under some conditions, memory components may enhance laterality effects; under others, it may attenuate them.

It may be, then, that the late emerging ear effects of the type seen by Mahoney and Sainsbury (1987) are a unique interaction of demands of the paradigm coupled with the specific stimuli under consideration. If time alone is the crucial factor, then a comparison between the paradigm used in this study, and one with interstimulus intervals in the range of 5 seconds, is not warranted. In this study, subjects not only had less processing time between binaural choices and trials, but also spent less total time under the headphones. An additional avenue of future research, then, would be to lengthen the ISI between choices as well as adding more trials.

At best, dichotic listening is an inferential process. Hence, it may be that as a methodology, dichotic listening is most suitable as a measure of how asymmetries change over time. In order to assess this, individual response patterns need to be evaluated. There may be an optimum, albeit narrow, "dichotic observation window" sensitive to the differences between the two ears. That window must attempt to accommodate the emerging properties of cerebral specialization.

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APPENDIX A

Source Tables for the Analyses of Variance

TABLE 1

Source Table for Preliminary Analysis of Variance of Speech Stimuli

Source	SS	df	F
Between Subjects			
Headphone position (H)	1.021	1	.35
Presentation order (O)	2.521	1	.87
H x O	.521	1	.18
Subjects within groups	58.250	20	
Within Subjects			
Ear (E)	1.688	1	.74
E x H	7.521	1	3.30
E x O	4.688	1	2.06
E x H x O	.021	1	.01
Error	45.583	20	

TABLE 2

Source Table for Preliminary Analysis of Variance of Emotion Stimuli

Source	SS	df	F
Between Subjects			
Headphone position (H)	.750	1	.31
Presentation order (O)	10.083	1	4.16
H x O	5.333	1	2.20
Subjects within groups	48.500	20	
Within Subjects			
Ear (E)	1.333	1	.64
E x H	.750	1	.36
E x O	.083	1	.04
E x H x O	1.333	1	.64
Error	41.500	20	

TABLE 3

Source Table for Preliminary Analysis of Variance of Mixed Stimuli

Source	SS	df	F
Between Subjects			
Headphone position (H)	.021	1	.00
Presentation order (O)	3.521	1	.53
H x O	1.688	1	.25
Subjects within groups	132.750	20	
Within Subjects			
Ear (E)	11.021	1	3.39
E x H	9.188	1	2.82
E x O	13.021	1	4.00
E x H x O	.188	1	.06
Error	65.083	20	

TABLE 4

Source Table for Order of Report Analysis of Variance of Speech Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.333	1	.17
Subjects within groups	42.667	22	
Within Subjects			
Ear (E)	2.083	1	.82
E x S	.083	1	.03
Error	55.833	22	

TABLE 5

Source Table for Order of Report Analysis of Variance of Emotion Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.083	1	.05
Subjects within groups	35.583	22	
Within Subjects			
Ear (E)	.750	1	.55
E x S	3.000	1	2.18
Error	30.250	22	

TABLE 6

Source Table for Order of Report Analysis of Variance of Mixed Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	1.333	1	.32
Subjects within groups	92.917	22	
Within Subjects			
Ear (E)	.333	1	.06
E x S	.750	1	.14
Error	115.917	22	

TABLE 7

Source Table for Stimulus Type Analysis of Variance of Distinctive Features of Speech Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	2.667	1	2.59
Subjects within groups	22.667	22	
Within Subjects			
Distinctive feature (F)	.667	1	.62
F x S	.167	1	.15
Error	23.667	22	
Ear (E)	8.167	1	5.76 *
E x S	.167	1	.12
Error	31.167	22	
F x E	.167	1	.14
F x E x S	4.167	1	3.50
Error	26.167	22	

* $p < .05$

TABLE 8

Source Table for Stimulus Type Analysis of Variance of Emotion Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.417	1	.73
Subjects within groups	.569	22	
Within Subjects			
Type (T)	2.708	4	1.73
T x S	.208	4	.13
Error	34.483	88	
Ear (E)	.417	1	1.01
E x S	.267	1	.64
Error	9.167	22	
T x E	.292	4	.16
T x E x S	.858	4	.46
Error	41.050	88	

TABLE 9

Source Table for Stimulus Type Analysis of Variance of Mixed Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.006	1	.25
Error	.568	22	
Within Subjects			
Class (C)	.034	1	4.00
C x S	.019	1	2.32
Error	.189	22	
Ear (E)	.031	1	3.67
E x S	.139	1	16.67***
E at Males	.261	1	15.74***
E at Females	.039	1	2.35
Error	.183	22	
Error at Males	.016	22	
Error at Females	.364	22	
C x E	.008	1	.69
C x E x S	.001	1	.02
Error	.261	22	

*** $p < .001$

TABLE 10

Source Table for Correct Response Analysis of Variance of Speech Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	2.667	1	2.59
Subjects within groups	1.030	22	
Within Subjects			
Ear (E)	8.167	1	5.76*
E x S	0.167	1	.12
Error	31.467	22	
Block (B)	.167	1	.20
B x S	.167	1	.20
Error	18.167	22	
E x B	13.500	1	11.00**
E at B 1	21.333	1	17.02***
E at B 2	.333	1	.24
Error	27.000	22	
Error at B 1	27.583	22	
Error at B 2	30.583	22	
E x B x S	.005	1	.003
Error	27.000	22	

* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 11

Source Table for Correct Response Analysis of Variance of Emotion Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	1.042	1	.73
Subjects within groups	31.292	22	
Within Subjects			
Block (B)	.042	1	.04
B x S	.167	1	.15
Error	24.292	22	
Ear (E)	.667	1	.68
E x S	.375	1	.38
Error	21.458	22	
E x B	.375	1	.23
E x B x S	10.667	1	6.62*
E at B 1: Males	1.500	1	1.14
E at B 2: Males	7.042	1	5.54*
E at B 1: Females	2.042	1	1.55
E at B 2: Females	2.667	1	2.65
Error			
Error at B 1: Males	28.958	22	
Error at B 2: Males	27.958	22	
Error at B 1: Females	28.958	22	
Error at B 2: Females	22.167	22	

* $p < .05$

TABLE 12

Source Table for Correct Response Analysis of Variance of Mixed Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.844	1	.26
Subjects within groups	71.813	22	
Within Subjects			
Block (B)	12.761	1	7.30*
B x S	0.570	1	.29
Error	38.479	22	
Ear (E)	4.594	1	3.70
E x S	15.844	1	12.76**
Error	27.313	22	
E x B	.844	1	.47
E x B x S	12.760	1	7.17*
E at B 1: Males	28.167	1	16.18**
E at B 2: Males	.667	1	.52
E at B 1: Females	5.042	1	2.90
E at B 2: Females	.667	1	.43
Error	39.146	22	
Error at B 1: Males	38.292	22	
Error at B 2: Males	28.167	22	
Error at B 1: Females	38.292	22	
Error at B 2: Females	33.833	22	

* $p < .05$
** $p < .01$

TABLE 13

Source Table for Response Position Analysis of Variance of Speech Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.003	1	.10
Subjects within groups	.567	22	
Within Subjects			
Position (P)	.021	3	.29
P x S	.149	3	2.12
Error	1.551	66	

TABLE 14

Source Table for Response Position Analysis of Variance of Emotion Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.027	1	.44
Subjects within groups	1.369	22	
Within Subjects			
Position (P)	.945	3	10.67***
P x S	.068	3	.77
Error	1.948	66	

***p. < .001 (Greenhouse-Geisser p. = .001)

TABLE 15

Source Table for Response Position Analysis of Variance of Mixed Stimuli

Source	SS	df	F
Between Subjects			
Sex (S)	.006	1	.23
Subjects within groups	.583	22	
Within Subjects			
Position (P)	.159	3	3.56*
P x S	.019	3	.43
Error	.986	66	

* $p < .05$ (Greenhouse-Geisser $p = .0256$)

APPENDIX B

Sample Spectrographs of Speech and Emotion Stimuli

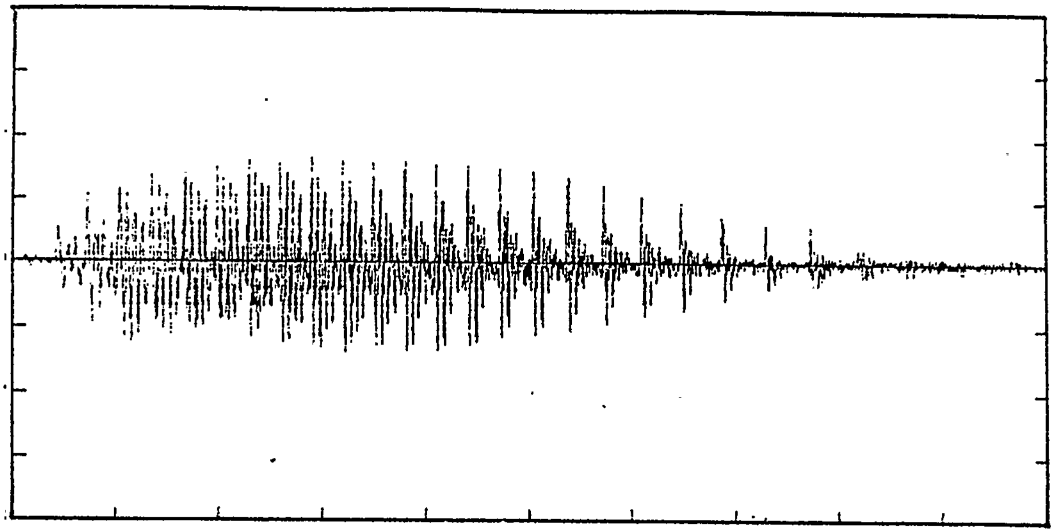

Figure 1: The time and amplitude domain of /ba/

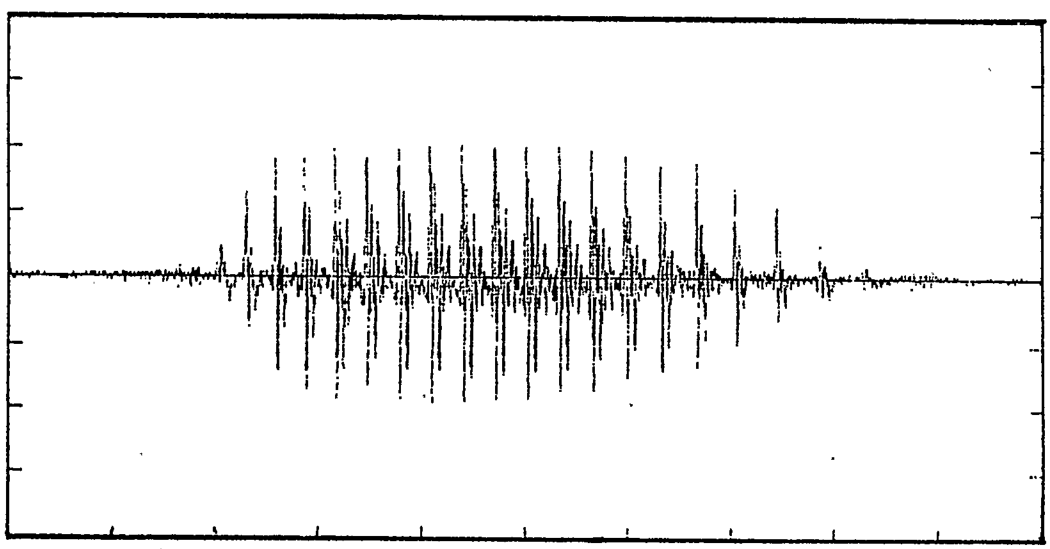

Figure 2: The time and amplitude domain of /pa/

Amplitude is represented on the ordinate, time (sec) on the abscissa

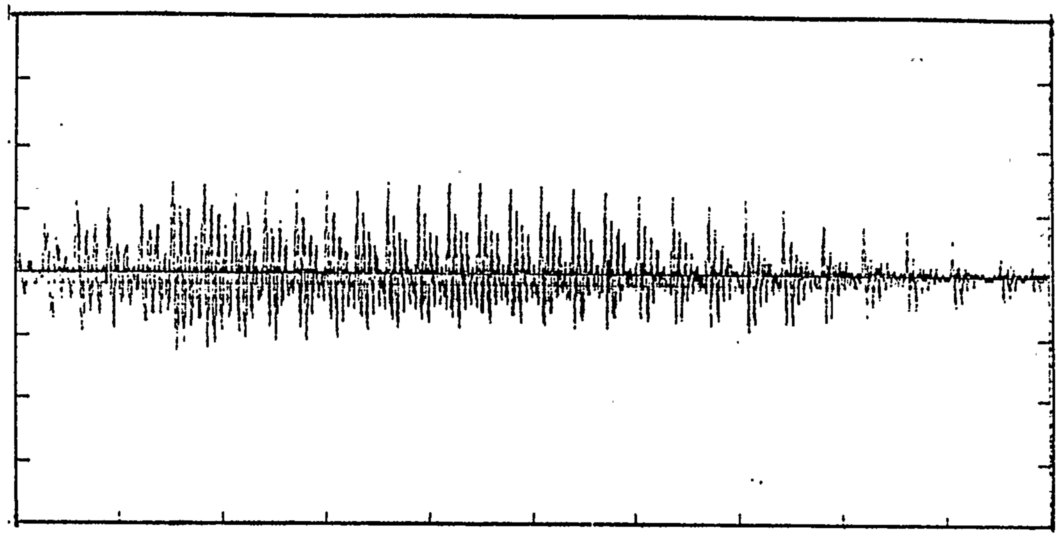

Figure 3: The time and amplitude domain of /da/

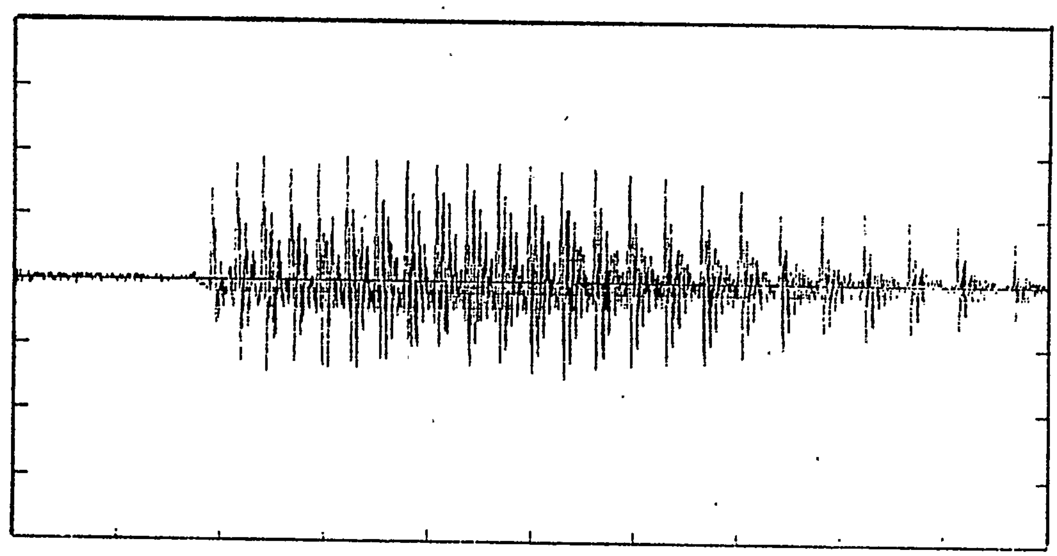

Figure 4: The time and amplitude domain of /ta/

Amplitude is represented on the ordinate, time (sec) on the abscissa

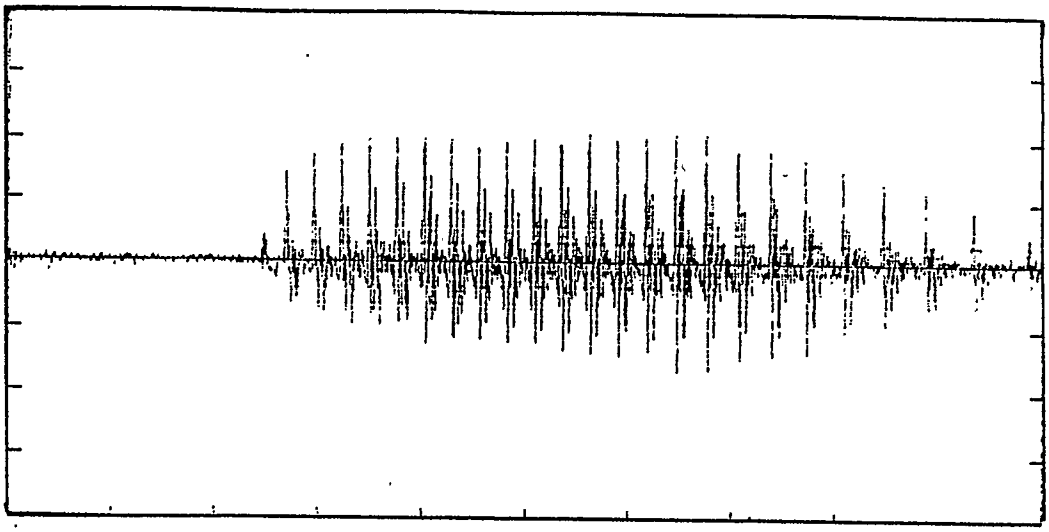

Figure 5: The time and amplitude domain of /ka/

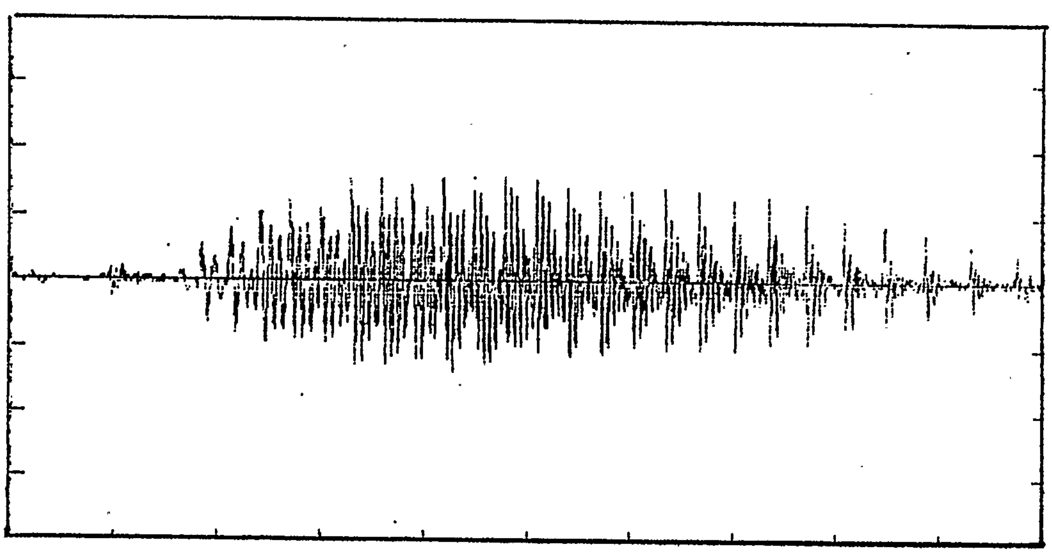

Figure 6: The time and amplitude domain of /ga/

Amplitude is represented on the ordinate, time (sec) on the abscissa

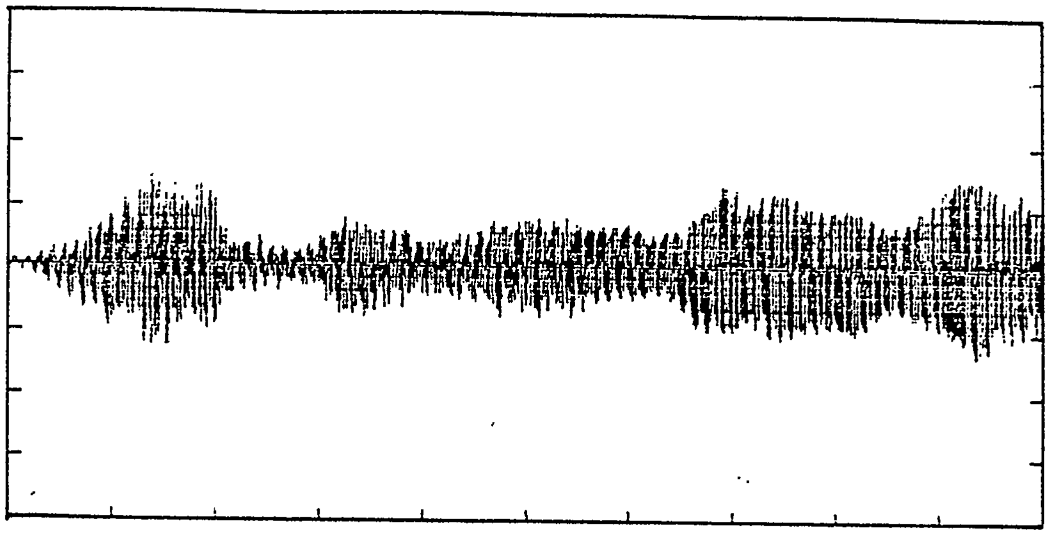

Figure 7: The time and amplitude domain of baby cry stimulus #1

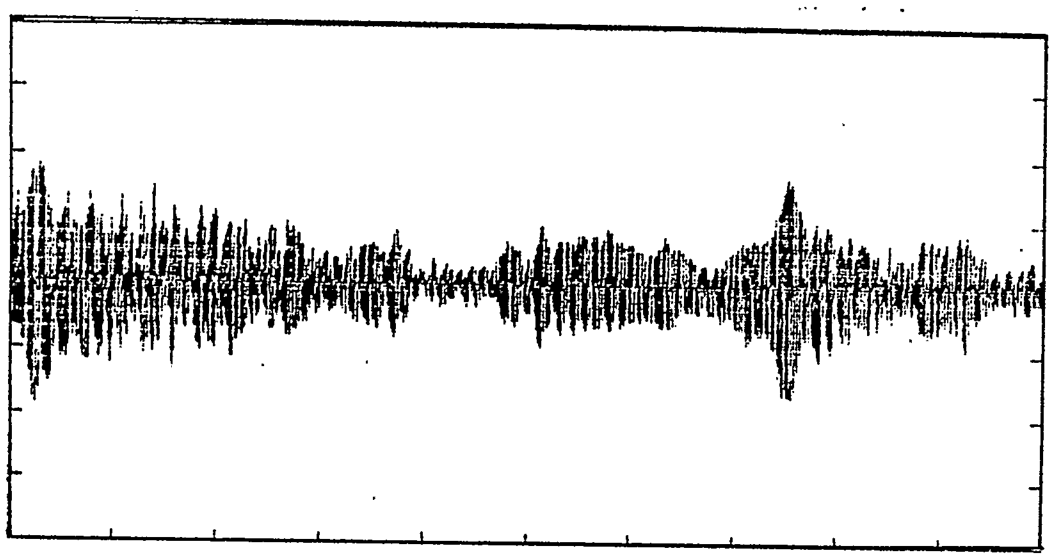

Figure 8: The time and amplitude domain of baby cry stimulus #3

Amplitude is represented on the ordinate, time (sec) on the abscissa

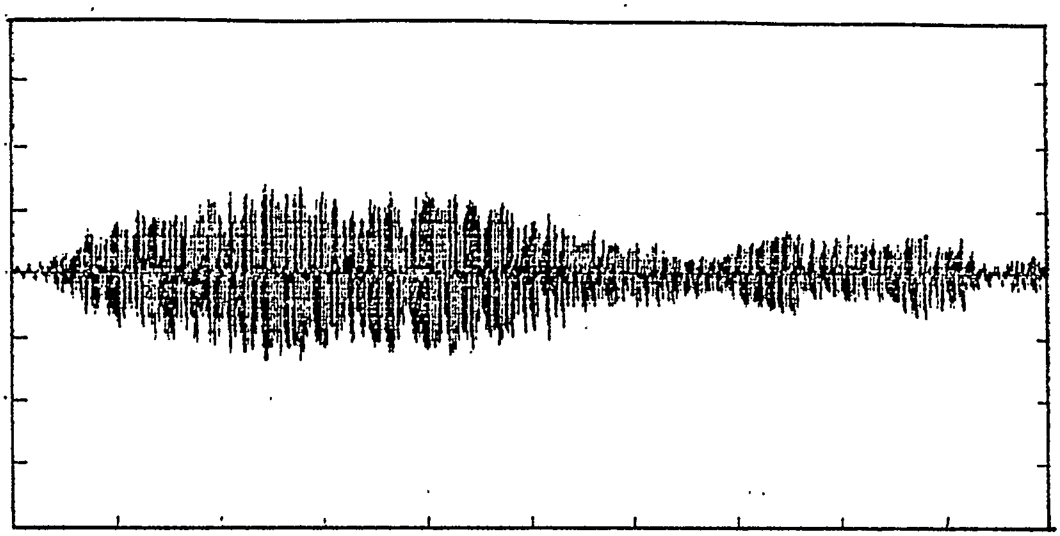

Figure 9: The time and amplitude domain of baby cry stimulus #6

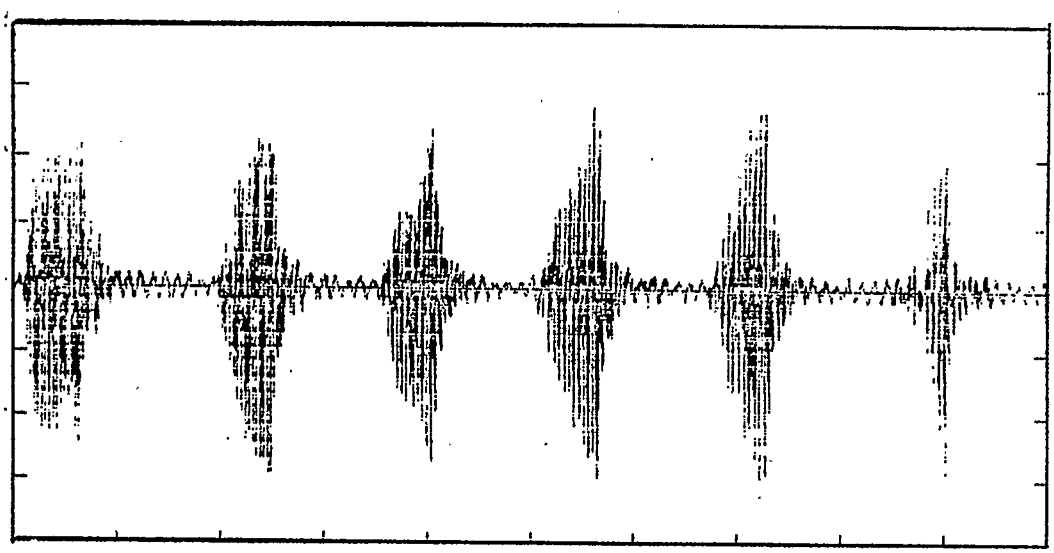

Figure 10: The time and amplitude domain of laugh stimulus #1

Amplitude is represented on the ordinate, time (sec) on the abscissa

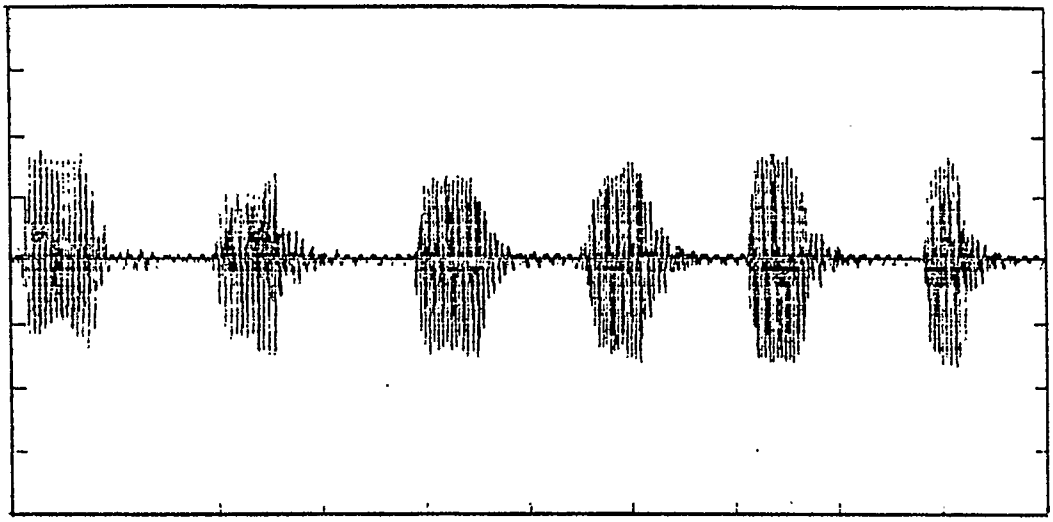

Figure 11: The time and amplitude domain of laugh stimulus #4

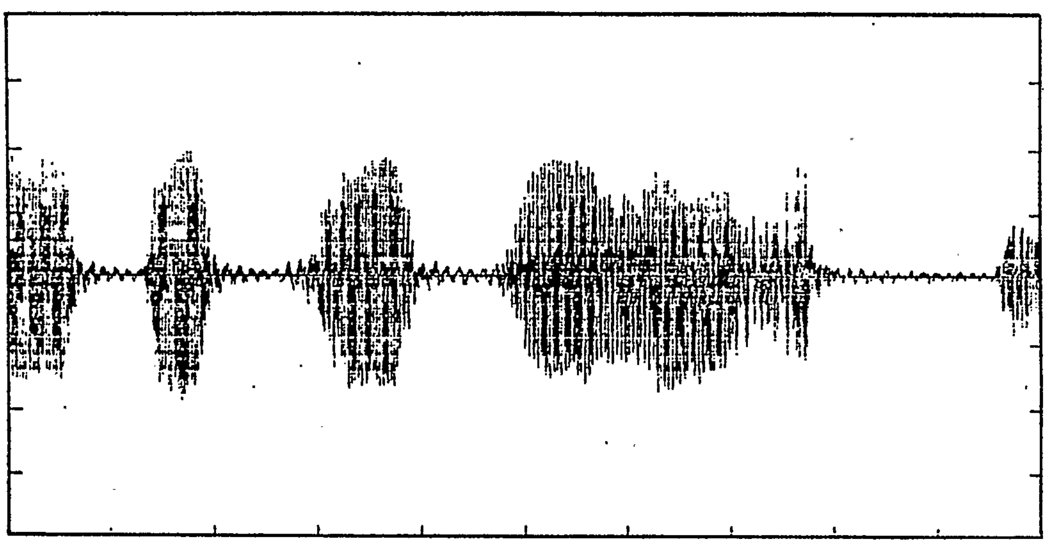

Figure 12: The time and amplitude domain of laugh stimulus #7

Amplitude is represented on the ordinate, time (sec) on the abscissa

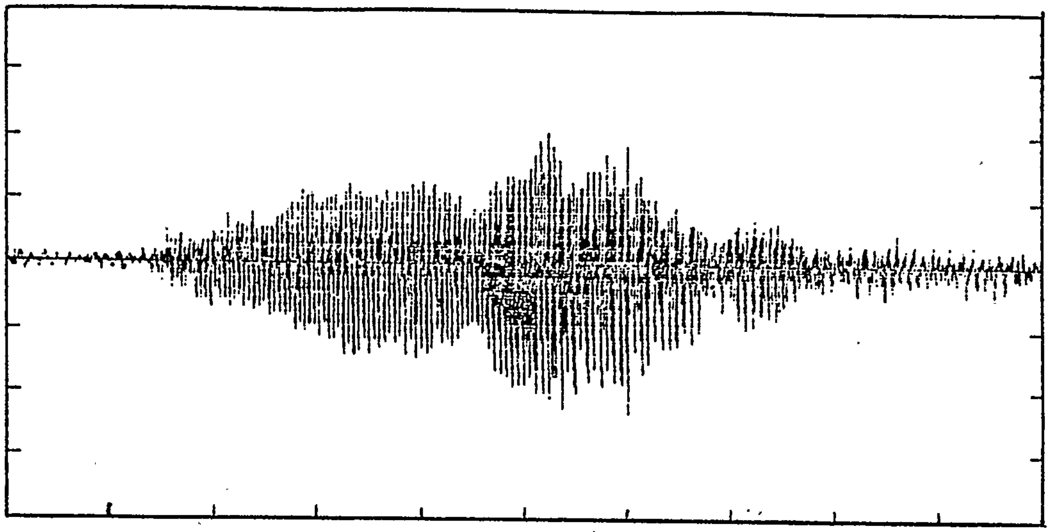

Figure 13: The time and amplitude domain of moan stimulus #2

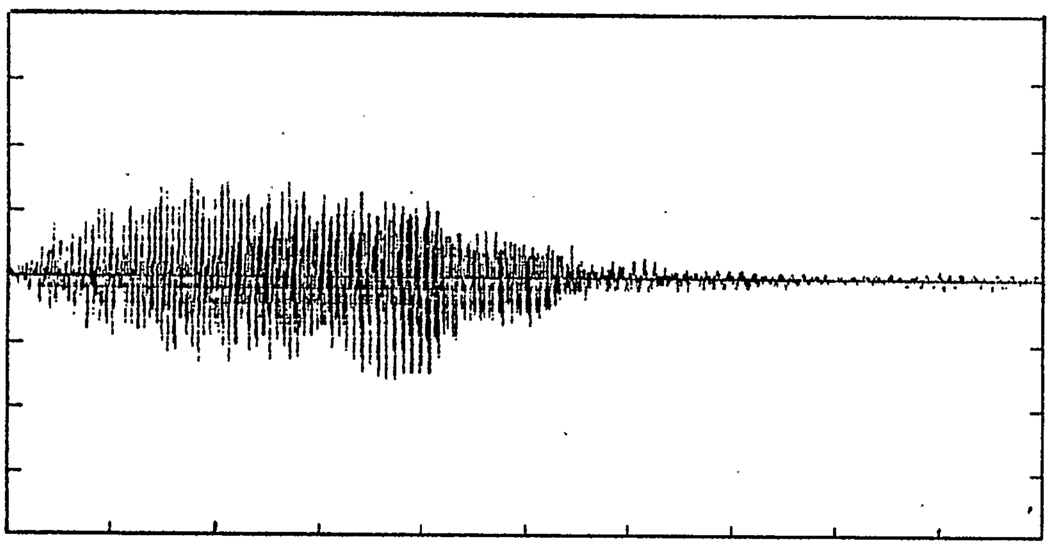

Figure 14: The time and amplitude domain of moan stimulus #5

Amplitude is represented on the ordinate, time (sec) on the abscissa

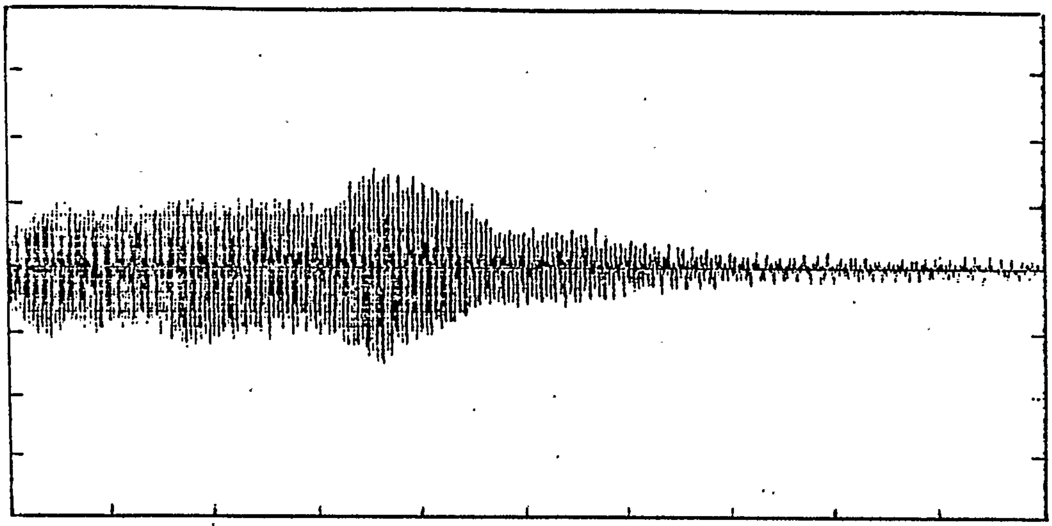

Figure 15: The time and amplitude domain of moan stimulus #7

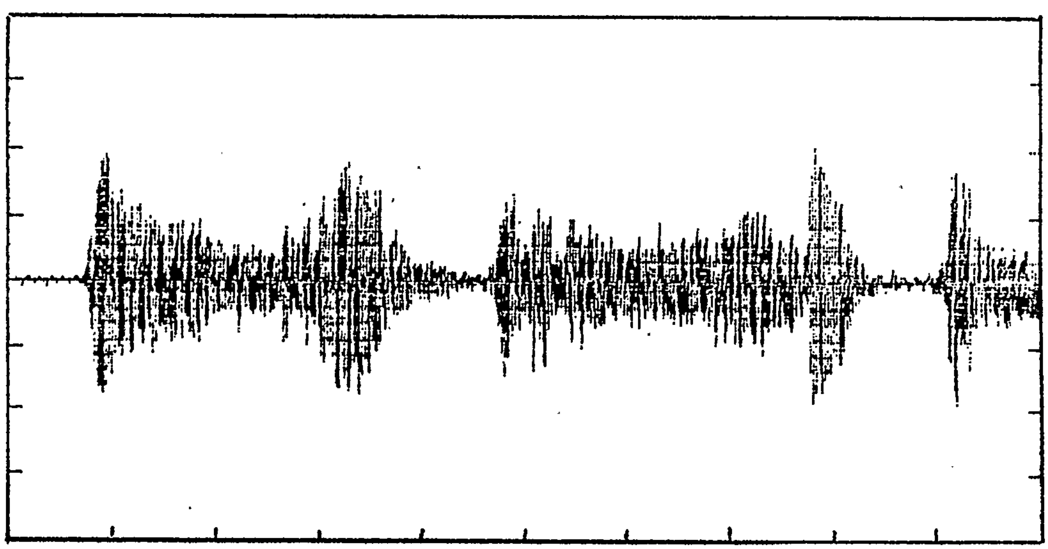

Figure 16: The time and amplitude domain of cough stimulus #1

Amplitude is represented on the ordinate, time (sec) on the abscissa

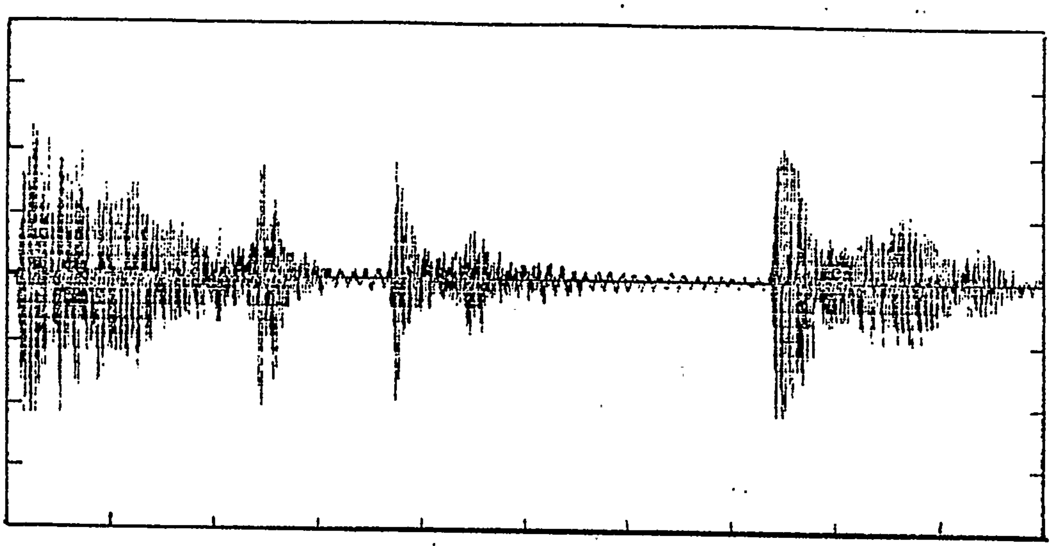

Figure 17: The time and amplitude domain of cough stimulus #2

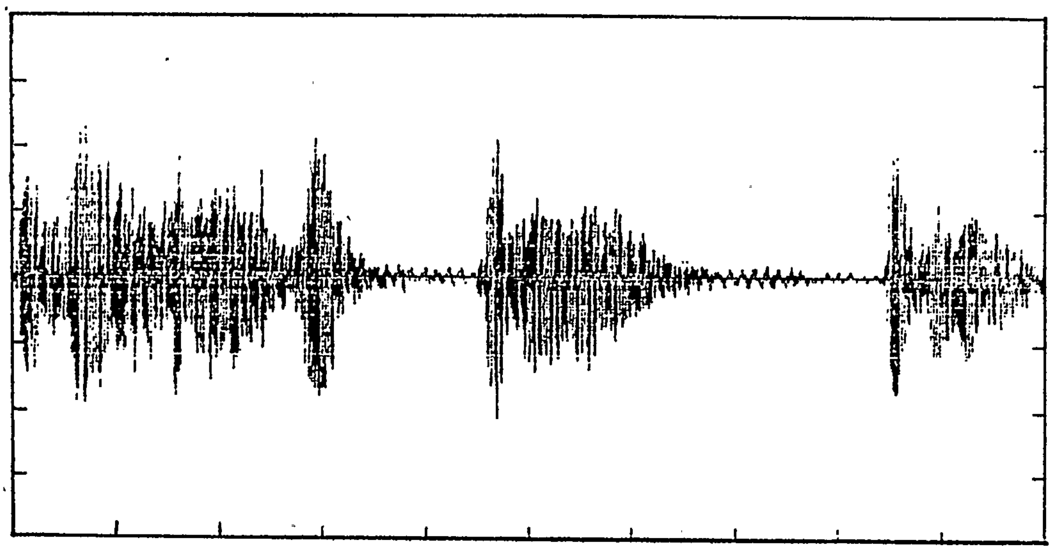

Figure 18: The time and amplitude domain of cough stimulus #5

Amplitude is represented on the ordinate, time (sec) on the abscissa

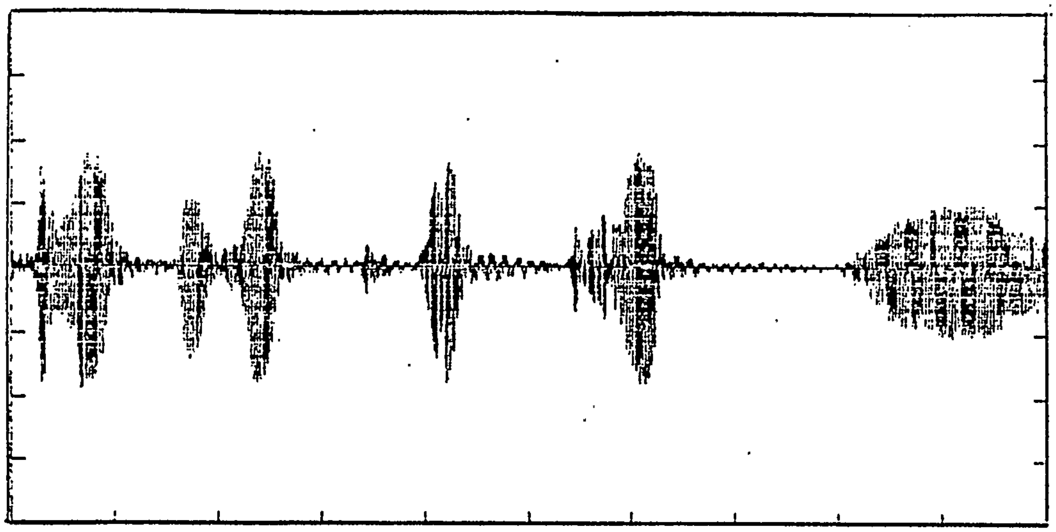

Figure 19: The amplitude and time domain of adult sob stimulus #3

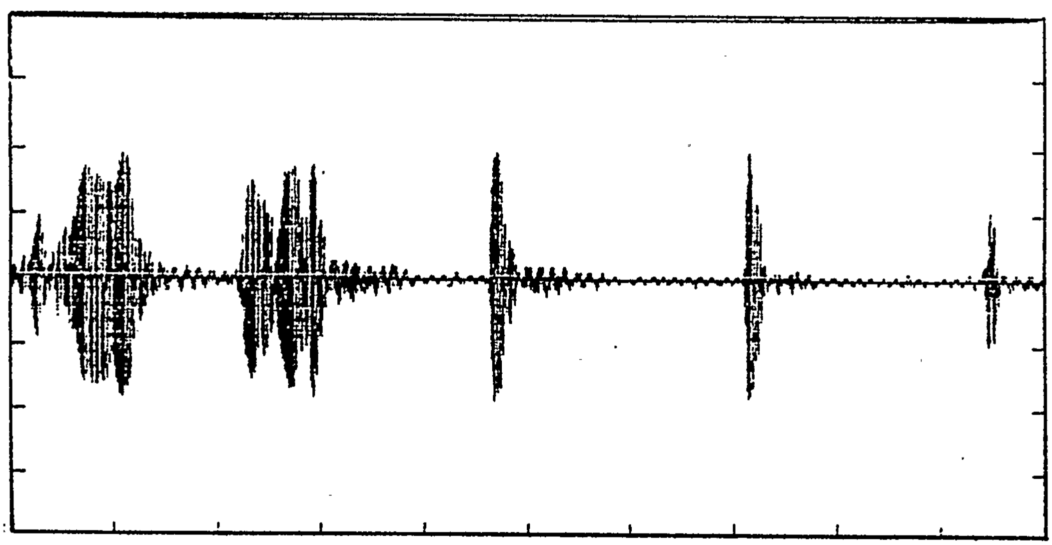

Figure 20: The amplitude and time domain of adult sob stimulus #6

Amplitude is represented on the ordinate, time (sec) on the abscissa

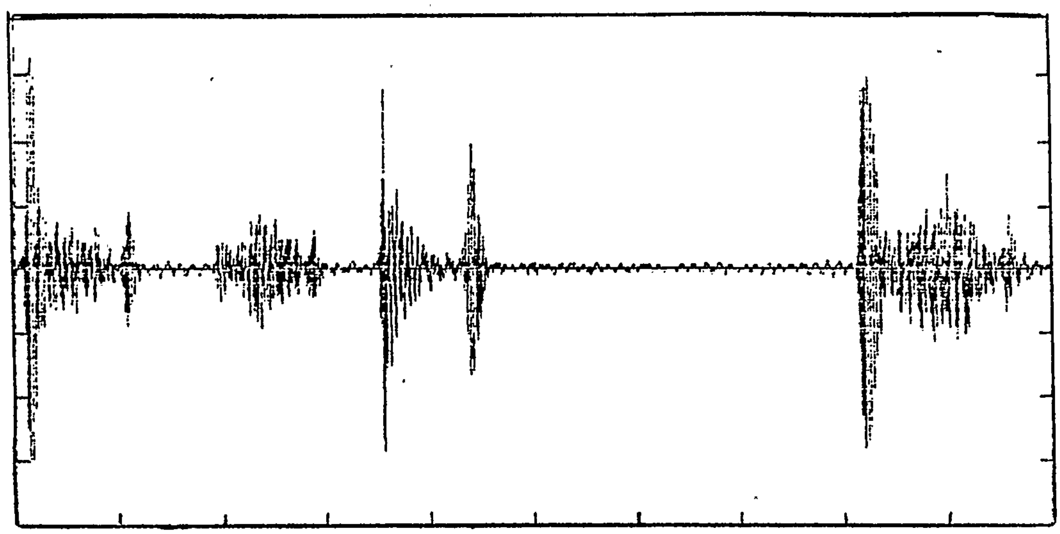

Figure 21: The amplitude and time domain of adult sob stimulus #8

Amplitude is represented on the ordinate, time (sec) on the abscissa