THE PROCESS CURRICULUM

Perceptual Competence

Auditory Perception

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CONTENTS

DEFINITION

Auditory perceptual competence is the conscious abilty to differentiate the features of sound waves (frequency, amplitude, timbre, duration, and direction), integrate them into patterns, and generalize the patterns to similar auditory experiences. Because sound waves are produced by a vibrating body or substance of some kind, they are potential conveyors of information about the environment. For this reason sounds come to signify events and later become the vehicle for language and thought.

DESCRIPTION

Sound is something one cannot see or touch, yet much of human experience is dependent upon it. Through sound, a distant tree is known to have fallen, the most abstract principles and the most tender emotions are expressed, the aesthetic experience of music is enjoyed. This awesome phenomenon can be understood by looking into the properties of sound and the physiology of the ear, and how sound is translated into meaning. This section will also discuss the special case of speech perception and the effects of experience on auditory perception. The specific processes which comprise auditory perception are described in a later section.

Properties of Sound

Sound is the mental experience derived from the effects of sound waves on the ear. Sound waves are the physical changes in an elastic medium (such as air) caused by a vibration or mechanical disturbance such that alternating areas of condensation and rarefaction are created in the medium. (Technically speaking, sound does not exist except in the mind of a hearer. If a tree falls over in the middle of a vast field and there is no one to hear it, there is no sound, only sound waves. In this discussion, the word "sound" refers to both, since for practical purposes the distinction need not be made). A given medium, for example air, is in a state of equilibrium when the small particles or molecules that make it up are evenly distributed throughout a given volume (Fig. 1). When a vibrating body is introduced into the medium, the vibration causes some of the particles to move closer together and others to move further apart, causing a disruption of the equilibrium. This pattern of alternating areas of greater densities (condensation) and lesser densities (rarefaction) of particles is called a sound wave (Fig. 2). The air itself does not move from place to place, but rather the particles that make it up move back and forth as they are condensed and attenuated. Sound waves thus "move" through the air, without moving the air itself as in the case of wind. One wavelength (one cycle) is equal to one condensation and one rarefaction (Fig. 3). The frequency of a sound is measured by the number of cycles per

Figure 1.
Schematic drawing of air particles with no movement.

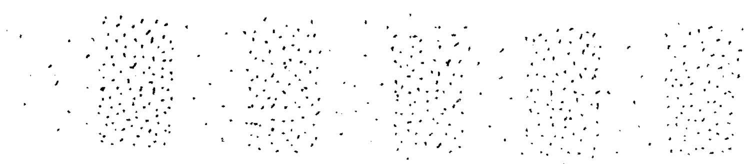

Figure 2.
Schematic drawing of sound wave showing areas of rarefaction (lesser density) and condensation (greater density).

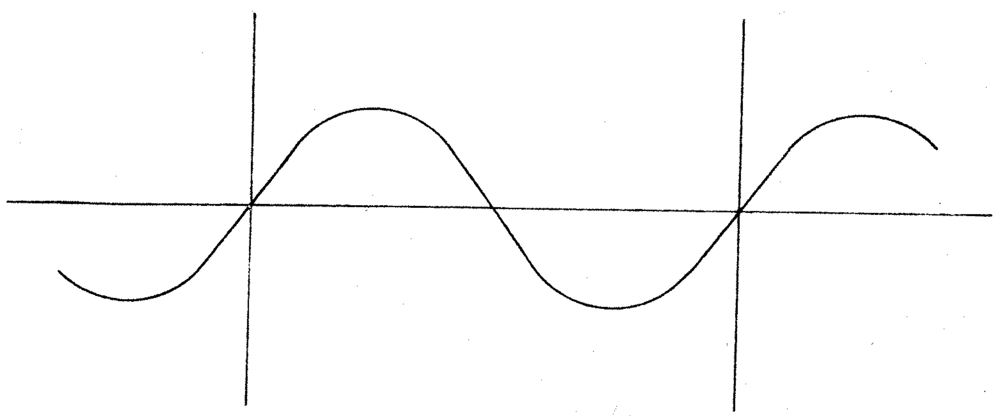

Figure 3.
Schematic drawing of sound wave showing one cycle.

second. The more cycles per second, the higher the tone. The amplitude or intensity of a sound is measured by the amount of pressure or the amount of displacement of the particles as illustrated by the height of the wave. The higher the wave, the louder the tone. Figure 4 shows sound waves of different frequencies and amplitudes.

The first condensation caused by a vibrating body is called the wave front. The wave front is the cue to the direction of the sound.

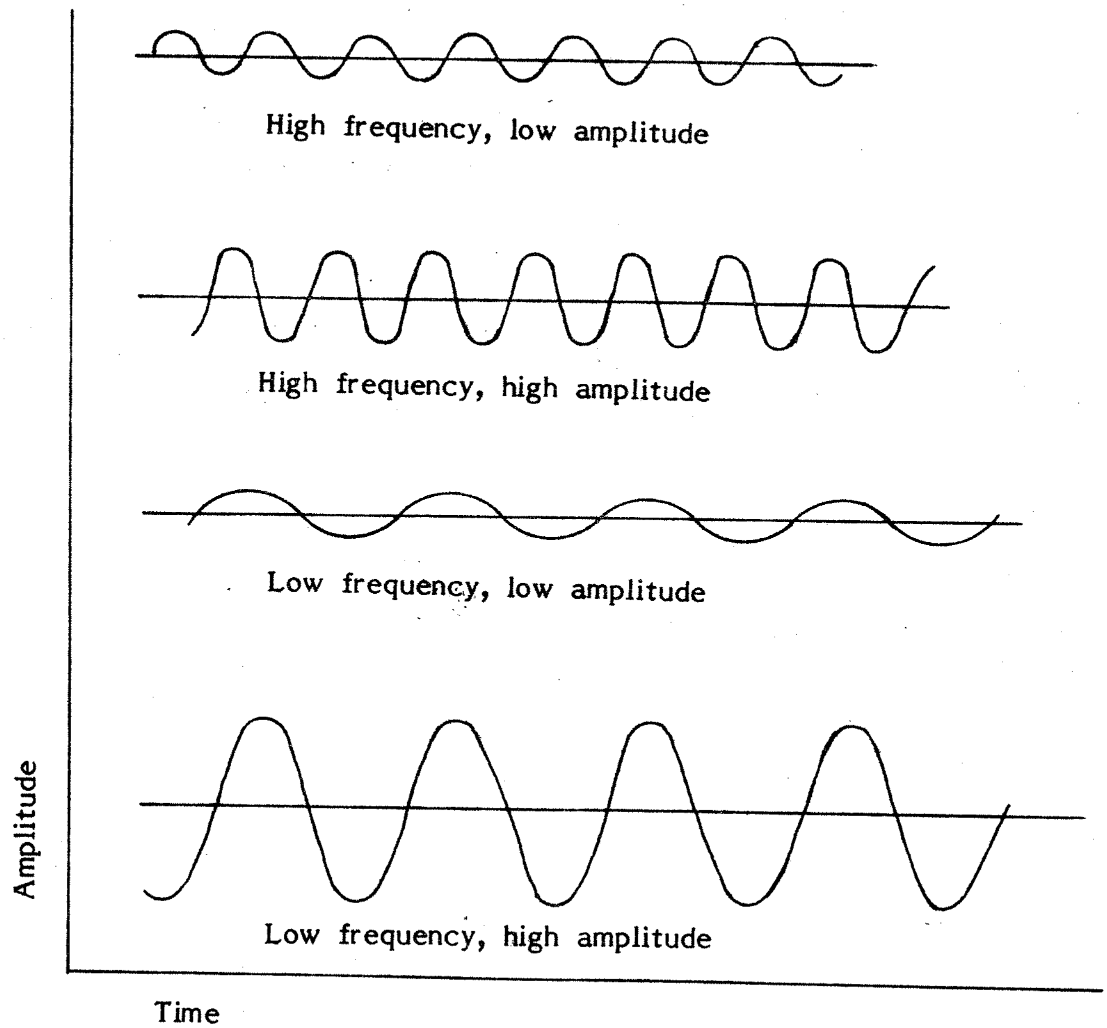

Figure 4.
Pure waves of variuos frequencies and amplitudes. After Murch.

Succeeding condensations and rarefactrions make up the wave train which carries the frequency of the tone. The amplitude of the tone decreases as it travels farther from the source of the sound until it no longer exists. These characteristics of sound will be discussed in greater detail in the section, "Processes of Auditory Perception".

When a sound wave meets an object, some of the sound is scattered, some is reflected and some penetrates the obstacle. The relative importance of these three effects depends upon the size, density and elasticity of the object. If the elasticity and density of the object are similar to the elasticity and density of the medium through which the sound is travelling, most of the wave travels through the object. If the object is denser than the medium, most of the sound is reflected.

To understand what happens when a sound wave enters the ear, a description of the physiology of the ear is necessasry.

Physiology of the Ear

For purposes of explanation, the ear may be divided into three parts: the external ear, the middle ear, and the internal ear.

The external ear is made up of the auricle (pinna) and the canal leading to the eardrum, called the external auditory meatus (Fig. 5). The auricle is made of cartilage; its function is to catch sound waves and direct them to the middle and inner parts of the ear. Some animals, such as dogs and cats, can move the auricle toward the source of sound. Human beings, however, must move the whole head in order to receive a direct signal. The shape of the auricle probably aids in localizing the source of the sound because it creates a sound shadow for sounds coming from the back of the head.

The external meatus (ear canal) begins near the center of the auricle and carries the sound a distance of approximately 2.6 cm. to the eardrum. The longitudinal axis of the canal is almost perpendicular to the side of the head.

The eardrum (tympanic membrane) seperates the outer ear from the middle ear. It is about 69 mm^2 in area and has the shape of a flattened cone pointed inwards. When sound waves enter the ear, they set the eardrum in motion and the waves are transmitted to the middle ear.

The middle ear consists of three tiny bones: malleus (hammer), incus (anvil), and stapes (stirrup), which are suspended in an airfilled cavity about half an inch high and a quarter of an inch broad. Air pressure is maintained in this cavity at a level equal to the external air pressure via the Eustachian tube which admits air from the mouth. The base of the

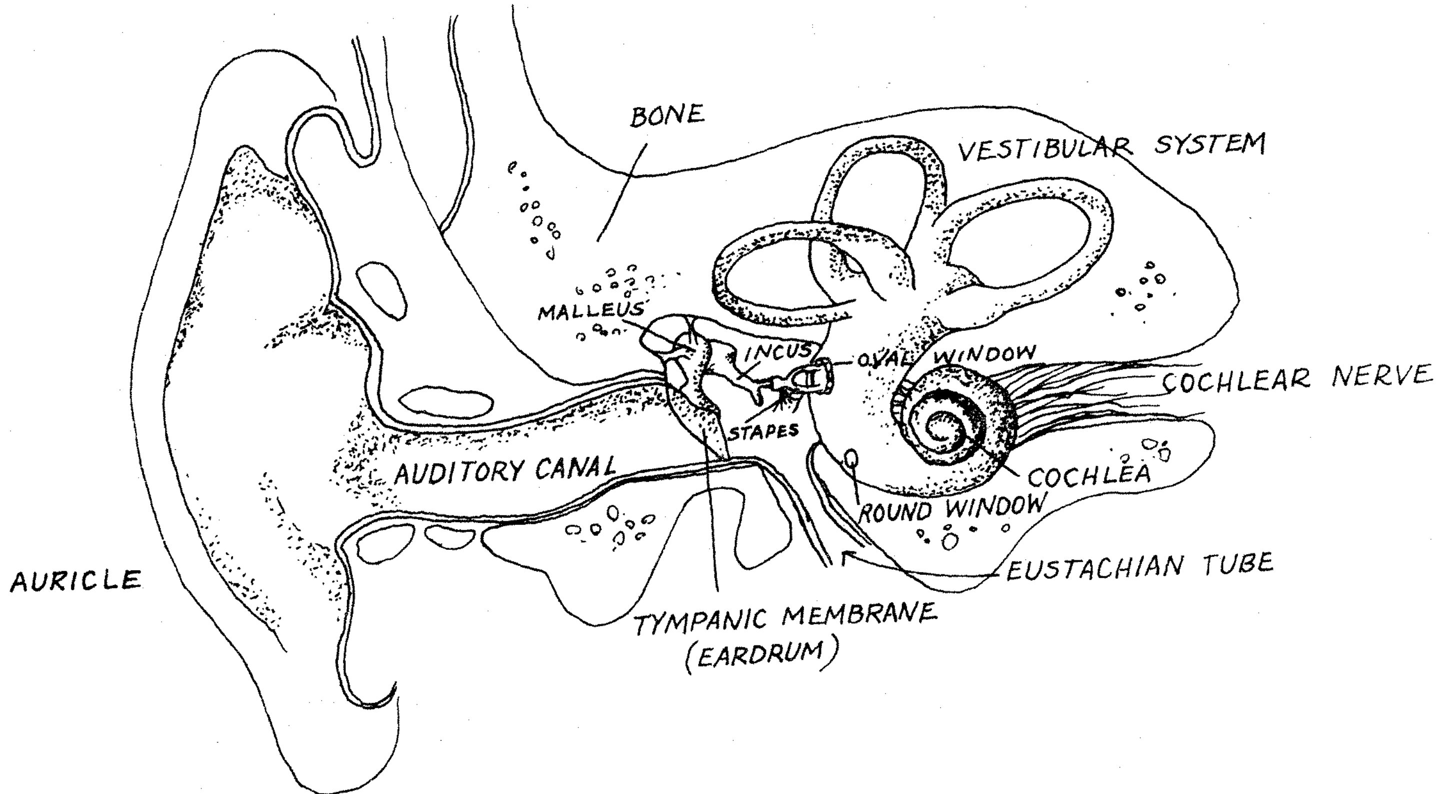

Figure 5.
Schematic drawing of the ear. After Gardner.

malleus is connected to the eardrum and the head is attached to the incus which is joined to the stapes. The footplate of the stirrup fits over the oval window which divides the middle ear from the inner ear. The three bones are held in place by ligaments and muscle attached to the walls of the cavity. The vibration of the eardrum causes each of the bones to vibrate in turn. The vibration of the stapes causes the fluid of the inner ear to begin moving. The middle ear is important in translating sound wave patterns to the fluid-filled chambers of the inner ear. Since the elasticity and density of the fluid is very different from the elasticity and density of air, sound waves going directly from the air to the fluid would be reflected. The eardrum and the bones transform the sound waves from the air into vibrations that can be processed by the inner ear.

The inner ear is called the cochlea (from the Latin for snail shell). It is a tube of decreasing diameter coiled upon itself two and three-quarters times. It is about one-quarter of an inch high at the center of the spiral. The cochlear tube is divided into three canals: the scala tympani, the scala vestibuli, and the scala media. These canals meet at the apex (Fig. 6). Sound or pressure waves are transmitted to the fluid in the scala vestibuli at the oval window. The waves move up the spiral

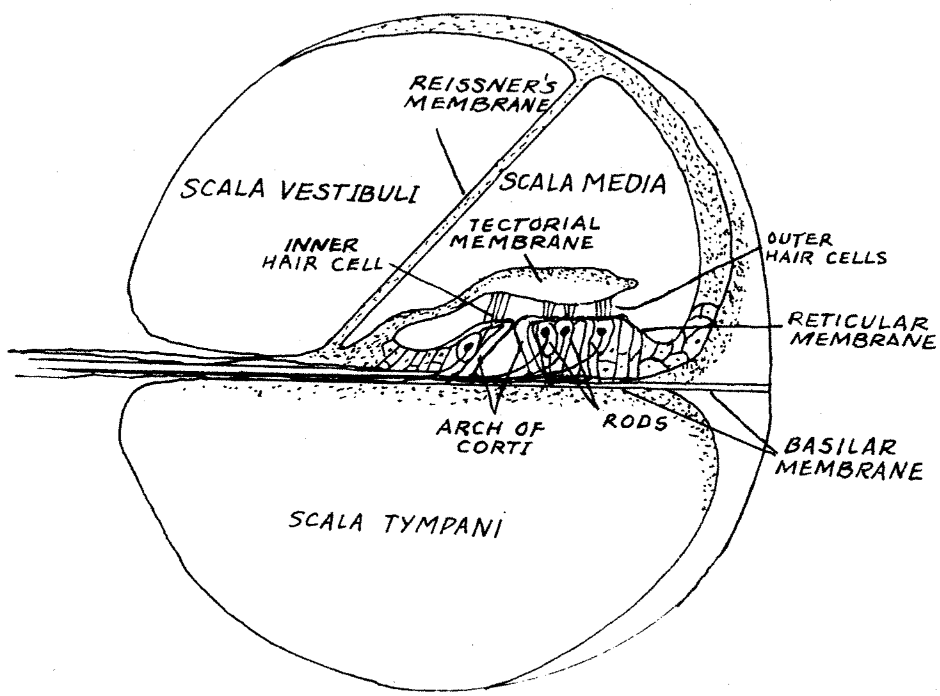

Figure 6.
Cross section of cochlea, showing the organ of Corti resting on the basilar membrane. After Gulick.

through the scala vestibuli to the apex and then down again through the scala tympani to the round window (a flexible membrane that acts as a pressure relief point). The principle mechanism of hearing, the organ of Corti, is located in the scala media. The movement of fluid in the two outer canals influences the movement of fluid in the scala media.

The organ of Corti is situated on top of the basilar membrane which seperates the scala tympani from the scala media. The most prominent structure of the organ of Corti is the arch of Corti that forms a tunnel running the length of the cochlea. Numerous hair cells surround the arch of Corti and are held in place by the reticular membrane. The bases of the hair cells and the cochlear nerve fibers form synaptic junctions. Every time a hair moves, a neural impulse is transmitted to the brain. The total of these nerve fibers or spiral ganglion form the cochlear nerve and run through the internal auditory meatus to the brain (Fig. 7).While the exact mechanism for the translation of pressure waves into meaningful patterns is not agreed upon, it is clear that the movement of the hairs caused by the

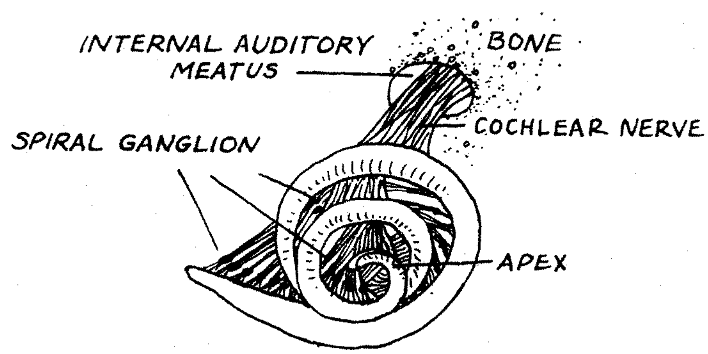

Figure 7.
Schematic drawing of uncoiled cochlea showing nerve fibers. After Gulick.

fluid in which they float and by the basilar membrane upon which they rest is the final and crucial stage of the translation of sound waves into patterns of nerve impulses. The impulses are then carried by the auditory nerve to the temporal lobe of the brain (the auditory cortex) (Fig. 8).

Translation of the Physical Stimulus into Meaningful Patterns

Sounds vary in pitch, loudness, time, texture and location of origin with respect to the hearer. Although researchers do not know exactly how the human ear discriminates the differences among sounds, it is, nevertheless, important to study these differences because they form the basis of meaning by combining sounds into repeatable patterns. The purpose of this section is to propose a general mechanism of perception which explains how sounds are integrated to form patterns and how patterns carry meaning.

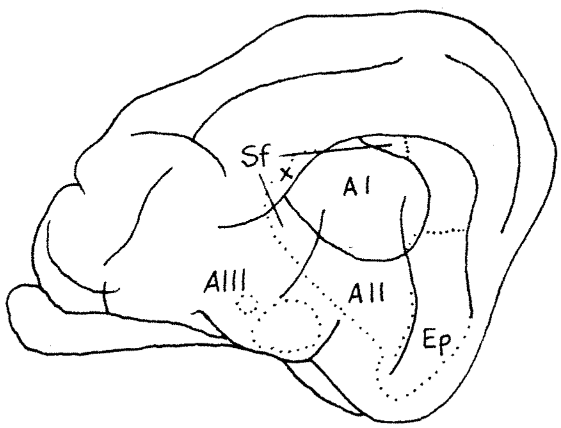

Figure 8.
Auditory cortex of a cat. Each of these areas of the brain plays a role in auditory perception. AI is the primary auditory perception area. After Gacek.

In meaningful sounds, pitch, loudness, time and texture are combined in highly complex ways.

> Instead of simple duration, they vary in abruptness of beginning and ending, in repetitiveness, in rate, in regularity of rate, of rhythm and in other subtleties of sequence. Instead of simple pitch, they vary in timbre or tone quality, in combination of tone quality, in vowel quality, in approximation to noise, in noise quality and in change of all these in time. Instead of simple loudness, they vary in the direction of change of loudness, the rate of change of loudness and the rate of change of change of loudness (Gibson, p. 87).

How does the brain make sense out of the infinite possibilities of sound combination? Deriving meaning from sound depends on a process of differentiation, integration and generalization of sound patterns and the association of the patterns with particular events. The explanation for this proposition comes from two theories, one that stresses the differentiation aspect (Gibson and Levin, 1975) and another that gives categorization the leading role in the perceptual process (Bruner, 1973).

Gibson and Levin define perceptual learning as,

> ...learning to extract the relevant information from the manifold available stimulation, that is, the invariant information that specifies the permanent layout of the environment, the distinctive features of things that populate and furnish the environment, and invariants of events that enable us to predict the outcomes and detect causes (Gibson and Levin, 1975, p. 13).

Bruner, on the other hand, states that,

> In learning to percèive, we are learning the relations that exist between the properties of objects and events that we encounter, learning appropriate categories and category systems, learning to predict and to check what goes with what (Bruner, 1973, p. 11).

The Anisa theory of development reconciles these two seemingly contradictory views because both differentiation and integration are regarded as integral to the perceptual process. When encountering an aspect of the environment, such as sound, the human mind identifies certain characteristics of the sound according to ones adaptive value or usefulness. A call of warning, for example, has features which distinguish it from a call of joy, even though they both may be high-pitched, loud, and rapid. Through experiences a child learns to identify the distinguishing features of a sound (differentiation), formulate the sounds into patterns (integration), and categorize the patterns with other similar patterns (generalization).

Differentiation is the process of selection. It means paying attention to particular attributes of a sound and ignoring others, or detecting the differences between two or more sounds. For example, when a child comes home from school and tells his mother about the day, she may listen to find out whether the child is happy or sad, or she may listen to find out whether he had reading or math. If she is interested in his mood, she will concentrate on the tone and amplitude of his voice and ignore the particular words he is using. If she is interested only in content, the words themselves will take on more importance and the tone of his voice will be less relevant. Usually, a mother listens for many types of information at the same time and depends upon different cues for every interpretation.

A teacher can assist children to make better and more conscious discriminations among the characteristics of a sound by asking them to identify certain features and ignore others. A given pitch at a given amplitude might be played on a clarinet, horn and violin. Holding frequency and degree of loudness constant will help the youngster focus on timbre (texture) or shape of the sound wave. To take a more complex example, the same paragraph of speech can be analysed for timbre, loudness, pitch, duration and location. Different combinations of these yield different words, moods and meanings. A teacher might read a passage or play it on a tape recorder and ask the children questions to focus their attention on particular features. Oral reading, dramatic arts and music all can be used to point out to children the complex ways in which sounds differ.

Integration is a process of combining or making patterns. Forming categories or classes is one expression of integration, while placing things in a category already formulated is an act of generalization. It means putting together sounds on the basis of certain distinctive features. While the sounds in one category may have many different attributes, they have at least one common and invariant feature in order to formulate the category. For example, a song written in a major key is distinguished by a certain harmonic pattern (certain relationships among the pitches). Everything about the song may change (melody, rhythm, or pitch), but the harmonic pattern must be the same if it is to remain in a major key.

A teacher may assist children to make integrations more quickly and with a fuller awareness of the process by asking questions and posing problems that focus the children's attention on category formation. Such questions might be: "How is this sound different from that one?" "Why did you say that boy sounded happy?" "What is a happy sound?" "Which sounds are made from vibrating strings?" "Which from vibrating columns of air (flute)?" Sample problems are: "Play the role of a child telling his friend about his birthday party," or "Make a sound in six different ways: loud, soft, slow, fast, high and low."

Generalization is the process of transfering learning from one experience to another. It requires finding distinctive features one has encountered before and using them to classify a sound according to an existing category. For example, once a child has heard bell-ringing sounds, he will be able to identify any sound produced by a bell, even if certain features vary, such as pitch or amplitude. Later, he may learn that particular bell sounds usually have meanings: answer the door or the telephone. He learns that the school bell means that it is time to go home and will automatically get ready to go when he hears it. However, the categories must not be too rigid. He also must be open to an event that doesn't fit a category. If the school bell rings in the middle of the day, he probably would not get up and leave, but would have to readjust his category system and wait for an interpretation of the event. Now his category system would tell him that the school bell rings when it is time to go home or when there is an emergency.

Some categories have a relational dimension such that a sound must be compared with another sound before it can be categorized. A sound may be loud compared to certain sounds, and soft compared to others. It is categorized as loud only in the former case. Also, a stimulus may shift categories depending on the particular attribute being considered. One sound may be high and loud. Categories may break down into sub-categories or become more general and encompass a large range of sounds. In discussing a musical selection written in the key of D major, for example, we can be very general and say it is in a major key, or be more specific and say it is in D major with one variation of the theme played in B minor and ending on a dominant seventh cord.

Teachers can help children to be aware of the numerous possiblities for categorization by encouraging them to find new ways of classifying a particular sound and to narrow or broaden existing categories. Questions such as the following may be useful: "What kind of material was vibrating to make that sound?" "What else is different about that sound?" "What other sounds make you think of the rain?"

As the child differentiates, integrates, and generalizes auditory stimuli, he begins to learn how the formation of categories of sound is influenced by a given environment. A sound at home, for instance, may mean one thing; the same sound at school may mean something else. Speaking loudly is appropriate outside; speaking softly is necessary inside. Exposing children to new environments and new sounds gives them the opportunity to classify auditory events and increase their ability to generalize.

Speech Perception

It is commonly accepted that the mechanism for interpreting speech sound is different from the mechanism for interpreting non-speech sounds. The evidence for this comes from a study in which speech sounds and non-speech sounds were presented to each ear independently. Speech sounds were identified better by the right ear, the impulses from which are interpreted in the left cerebral hemisphere. Non-speech sounds, such as melodies and sonar signals, were identified better by the left ear, the impulses from which are interpreted in the right cerebral hemisphere. It may be tentatively concluded that children distinguish speech from non-speech sounds innately and, hence, it is not necessaary to teach them the distinction.

Speech sounds are not distinguished from each other by the characteristics that identify other sounds such as pitch, loudness and time. A word may be spoken in different ways (high, low, loud, soft, fast, or slow) and still be recognized as the same word. The distinctive features of speech sounds are determined by complex combinations of amplitude, timbre and frequency. Different ratios among these features and the sequence of the combinations determine the way the vocal tract will resonate for a given speech sound. The vocal tract resonance, which is unique for each phoneme is called a format and can be represented on a spectogram. A phoneme will have the same basic spectogram no matter who pronounces it (Fig. 9).

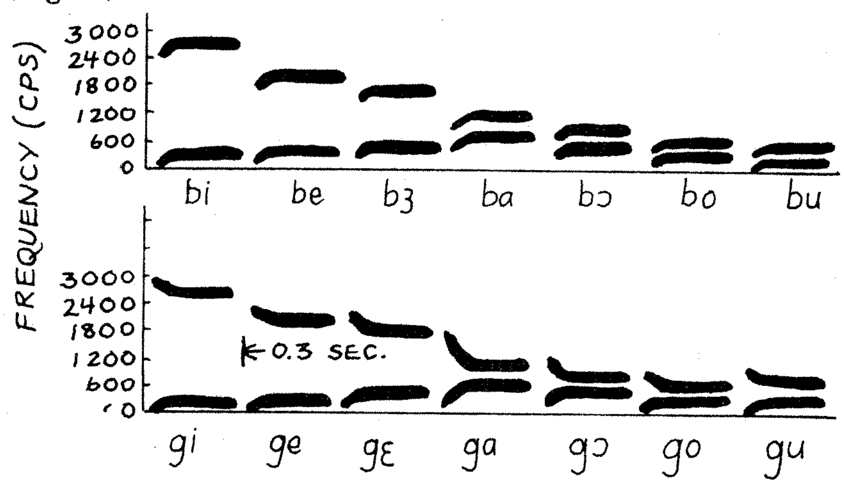

Figure 9.
Schematic drawing of spectogram patterns for selected phonemes. Each phoneme has a distinctive pattern which can be represented visually. After Bartley.

It is the unique pattern of each phoneme that the human brain processes. Evidence shows (Stevens and House, 1970) that the listener characterizes a phoneme according to a certain pattern or attribute and then uses that pattern to identify future phonemes. The phonemes are not on a continuum with one sounding "almost like" another. Rather, they fall into categories and a child must learn the distinctive differences, first by discriminating between widely different phonemes and then between similar phonemes. Phonemes will be easier to differentiate if they are in clear figure. For example, the initial sounds of rhyming words will be easier to differentiate than the initial sounds of two words that differ in other aspects as well because, in the former case, the initial sounds are in clear figure.

Hearing spoken language is closely related to production. Liberman hypothesizes that encoding and decoding language are one and the same process:

> The assumption is that at some level or levels of the production process there exist neural signals standing in one-to-one correspondence with the various segments of the language--phoneme, word, phrase, etc. Perception consists of somehow running the process backward, the neural signals corresponding to the various segments being found at their respective levels (Liberman, 1967, p. 454).

The evidence for this statement comes from the fact that the same phoneme is distinguished in a variety of contexts and dialects. Even though a phoneme may sound different in different circumstances, the listener doesn't seem to have much trouble in identifying it. Thus, it would seem that speech and articulation training go hand in hand with auditory perception training.

Although the phoneme is the most fundamental unit of speech discrimination, the context within which it is found provides important cues to its identification. The child's knowledge of phonological and syntactic rules, vocabulary and semantic rules will aid him to discriminate and interpret what he hears. Training in speech perception must take advantage of context cues.

Effects of Experience

Every person has a unique set of categories which he has developed by perceiving common features of experience and putting them together. When a new experience comes along, the individual tries to fit it into an exisitng category. Since each individual has different categories, the same event newly experienced by many persons may be placed in a different category by each individual. This is why two people often have quite different interpretations of a common experience.

The experience of an individual also gives him certain expectations which he brings to every new situation. If a person went to hear the Boston Symphony once and did not like it, he probably will not expect to enjoy it in the future.

When working with children, it is important to "set the stage" for any experience so that they have the same expectations as the teacher. It is possible to give children a positive attitude toward a new experience simply by preparing them for it. Communicating with children about their expectations and experience is essential to successful teaching since children's perceptions are often widely divergent from each other and from the adult's perceptions.

Future aspirations, as well as past experience, affect perception because one is always looking for opportunities to achieve goals based on aspirations. Information from the environment which will assist in attaining the goal will be selected over irrelevent or useless information. Here again, communication is necessary so experiences can be planned that help achieve everyone's goals.

Experience is implicated in the phenomenon of auditory fatigue. There is some evidence that the cochlea can become "fatigued." A loud continuous sound may seem to become quieter over a period of time. If one ear is stimulated continuously, a less intense tone played in the other ear will seem equally as loud. This evidence supports the principle that novelty must be introduced at crucial times in any learning experience; otherwise,habituation or fatigue may reduce the rate and quality of learning.

THEORETICAL JUSTIFICATION: ANISA

This section will relate auditory perception to learning competence and consider its role in gaining mastery over the environment. Three curriculum areas, language arts, music, and science, will serve to illustrate the relationship of auditory perception to the total curriculum.

Relationship to Learning Competence

Since auditory perception affords clear examples of differentiation, integration and generalization, developing auditory perceptual competence can be used to strengthen learning in other areas. The ability to differentiate and integrate speech sounds facilitates the developement of visual differentiations and integrations of the graphemes that comprise the written word. Learning that two birds make different sounds is a clue that there might be other differences between them as well. Auditory differences are often associated with visual, tactile and olfactory differences and alert the hearer to notice these differences. Furthermore, learning consciously to differentiate, integrate and generalize in the auditory mode will facilitate differentiation, integration and generalization in other modes.

The sense of hearing is fundamental to human growth and development because it is essential to survival. A call of warning, a fire alarm or an emergency signal alert people to danger. A mother's ability to hear her baby cry has survival value for the child. Probably most important of all is the role that hearing plays in communication. Through speaking and listening, people communicate and transmit knowledge from generation to generation.

Auditory perception is necessary for music appreciation and the refinement of the processes that make up auditory perception is the key to one important area of aesthetic awareness. There are no cultures in the world that have not developed musical forms; musical expression seems to be a universal human need. It uplifts the spirit of man; it gives him more enjoyment out of work and play. Music can be a source of motivation to any educational experience and it can heighten sensitivity. Furthermore, music can be produced only if the sense of hearing is refined.

The process of refining auditory perception can be in itself a motivation for further exploration of the environment. In the words of one author:

> A clear, definite, and well-organized percept is rewarding; to have wrestled with an unstructured environment and to have won is gratifying (Solley, 1960, p. 82).

Discovering the auditory structure of the environment is rewarding because it reduces uncertainty and increases the probability of identifying predictable relationships. The acquisition of higher level auditory skills, identifying bird calls, analyzing a symphony or discovering a heart murmur, gives one greater control over the environment and motivates him to strive for greater refinement. The satisfaction that comes from achieving mastery in auditory perception also encourages the individual to strive for mastery in other areas of learning.

Relationship to Curriculum

The sense of hearing cannot be turned off. Whatever activity the child pursues, his ears will be open both to the immediate requirements of the task and to background sounds that at some point may have meaning to him. Thus, auditory perception pervades all learning, whether it means selecting some sounds and blocking out others, or ignoring all sounds, or learning to make finer and finer discriminations between sounds. Because almost every part of the curriculum will have an auditory perception component, careful consideration should be given to the ways in which the arrangement of the environment, the organization of children in the classroom and planning of the daily schedule will affect auditory perception.

Language arts, music, and science are three aspects of the curriculum which depend heavily upon the development of auditory perception.

Language arts. Auditory perception is central to language development because it is by hearing language that children receive numerous samples of speech from which they are able to make generalizations about grammatical and syntactic rules and thus learn to communicate. Deaf people require much more time to learn grammar and vocabulary than do young children because the symbols of language are not readily available in the environment. Language development begins at a perceptual level where sounds are repeated, but there is little comprehension of meaning. Later, the sounds are related to experience and cognitive structures emerge. The ability to make abstractions, one of the central processes of cognitive development, relies, in part, upon language development and, therefore, upon auditory perception. Of course, spoken language is only one type of abstraction. Deaf people certainly learn to make abstractions through other modalities.

Auditory perception also plays a central role in learning to read. While an adult may be able to translate the written word directly into meaning when first hearing the word, the child when learning to read must first translate the written word into auditory stimuli which he has already experienced and from the auditory stimuli he extracts the meaning. As the child learns to read,

> Graphemes are transformed into phonemes; printed words are transformed into spoken words. If a child is unable to receive phonemes clearly, respond to them discretely, retain them in accurate sequences, and organize them into linguistic signs, he is likely to encounter formidable difficulties in learning to read (Flower, 1968, p. 21).

Auditory discrimination and auditory memory have been shown to correlate with reading ability (Morency, 1968) and auditory training can improve reading ability (Halliwell and Solan, 1972).

Music. The study of music includes two aspects: appreciation and production. Appreciation requires an ability to hear patterns and the relations between them; production depends upon the ability to detect fine discriminations among sounds and to reproduce the discriminations with the voice or on a musical instrument.

Musical patterns can be made up of three primary components: melody, harmony and rhythm. The arrangement of pitches over time comprise the melody. Harmony occurs when two or more pitches are sounded at the same time. Rhythm is the pattern of accents or beats determined by relative amplitude among the sounds and the relationship between the duration of a tone and the length of time between tones. In order to appreciate music, one must be able to discriminate between the melodic, harmonic and rhythmic patterns and integrate them into a whole.

Producing music involves more than differentiating and integrating melody, harmony and rhythm. It requires an ability to make consistently fine discriminations of pitch, loudness, time and timbre and the relationships among them. Every tone produced is compared with the tone that preceeded it to be sure that the relationship is correct (i.e., the pitch, loudness, time and timbre sound as the musician intends them to sound). If a trumpet player blows too hard, or not hard enough, the tone may be slightly off pitch or too loud or too quiet. The auditory system continuously informs the lips and the lungs what to do. Without refined auditory perception, it is impossible to master a musical instrument.

Singing or playing an instrument with others requires the ability both to produce sound and to integrate it with the sounds that others make. The process of figure-ground perception is involved here. One must be able to evaluate the sounds one produces in relation to the sound produced by the total ensemble. Doing both of these things at the same time depends upon highly developed auditory capabilities.

Science. The first step in scientific investigation is observation. All of the human senses are used in this step. The study of sound and its uses is an integral part of the science curriculum and contributes to the child's ability to understand the physical world. A zoologist identifies birds and animals by the sounds they make. A medical doctor evaluates a patient's condition by listening to his heartbeat. Physicists send out sound waves to detect the location and speed of objects by calculating the time it takes to bounce off and return to the source. This methodology, called sonar, is used to navigate submarines. Geologists detect earthquakes by monitoring vibrations in the earth. Thus, understanding the nature of sound waves has been an important part of technological advancement and has helped man gain control over the environment.

DEVELOPMENTAL CONSIDERATIONS

While the major portion of the development of auditory perception takes place during infancy, the refinement of auditory discrimination and accurate interpretation of auditory cues continues to improve throughout life. A discussion of developmental trends will follow a description of infant development. Two special cases of auditory development--speech and monotonality--will be mentioned briefly.

Development of Auditory Perception in Infancy

The developmental studies of Gesell and Amatruda (1974) give a general picture of the development of auditory perception in infancy. They observed many children and noted the behavioral characteristics of the child in each age range. The following observations relate to the development of auditory perception:

Four weeks or less	Attends to a bell by diminishing activity.
Eight weeks	Attends to a bell by inhibiting activity, frowning, smiling, or widening the eyes.
Twelve weeks	Vocalizes in some manner or "talks back" in response to social stimulation.
Twenty-eight weeks	Bangs on the bell; shakes the rattle vigorously; makes controlled polysyllabic vowel sounds.
Thirty-two weeks	Makes single consonant sounds as well as vowel sounds.
Thirty-six weeks	Combines two consonant sounds, but without specific meaning; imitates sounds such as clicking of the tongue.
Forty weeks	Waves and shakes the bell; understands words and responds appropriately; uses one-word phrases.
Fifty-two weeks	Gives a toy on request; responds to music and simple rhythm play.
Fifty-six weeks	Increases vocabulary to several words; speaks two or three wordlike phrases; identifies objects by pointing to them.
Eighteen months	Uses words to express ideas and adopts words as substitutes for gestures (transition age); swings rhythmically with whole body in response to music; hums spontaneously and sings syllables with wide ranges in tone, pitch and intensity of voice.
Three years	Asks rhetorical questions. Expresses desires, refusals and denials, (Still not able to imitate the frequencies involved

in difficult consonants. Mature, articulate speech may not appear until age five.)

Bends at the knees, sways, nods head or taps foot to keep time in response to music. Sings as rocks in a chair. Recognizes a melody, and sings phrases of songs. May reproduce the entire song. Begins to match simple tones. Enjoys group participation in rhythmic play. Gallops, jumps, walks and runs, keeping good time to music.

A study by Spencer (1958) showed a steady increase in auditory perception with age up to about five years old. Her tests of auditory perception included the recognition and identification of sounds and patterns of sounds, and were correlated with intelligence.

Developmental Trends

The improvement of auditory perception with age and experience depends upon the increasing ability to differentiate, integrate and generalize auditory stimuli. Differentiations become more and more specific. Sounds with only slight differences become easier to discriminate from one another. At the same time, it becomes easier to focus on the distinguishing features of a sound and to ignore irrelevant features. This ability stems from previous integrations which enable one to predict what features will be useful in making new integrations. Experience also increases "economy of information pickup" (Gibson and Levin, 1975). As children get better at detecting order and structure (generalization), they are able to use "the smallest distinction...that suffices for a decision," and to pick up "the largest units that carry structured information" (Gibson and Levin, 1975, p. 43). Generalization involves the development of rules which cue the organism to the information needed based on past integrations and determined by the predictive value of the information for identification and use of the stimulus. With experience, rules or generalizations are formulated to cover an increasingly broad range of possible sounds.

Recognizing any stimulus is always easier than recalling it. The presentation of a sound stimulates the recall of any information stored in the brain with which it has been associated previously. If one hears a familiar bird call, the name of the bird usually is associated with it, and one is able to name the bird readily. It is more difficult to recall and produce the bird's call given the name of the bird. This not only requires that an association be made, but that a complex pattern of sounds be generated after hearing only the name. Thus, it is important to make sure that children are able to recognize a sound, a word, or a melody and have the occasion of rehearsing it before expecting them to recall it.

Development of Speech Perception

In a study of the ability to discriminate initial consonants, Tikofsky and McInish (1968) conclude that by age seven most children articulate accurately all the phonemes of their native language. The consonants [s], [z] and [sh] are among the last to be discriminated, while the low frequency sounds, such as [m], [w] and [n], and vowel sounds, appear much earlier. Spencer explains that the child's hearing develops first for lower frequencies of speech and later for higher frequencies (such as [s], [z] and [sh]). Since the child does not hear these higher frequencies at first, and "since their production does not involve movements easily distinguished by the eye... [the child] may not even know they exist" (Anderson, 1953, p. 31). Moreover Tikofsky and McInish (1968) found that initial sounds differing by only one distinctive feature are more difficult to discriminate than sounds differing by two or more distinctive features. Sounds within a category are more difficult to discriminate than sounds between categories. Thus, children should be introduced first to sounds with maiximum differences and low frequencies and later to sounds with minimum differences and high frequencies.

Monotonality

Monotone means "one tone". It refers to a person who sings only on one pitch or on a narrow range of pitches. Such a person either has an inability to discriminate among the pitches he hears or is unable to match the pitch he produces with the pitch he hears. Many young children sing in a monotone because they have a narrow voice range. With age and training, the voice range increases and monotonality decreases. Songs in group singing should be presented at different pitch levels to accomodate all the possible voice ranges of the children in the class. Children with a low pitch level should be provided for by giving them a different part to sing or by dividing the class. Songs with a wide pitch range usually should not be selected for young children.

PROCESSES OF AUDITORY PERCEPTION

The processes of auditory perception have been divided according to the types of information sound waves can carry, and the ear can distinguish and the human mind can interpret. While none of the processes can operate independently of the the others, each can be discriminated for any given sound and there is some evidence that the neural mechanism for each process is distinct.

Auditory figure-ground perception is the ability to attend to certain sounds (the figure) and to ignore the others (the background). It is the initial stage of any auditory experience. It will be discussed here briefly and the reader should turn to the figure-ground specification for further elaboration of the topic.

Sounds differ in frequency, amplitude, duration and timbre. The human ear hears each of these differences in terms of pitch, loudness, time and tone quality and, therefore, each will be treated as a separate process. This paper will explain the physical phenomenon involved in each, the process which mediates its interpretation by the brain and the ways in which the process can be strengthened through experience.

Sound localization is the ability to identify the direction from which sound is coming and the direction and speed of a moving object that is making sound waves. The ability to discriminate pitch, loudness and time are all required here. However, since a special relationship between these three factors is involved, it is considered as a separate process. An explanation of how sound is localized will be followed by suggestions for strengthening competence in this area.

Auditory Figure-Ground

Figure-ground perception is the process of differentiating certain features from a previously undifferentiated field and integrating these features into a figure or pattern that is distinctly separate from and predominant over the remaining information in the perceptual field. Those aspects of the field unassociated with the figure become the background, or simply ground (from ANISA specification on figure-ground perception). Auditory figure-ground perception, then, is the differentiation of certain sounds and their integration into a meaningful pattern, e.g., speech, music, or other symbolic patterns.

The characteristics of the sound waves produced by the environment determine whether or not a pattern can be detected. The factors of similarity, proximity, contrast, experience and labeling enable the human mind to discern patterns amidst the conglomeration of sounds that continually impinge upon the ear. The emergence of a pattern may be due to any of the following factors:

1. Similarity Sounds that are similar in texture will tend to be grouped together. For example, speech sounds are easily distinguished from non-speech sounds and one voice from another voice. In an orchestra, the musical line of the clarinet can be discriminated from all the other instruments because each instrument has a distinctive tone quality. If different parts of the melody are played by different instruments, the

melody will be more difficult to recognize than one played by only one instrument or a group of instruments.

2. Proximity Sounds which are close together will tend to be grouped together. For example, sounds coming from the same location will be heard together and are likely to form a pattern. If the pitches in a melody are spread out over several octaves, the melody will be much more difficult to discern than if the pitches are in the same octave (Fig. 10).

3. Contrast Sounds which contrast with other sounds in the environment will become figure and the other sounds will become ground. They may contrast in pitch, loudness or timbre. For example, the melody of a song is usually played louder than the accompaniment. It may be played at a higher pitch, or with a different instrument.

4. Experience Sounds that have been grouped together in the past will tend to be grouped together again. A familiar melody will be more easily distinguished from a conglomeration of sounds than an unfamiliar melody. A familiar melody can be recognized even with some of the notes left out, because the ear fills in the other notes from experience.

Figure 10.
The melody is easily distinguished in the top line because of the factor of proximity.

5. Labeling A pattern of sounds that has a name will be easier to recognize again as the same pattern than a pattern that has not been labeled. Labeling makes conscious the process of categorizing sounds and patterns of sounds. The association between the label and the sound pattern makes the pattern easy to retrieve at the mention of the label.

When an auditory stimulus (e.g. the teacher's voice, music, records, tape, a child's voice) is presented to children, it should be in clear figure. Similarity, proximity, contrast, experience and labeling are factors that should be kept in mind when presenting the stimulus. The day-to-day environment of the classroom should be relatively quiet so that any auditory stimulus will contrast with the environment and will be clearly heard. Providing auditory and visual shelter in the classroom, establishing and enforcing the ground rule of talking in low voices only and speaking in a low voice oneself, are ways of maintaining a low noise level in the environment. While a quiet background is best for most auditory experiences, the objective in some experiences may be to strengthen the child's ability to pick out an auditory pattern or figure from a complex or noisy background. Some commercially produced tapes provide this experience in increasing levels of difficulty. One example of this might be two voices with noise in the background. Music analysis requires the ability to extract patterns, melodic, harmonic and rhythmic from a musical selection. The pieces chosen for musical analysis can be simple at first and become increasingly complex. Children's songs or recorded music of all kinds can be used for this analysis.

Pitch Perception

The frequency of a sound is the number of displacements of the medium that occur in a given period of time (See p. 1). Frequency is measured on the Hertz scale (one Hz = one cycle per second). The human ear can hear sounds ranging from 16 Hz to 22,500 Hz (Murch 1973), although there is a great deal of individual difference. Musical tones usually range from 65 to 4,000 Hz.

When the frequency of a sound wave changes, the listener perceives a change in pitch. (Note: pitch refers to a sensation while frequency refers to the physical properties of sound waves.) However, the change in pitch does not correspond directly with the change in frequency. For tones below 1,000 Hz or above 4,000 Hz as the frequency increases, there is a disproportionate increase in pitch. For tones between 1,000 Hz and 4,000 Hz, each increase in frequency is accompanied by an equal increase in pitch. To account for this discrepancy, Stevens, Volkman and Newman (1937) developed a scale of pitch as a function of frequency called the mel scale, later revised by Siegal (1965). (See Fig. 11). 1,000 mels was set at 1,000 Hz. The numbers on the mel scale are related to the physchological effect of the pitches they represent. For example, a pitch of 500 mels is twice as high as a pitch of 1,000 mels. However, the corresponding frequencies do not bear the same numerical relationships (Gulick, 1971).

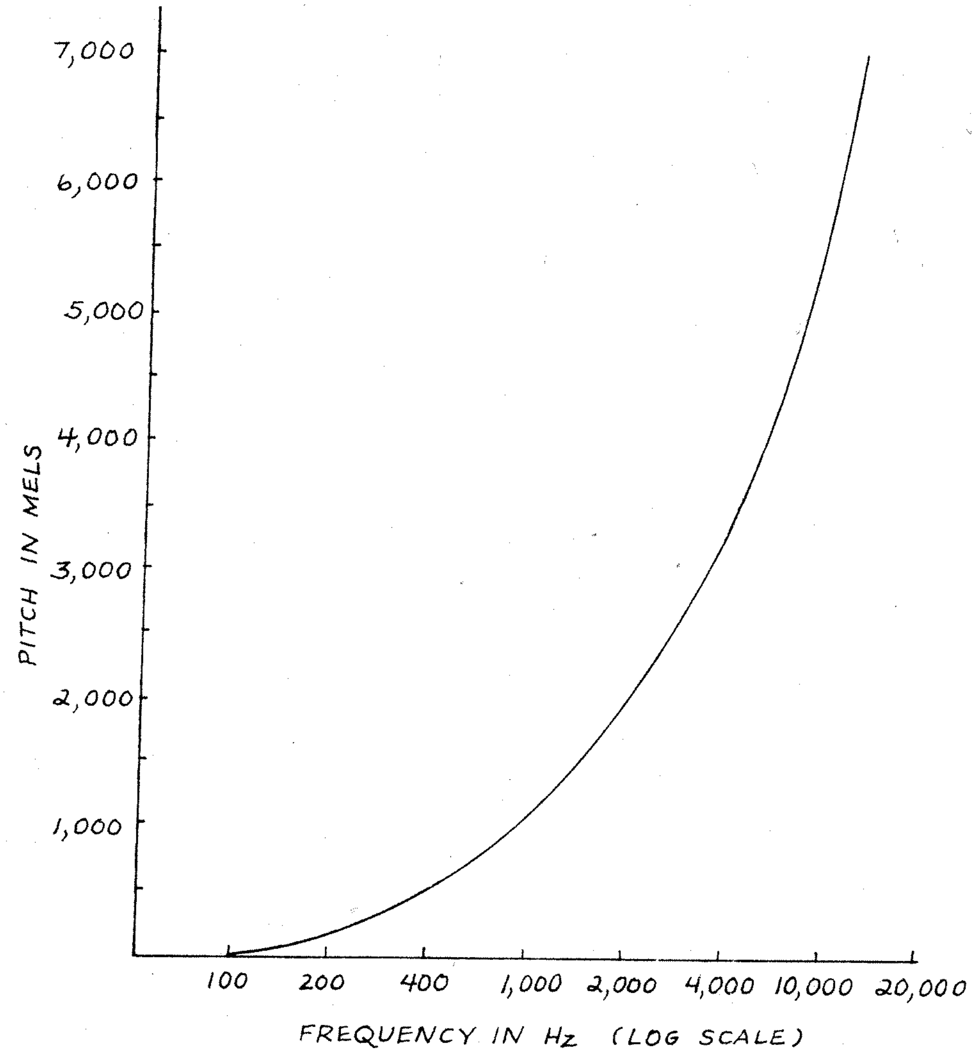

Figure 11.
Mel scale of pitch developed by Siegal (1965). After Murch.

Pitch also varies with fluctuations in intensity, even with frequency held constant. For instance, a tuning fork may change pitch slightly when brought close to the ear, or a band in the football field may sound somewhat off-key to the fans in the stands. Greater intensity decreases the pitch of low-frequency sounds and raises the pitch of high-frequency sounds.

Duration has an effect on pitch such that very short tones will be regarded as clicks with no pitch. A duration of 10 msec above 1,000 Hz or 3 to 6 cycles below 1,000 Hz is necessary in order for the listener to discriminate the pitch reliably.

The translation of the frequency of sound waves into the psychological experience, identified as pitch, has been explained by two prominent theories, the place theory and the frequency theory. The place theory states that there is a separate nerve element that is activated by a certain frequency. Each frequency stimulates the area of the cochlea responsive to it and the nerve carries the message to the brain. The frequency theory holds that the activity of the entire sense organ is necessary to detect pitch. The sound wave coming in stimulates different parts of the cochlea at different times. The signals are sent to the brain where they are sorted out and pitch is determined. The frequency-place theory of Wever (1949) suggests that both frequency and place of sound aid in the interpretation of pitch. This seems to be the most acceptable theory at this time.

There is evidence to show that pitch discrimination improves with age and training (Kidd and Kidd, 1966). A group of "pitch deficient" adults were trained to improve their ability to discriminate pitch through immediate feedback, repetition, labeling of pitch, drill on interval recognition, matching pitches and the use of imagery (e.g. viewing the tones going up a ladder) (Wyatt, 1945). It is reasonable to assume that children will benefit from pitch training during the time their ears are maturing because connections between physical stimulus, perception of pitch, and the label of the pitch will be made at every level of maturation, thereby reinforcing learning.

Absolute pitch is "the ability to perceive and name the pitch of a sounded note without being able to compare it with other previously sounded notes" (Franklin, 1972, p. 27). Relative pitch is the ability to perceive and name a particular pitch in relation to another pitch (singing a G after hearing a C). Few people have absolute pitch and even fewer can learn it. Most people, however, can acquire relative pitch. If trained at an early age, children can develop a strong sense of the relationship between pitches and can sing a melody regardless of the pitch on which it starts.

Pitch training can be a part of any musical activity. Every time a melody is learned children are exercising their ability to recognize and produce pitches. Some pitch training should also be done in isolation from songs so that children gain a conscious understanding of the definition of pitch, the relationships between pitches and the necessity of accurate pitch.

Loudness Perception

Loudness as perceived by the listener does not correspond directly to the physical intensity of the sound. The physical intensity, or amplitude of a sound wave, is measured in decibels (dB). The loudness of a sound (the psychological experience) is measured in sones or phons. At low intensities, a small increase in intensity produces a large increase in loudness compared with high intensities where a large increase in intensity is required to make a noticeable difference in loudness (Fig. 12). If two identical tones are sounded simultaneously, they are not twice as loud as one play alone. Loudness increases only slightly when the second tone is added. Loudness is also affected by frequency. Very high or very low

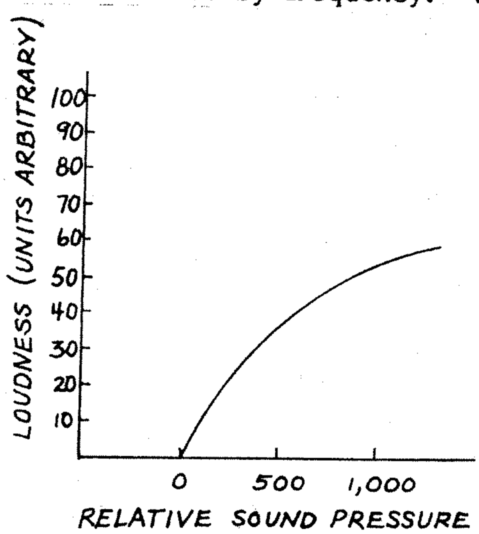

Figure 12.
Perceived loudness vs. sound pressure.
Perceived loudness is not directly proportional to intensity (sound pressure). At high levels of intensity a greaster increase is necessary to perceive a change in loudness than at low levels of intensity. After Gulick.

tones have greater intensity than middle range tones with the same loudness. Figure 13 shows the relationship between frequency and intensity. Each curved line on the graph represents one loudness-level.

The duration of a tone affects the loudness such that tones shorter than 200 msec. must be more intense than tones of 200 msec. duration to maintain constant loudness. However, as the duration of the tone increases beyond 200 msec., auditory fatigue begins to operate and higher intensity is necessary to maintain loudness.

If two tones are sounded, one shortly after the other, the second tone will "mask" the first tone. That is, the first tone will be no longer heard even though it has maintained its intensity level. The phenomenon of auditory masking has implications for teachers who expect children to hear directions in a noisy classroom.

In music, differences in loudness are sometimes called dynamics. Children can learn to recognize when a musical phrase is getting louder and when it is getting softer, and the can learn to vary the loudness of their own voices. For instance, certain tones could receive emphasis, i.e., they might be played or sung much louder than the others. Dynamics and emphasis play an important role in the interpretation of a piece of music; they help to set the mood of the composition.

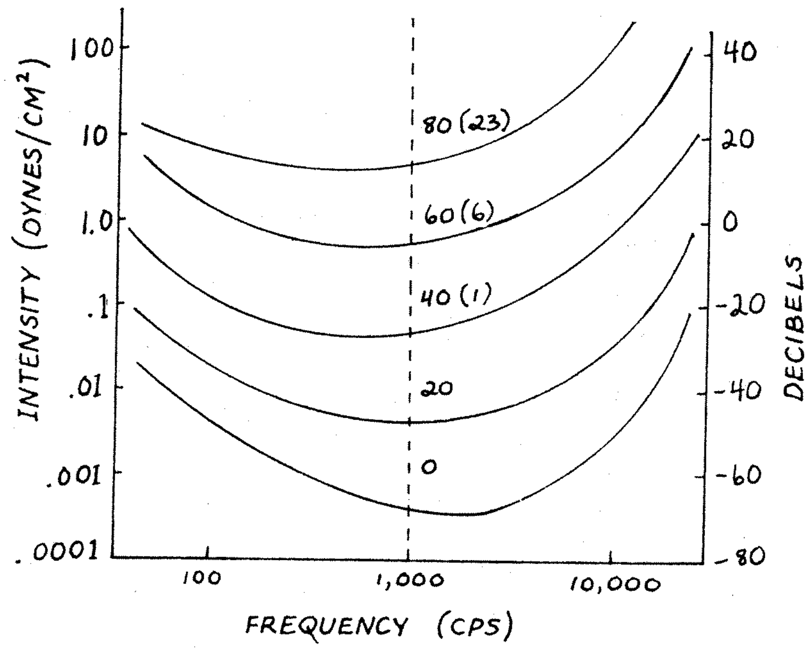

Figure 13.
Equal loudness contours showing the changes in intensity required to maintain a constant loudness for different frequencies. Loudness level is indicated in phons, (sones in parentheses). After Gulick.

Duration Perception

Duration is the length of time that a single tone is sounded. It has been shown that a certain duration is required in order to identify the pitch and loudness of a tone. This is of secondary importance, however, compared to the use of duration in the formation of rhythm. Rhythm is "the organization of the duration of sounds and silences" (Marsh, 1970, p. 66). A rhythmic pattern is a specific combination of long and short sounds and silences, and the placement of emphasis.

Rhythm is an essential aspect of all musical experience. Simple rhythm experiences can be designed for children of all ages. Hand clapping and rhythm instruments can be used to match, to discriminate, and to memorize rhythms. Simple rhythms can be put together in various combinations to produce more complex rhythms. Children can learn to pick out the rythm in familiar songs. Nonsense rhymes, poetry, bird songs, and machines also can be used.

Timbre Perception

Timbre refers to tone quality, the complexity or shape of the sound wave. A pure tone, such as the sound made by a tuning fork, is made up of a single frequency. Most sounds we hear are complex; they are comprised of several frequencies. Two tones played at the same pitch may sound very different depending on the particular frequencies that are emphasized. Timbre depends upon the existence of harmonics in sound. Most vibrating bodies produce more than one sound wave at the same time. The body vibration, as a whole, generates the fundamental tone. Higher frequencies or overtones occur as a result of the vibrations of the body in parts. For example, the string in Figure 14 is vibrating in halves and in quarters. The sound wave of a complex tone is shown in Figure 15. The combination of frequencies particular to each sound gives the sound its different timbre.

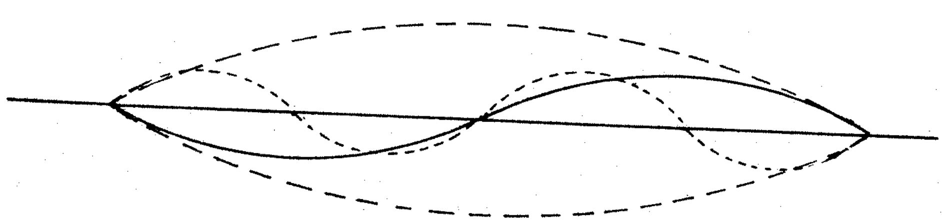

Figure 14.
String vibrating in whole, halves and quarters.
After Murch.

So far, we have been speaking of musical sounds. The sounds in the environment that we call noise are also made up of numerous frequencies, but they are not related to each other harmonically. The complex wave of noise has no repeating pattern.

Children can be given exercises in identifying different sounds in the environment, different musical instruments and different human voices. They can learn to distinguish musical sounds from noise and pure tones from complex tones.

Sound Localization

Sound localization is the ability to detect from what direction and distance a sound is coming. There are two major cues which assist in determining the direction of a sound; both cues depend on the fact that we have two ears. The first is loudness. When a sound is located to the left of the listener, it will be louder for the left ear than for the right ear. Not only is the sound closer to the left ear, but the head casts a shadow which reduces the intensity of the sound to the distant ear. The second is time. The wave front of a sound located to the left of the listener will arrive at the left ear slightly before it arrives at the right ear. In general the loudness is more important for high frequencies, and the time factor for low frequencies. A person who has lost the hearing of one ear will not be able to determine whether a sound is coming from the right or the left.

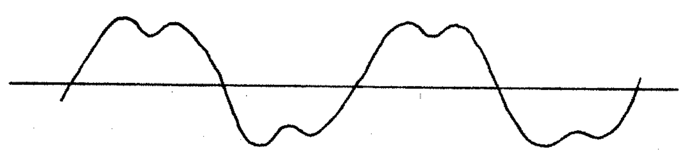

Figure 15.
Sound wave of a complex tone. After Gulick.

Sounds coming from up and down or from back and front are more difficult to locate. Usually the listener simply turns his head so he can use the right and left cues. The auricle provides additional assistance by shadowing sounds that come from behind. It is thought that the auricle also may transform sound by means of echoes which vary depending on the angle at which the wavefront strikes the auricle (Mills, p. 335).

Judging the distance of a sound depends largely upon its perceived intensity. Sounds which are close will appear louder than sounds that are far away. As a sound gets further away (beyond 15 meters) it becomes increasingly difficult to determine how far away it is (Murch, 1973, p. 212). The change in the frequency spectrum of complex tones is also a cue to distance. Complex tones lose their overtones at great distances such that a complex noise pattern may be reduced to a monotone.

Visual cues often are used together with auditory cues to identify the direction and distance of a sound. At first, exercises in sound localization may be given to children with visual cues present. Later, they should have practice locating sound with the eyes closed or blindfolded. When vision is blocked, the children will have to rely more on auditory cues, thus increasing auditory awareness.

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