from *Soundmaking*, by peter Oswald

HOW TO MAKE STATEMENTS ABOUT SOUND

Before we go any further into the analysis of soundmaking, it is necessary to consider the problem of descriptive terminology. Words like pitch, loudness, and rhythm already appeared in the previous chapters. Now these and other terms must be defined. This chapter also introduces an acoustic method for measuring sounds, which is applied for the clinical studies to be reported subsequently.

Sounds are vibratory occurrences which listeners perceive auditorily and integrate into mental patterns based also on information from nonacoustic sources like visual input, memory, fantasy, and feeling states (63). Many of the complex psychophysiologic processes involved take place outside the listener's awareness. That part of the auditory pattern which a listener does notice must be translated into words if it is to be communicated to others. Since this translation itself comprises the complicated chain of phonetic and semantic events outlined in Chapter 2, it is not surprising that statements made about sounds often have little to do with actual acoustical happenings. At best the verbal statements one can make about sounds reveal a small portion of this total acoustic-auditory pattern (128).

To serve practical needs, those persons who study acoustic phenomena and teach soundmaking have devised various terminologies and descriptive schemes for communicating verbally about sounds. Musicians speak of intonation, timbre, and tempo; acousticians talk of noise, decibels, and frequencies; linguists use terms like inflection, stress, and pitch levels; voice therapists describe hoarseness, registers, and melody. This is but a small sample from some of the many different and often confusing terms used to describe sounds (5). Future investigations will have to find out which words from the various disciplines actually refer to identical acoustic phenomena. At the present time all one can do is try to eliminate the redundancy of overlapping terminologies now in use, and distinguish between *qualitative attributes, visualization of sound,* and *acoustic measurement.*

QUALITATIVE ATTRIBUTES OF SOUND

Qualitative attributes are functions of the system *sound-plus-listener.* They derive from the admixture of sensory and interpretive responses listeners display towards the sound in question. Qualitative attributes fall into seven categories, each of which represents a gradient confined by extreme endpoints. The categories are:

1. rhythmicity
2. intensity
3. pitch
4. tone
5. speed
6. shape
7. orderliness

1. *Rhythmicity* refers to those characteristics of sound defined along the gradient

rhythmic ———————— *irregular*

An example of a rhythmic sound is one produced by someone rocking back and forth in a rocking chair; the temporal pattern of this sound is regular and predictably recurrent. At the other extreme is the sound produced when someone leans back slowly in a squeaky swivel chair. This sound has little predictable timing.

Rhythmicity is one of the most basic attributes of sounds living creatures produce. There is evidence for an innate biologic rhythmicity (22) and for spontaneous fetal rhythmicity among mammals enhanced by throbbing of the maternal uterus (80). The regular ticking of a clock or metronome is rhythmic, in contrast to the roaring of an electronic white-noise generator or the sound of a waterfall.

2. *Intensity* refers to the characteristics of sound as defined along the gradient

loud ———————— *soft*

The level at which sound produces pain in addition to auditory sensation (about 120 decibels) is a useful endpoint for loudness. The physiologic threshold of hearing (0 decibels) represents the soft extreme of this gradient (10).

Few sounds of human origin ever reach the pain threshold. Jet-engine noise, artillery blasts, and other high-intensity noises do get this loud, and ear protection is therefore necessary for those in close proximity to the sound source (51). As we shall see in Chapter 4, the peak of a baby's cry also approaches the pain threshold, but only if one measures this sound very close to the infant's mouth. As for extremely soft sounds, there is considerable debate about this, and recent psychoacoustic studies challenge the idea of an absolute physiologic threshold of hearing. Intensity limits of the auditory system seem to vary with age, attentiveness, and the listener's knowledge about a particular stimulus (131). It seems doubtful that absolute silence is attainable. Acoustic vibrations capaple of moving the eardrum only a fraction the diameter of one hydrogen atom suffice to produce some sensation. Also the ear mechanism itself produces a certain amount of noise (Weaver-Bray Effect).

3. *Pitch* refers to the characteristics of sound as defined along the gradient

high-pitched ———————— *low-pitched*

Pitch depends on the frequency of acoustic vibrations reaching the ear. Endpoints for the pitch gradient are difficult to define, since in making pitch judgements, listeners are also influenced by other attributes of the acoustic stimulus than pitch (73). Nevertheless, most textbooks give the audible frequency range of hearing as 20,000 cycles per second for the high end, and 20 cycles per second for the low end. Age is an important consideration here, since children have a greater hearing range than do older people.

The hissing noise of certain consonants (s, ch, z, f, th) can get up to 10,000 cps or to even higher frequencies (see Chapter 5). But musical sensibility on which pitch judgement is based seems to stop around 4,000 cps, approximately the pitch of the highest note on the piano, C=4,186 cps. Very low-pitched sounds are perceived in more than just an auditory sense; they may be felt as rumbling, as vibrations, or environmental turbulence, as for example the extremely low tones of a pipe organ. Pitch perception becomes hazy at these low frequencies; the lowest A of the piano vibrates at 27.5 cps.

4. *Tone* refers to the characteristics of sound as defined along the gradient

tonal ————————— *noisy*

A tonal sound is made up of a single vibratory frequency or contains several vibratory frequencies which are simple multiples of each other. At the opposite extreme is noise (not to be confused with noise in the sense of "unwanted sound"). Noise is composed of numerous vibratory frequencies that overlap and intermingle with one another to produce highly complex wave-forms (11).

At the tonal end of this gradient is the socalled "pure tone"; it represents a sine-wave pattern of uniform acoustic vibration at a single point of the frequency spectrum. For instance, a tuning fork gently set into motion produces a pure tone. The opposite extreme, random wave forms called noise, is exemplified by the output of a white-noise generator. This electronic device produces acoustic vibrations simultaneously along the entire audible frequency spectrum from 20 to 20,000 cps.

5. *Speed* refers to the characteristics of sound as defined along the gradient

fast ————————— *slow*

Our ability to perceive the speed of acoustic stimuli is, as in the case of intensity, pitch, and tone, governed by the physiologic limitations of the hearing apparatus. At fast speeds, successive acoustic impulses merge together, producing the sensation of a steady sound. This happens when the impulse rate begins to exceed twenty sounds per second. At the slow end of the gradient there is a lapse of consciousness after about 0.8 second, so that when impulses fall below the rate of one sound per second the listener needs additional acoustic cues—say a melody or meaningful context—to sustain his attention to the sound (10).

Flutists, clarinetists, and other players of woodwind instruments may approach the fast limits of sound by "triple-tonguing" their instruments; virtuoso violinists and pianists often trill quickly enough to produce a blur of sounds. But in speech where a high degree of comprehensibility is desired, speed is held down to an optimal level of about five morphemes per second, with frequent interruptions of soundmaking to give the listener time to catch on. The resting cardiac pulse, and the lethargic march of a funeral procession exemplify slow forms of soundmaking. Below that rate, it takes a composer of Beethoven's skill to sustain the impression of speed; some of his *largo* movements are played as slowly as forty impulses per minute.

6. *Shape* refers to the characteristics of sound as defined along the gradient

impulsive ———————— *reverberant*

The explosive sound of a pistol shot in an anechoic chamber exemplifies a sound at the impulsive end of the gradient. It begins suddenly, rises rapidly to a peak intensity, and decays quickly to silence. This kind of sound is experienced subjectively as abrupt and crashing. At the reverberant extreme is sound like that of water running continuously into a large empty barrel. This sound starts gradually, builds into a steadily reverberating pattern which maintains a semi-tonal quality depending on the force of the water and the shape of the barrel, and dies out very slowly.

Shape as used here refers to the acoustic elements comprised by the technical term *envelope* (84). It is an attribute related to the onset, growth, steady-state, duration, decay, and termination of an individual sound. A listener's perception of shape depends not only on the wave-form at its point of origin, but also on the distance of the listener from this point and the acoustic properties of the surrounding room.

7. *Orderliness* refers to the characteristics of sound as defined along the gradient

compact ———————— *expanded*

A sound is compact when its single units are approximated into an orderly recognizable pattern. This approximation may be basically rhythmic as in the Morse code, tonal as in the chiming of Big Ben, or simultaneously rhythmic and tonal as in a musical melody. Compactness can also be a function of patterned intensity, as for instance the stress accents in poetry. Certain contemporary music which serially specifies intensity gradations also gains compactness thereby. At the expanded extreme of the gradient, sounds lack rhythm, tone, or intensity organization and are called dissonant, monotonous, or cacophonic.

In contrast to rhythmicity which appears to be a biologically determined auditory experience, orderliness depends greatly on the listener's social adaptation and learn-

[a]	*alms*	[amz]	[i]	*pin*	[pin]	[r]	*rod*	[rɑd]
[ɑ]	*odd*	[ɑd]	[j]	*yes*	[jes]	[s]	*sod*	[sɑd]
[b]	*big*	[big]	[ǰ]	*gem*	[ǰem]	[š]	*shove*	[šov]
[č]	*chin*	[čin]	[k]	*cat*	[kɛt]	[t]	*tin*	[tin]
[d]	*dig*	[dig]	[l]	*lamb*	[lɛm]	[θ]	*thin*	[θin]
[ð]	*then*	[ðen]	[m]	*miss*	[mis]	[u]	*put*	[put]
[e]	*egg*	[eg]	[n]	*knot*	[nɑt]	[v]	*van*	[vɛn]
[ɛ]	*add*	[ɛd]	[ŋ]	*sing*	[siŋ]	[w]	*wag*	[wɛg]
[f]	*fan*	[fɛn]	[o]	*up*	[op]	[z]	*zip*	[zip]
[g]	*give*	[giv]	[ɔ]	*ought*	[ɔt]	[ž]	*rouge*	[ruwž]
[h]	*hand*	[hɛnd]	[p]	*pin*	[pin]			

Fig. 1. A phonetic alphabet of standard English (from p. 91, Bloomfield, L. : *Language*, Henry Holt and Co., New York, 1933 (c) 1961).

ing. For example, before one learns to recognize the orderliness of a foreign language it sounds chaotic and incomprehensible. Also much music criticism represents a prejudice against those acoustic patterns which appear expanded, i. e., sounds whose orderliness escapes the listener.

VISUALIZATION OF SOUNDS

Visualization stands half-way between verbal description and acoustic measurement as a way to make statements about sound. The first successful visualization of human sounds was probably the *phonetic alphabet,* of ancient Egyptian origins. A phonetic alphabet consists of schematized pictures of individual speech sounds, often in terms of their anatomic origins (see Fig. 1). For example, in our alphabet "O" portrays the mouth open and rounded for production of this vowel; the letter "B" portrays the lips compressed as during articulation of this consonant. A phonetic alphabet distorts the flowing nature of soundmaking so as to visualize small informational segments. It artificially stops sound in midstream, as it were, much like a single motionpicture frame, which freezes the continuous character of bodily movement.

The *system of neumes* visualizes sound in a more natural way; added to the phonetic alphabet it shows how the voice is inflected during speech (See Figure 2). Neumes were invented in ancient times to denote vocal embellishment for the chanting of prayers (41): the hand was raised to indicate a rise in pitch, lowered to indicated a fall in pitch, and shaken back and forth to indicate wavering tones. The vigor of these hand movements indicated various degrees of intensity. These hand signals were later translated into written signs and incorporated into texts, for example the Hebrew Bible. Ultimately neumes came into prominence throughout the world; they are found in the Gagaku Plays of Japan, Roman Catholic Hymnals, and Folk Song Books of the Middle East. The diacritical marks in dictionaries, the accentual notation used to mark poetic meter, and some of the signs used in modern microlinguistics are all descendants of the old system of neumes. These visual signs improve the accuracy of our phonetic alphabet.