2.3 SECONDARY CONSONANTAL SOURCE FEATURES

This class includes:

1) two types of features due to the primary source: a) envelope features, and b) the stridency feature,
2) the voicing feature due to a supplementary source.

2.31 Envelope Features

By the temporal envelope of sound intensity we mean the speech power averaged over about 0.02 seconds as a function of time. There are two basic types of envelope: smooth and rough. Phonemes with smooth envelopes have gradual onsets and decays and no abrupt changes in their temporal course. Phonemes with rough envelopes have abrupt variations of power in their temporal course. The latter can be subdivided into two groups depending upon whether or not there is sound after the abrupt variation in power.

Phonemes with smooth onsets are called continuants. They are opposed to interrupted (more exactly, discontinuous) phonemes, which have an abrupt onset. According to their decays, phonemes are divided into checked (with abrupt decays) and unchecked (with gradual decays.)

2.311 Interrupted vs. Continuant

2.3111 Stimulus. The abrupt onset distinguishes the interrupted consonants (stops) from the continuant consonants (constrictives). The onset of constrictives is gradual. The main characteristic of stops, on the contrary, is a sharp wave front preceded by a period of complete silence, for which, under certain conditions, a mere vibration of the vocal bands may be substituted. The spectrograms show here a sharp vertical line preceded either by a period of silence or a "voice bar" (1).

In English the abrupt onset of /p/ as in pill or of /b/ in bill is opposed to the smooth onset of /f/ as in fill or /v/ in vill. Similarly, /t/ as in till is opposed to /θ/ in thill and to /s/ in sill.

In the liquids it is not primarily the onset and decline that serve a distinctive purpose, but rather the interruption of the sound course. The continuant l-sound is opposed to the interrupted r-sound. There are two varieties of the latter: the flap with a single interruption and the trill with recurrent interruptions, which is much more common. Measurements of Czech trills show normally from two to three taps in the sound; in final position this may be reduced to a single tap, while the initial trill in emphasis has 4 to 5 taps. The rate of the taps is approximately 25 per second. There are languages, e.g. Mongolian, which have a considerably more rolled /r/ with a higher number of interruptions. Examples of the interruption feature in Czech liquids: /kora:l/ "coral" - /kola:r/ "Roman collar".

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As for the so-called "continuant r", it is actually a non-syllabic vowel. For example, the English "Received Pronunciation," possesses a vowel phoneme, which is opposed as diffuse to /a/, as grave to /i/ and as unrounded (plain) to the rounded (flat) /u/. This phoneme is split on the prosodic level into an unstressed /ə/and a stressed /'ə/. The former loses its syllabicity in the neighborhood of another vowel phoneme (bear /b'eə/) and becomes still "closer" when followed by a vowel (red /ə̯'ed/). The stressed phoneme /'ə/ is represented by a more advanced and close variant before an unstressed /ə/ (bird /b'əəd/) and by a more retracted and open variant[ʌ]in other positions (bud / b'ə d/).

2.3112 Production. The stops have complete closure followed by opening. The constrictives have incomplete closure; but the narrowing considerably reduces the contribution of the cavities behind the point of articulation (3). The continuant liquids, i.e. laterals like /l/, combine a median closure with a side opening, whereas in the interrupted liquids like /r/, complete or partial cut-off of the air stream is effected by one or more taps of the apex of the tongue, or of the uvula.

2.3113 Perception. Experiments conducted by L. G. Jones at Northeastern University have demonstrated that when the onset of a constrictive like [s] or [f] is erased from a recording, the sound perceived is a stop: [ŝ] or [t] for the [s]; [f̂] or [p] for the [f]. (On the distribution of these two alternative perceptions see Sec. 2.323).

2.3114 Occurrence. The opposition of interrupted (stops) and continuant consonants (constrictives) is found in most languages. As a rule, the number of constrictives in a language is lower than that of the stops and occasionally the class of constrictives contains but a single phoneme, usually /s/. In languages in which the opposition of constrictives and stops is not autonomous, it is either a concomitant of the opposition strident vs. mellow (see below 2.324), or, all the consonants are stops in contradistinction to the vowels. The latter is the case in some languages of Oceania and Africa.

In a great number of languages, for example in nearly all languages of the Far East, liquids are not divided into interrupted and continuant phonemes. The liquid phoneme in these languages may be represented either by [l] as in Chinese, or by [r] as in Japanese, or by a complementary distribution of two contextual variants - [r] and [l] pertaining to one single liquid phoneme as in Korean. In Korean the liquid phoneme in prevocalic position is [r]; elsewhere it is [l]. For this reason the Korean alphabet has only one letter for the two sounds, in [maru] "floor" and [pal] "foot", for instance. By a Korean the Czech words /karar/, /volal/, /oral/ and /dolar/ are all perceived and reproduced as terminating in [-ral].

2.3115 Double Stops. The peculiar consonants with a double closure, which are widespread in languages of South Africa, are but special forms of conso-

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nant clusters. They are extreme cases of co-articulation, which is widely used in language for building up phonemic sequences (5). In the production of such consonants, the two closures attain their release in immediate succession. Nevertheless, they are perceived as clusters since the two releases are not simultaneous despite the considerable contraction of the sequence, and since other types of clusters do not occur in these languages (or at least not in the same positions). In the South African clicks that are produced by a sucking in of air, the more frontal closure, e.g. dental or palatal, is released first and then the velar, as can be seen in the spectrograms (Fig. 2). The opposite order is shown in the African labio-velar stops spelled kp, gb. Since they are produced by expiration, the velar closure is released before the labial (6).

2.312 Checked vs. Unchecked

2.3121 Stimulus. An abrupt decay is the opposite of a smooth one. In spectrograms, checked phonemes are marked by a sharper termination, but this is ordinarily less prominent than an abrupt onset.

2.3122 Production. The air stream is checked by the compression or closure of the glottis.

2.3123 Occurrence. Certain varieties of checked stops, called glottalized, are found in many native languages of America, Africa, the Far East and the Caucasus; e.g. the spectrograms of the Navaho and Circassian glotallized stops (for the latter see Fig. 1) disclose a striking similarity of structure.

Examples: checked vs. unchecked stops: Circassian /t'a/ "dig!" - /ta/ "we"; /c'a/ "name" - /ca/ "tooth"; /p'a/ "place" - /pa/ "be out of breath!". Less clear and most uncommon is the glottalization of constrictives (7) observed in Tlingit (Northwestern America) and Kabardian (N. Caucasus).

In languages that have an opposition of checked and unchecked stops, the checked glide (called "glottal catch") is related to the unchecked (even or gradual) glide as a glottalized consonant is to the corresponding non-glottalized.

2.32 Strident vs. Mellow

2.321 Stimulus. Sounds that have irregular waveforms are called strident. In the spectrogram such sounds are represented by a random distribution of black areas. They are opposed to sounds with more regular waveforms. The latter are called mellow and have spectrograms in which the black areas may form horizontal or vertical striations. The proper measure for this property is an auto-correlation function. Mellow sounds have a wider auto-correlation than the corresponding strident, ceteris paribus, i.e. if the sounds in question have been properly normalized.

In the case of constrictives, mellowness is a consequence of a limitation upon the randomness in the energy vs. frequency distribution. While there are no

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clear formant regions observable in the spectrum of the strident /s/, we can easily discern them in the mellow /θ/ (see Fig. 3). The oscillograms show a distinctly higher periodicity and uniformity in mellow constrictives such as /θ/ in comparison with /s/ and other strident constrictives.

In the case of stops, mellowness is achieved by a limitation upon the randomness of the phase. Cf. the pertinent remark of Licklider:

> "..... the various frequency components of the white noise are assigned their phase angles at random; the frequency components of the single pulse all reach their maximum amplitudes at the time t = O, and they cancel one another at all other times. As a result, we hear the white noise as sshhhh and the single pulse as pt." (8)

Examples. Strident vs. mellow constrictives: English sin - thin /θ'in/, breeze /br'iiz/ - breathe /br'iið/; Ewe (West Africa) /fu/ "feather" - /ɸu/ "bone", /vu/ "tear" - /βu/ "boat"; Low Sorbian /ʃiç/ "to sew" - /çiʃ/ "calm", Circassian /χy/ "sea" - /xy/ "net". Strident and mellow stops: German Zahl, /ŝa:l/ "number" - Tal, /ta:l/ "valley" - Pfanne, /p̂anə/ "pan" - Panne, /panə/ "breakdown", Czech čelo /ʧelo/ "brow" - tělo, /celo/ "body"; Chuckchee (in Northeastern Siberia) /q̂ale/ "cap" - /kale/ "drawing".

The strident stop is called affricate. The sequence of stop plus constrictive is distinguished from an affricate by an intervening intensity minimum, which can be observed on a display of the speech wave as a function of time. Cf. Polish czy /ʧi/ "or" - trzy /tʃi/ "three"; czech /ʧex/ "Czech" - trzech /tʃex/ "of three" (31).

2.322 Production. Strident phonemes are primarily characterized by a noise which is due to turbulence at the point of articulation. This strong turbulence, in its turn, is a consequence of a more complex impediment which distinguishes the strident from the corresponding mellow consonants: the labiodentals from the bilabials, the hissing and hushing sibilants from the non-sibilant dentals and palatals respectively, and the uvulars from the velars proper. A supplementary barrier that offers greater resistance to the air stream is necessary in the case of the stridents. Thus beside the lips, which constitute the sole impediment employed in the production of the bi-labials, the labiodentals involve also the teeth. In addition to the obstacles utilized in the corresponding mellow consonants, the sibilants employ the lower teeth (see Fig. 3) and the uvulars, the uvula. The rush of air against such a supplementary barrier following the release of the strident stops yields the characteristic fricative effect that distinguishes these from other stops.

2.323 Perception. Experiments of L. G. Jones in which the onset of recorded constrictives (like [s]) was erased showed that as long as the sound interval remained over 25 to 30 millisec., the consonant was identified by listeners as an affricate (like [ŝ]) while a shorter sound interval was identified as a mellow stop (like [t]).

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2.324 Occurrence. The maximum, hence optimal, distinction of consonants from vowels may be achieved either by the greatest muffling of sound or by the closest approximation to noise. High degree of muffling is found in the mellow stops, while noise is best approximated by the strident constrictives. Thus the optimal constrictive is strident, while the optimal stop is mellow, and in numerous languages the opposition constrictive vs. stop merges with the opposition strident vs. mellow. For instance, in French all constrictives are strident /f v s z ʃ ʒ/ and all stops mellow /p b t d k g/.

In some of these languages the opposition strident vs. mellow alone is relevant and constant; the difference of constrictives and stops becomes a redundant feature which, under certain conditions, can fail to materialize. This happens in Portuguese, where the intervocalic [d b g] become mellow constrictives [ð β ɣ] so that they are opposed to /z v ʒ/ not by the stop feature but only by their mellowness. In other languages with a fusion of both oppositions, the stridency feature may become redundant, if some of the stop phonemes, at least under certain conditions, are represented by affricates.

In addition to strident constrictives and mellow stops, many languages possess such classes of phonemes as strident stops (affricates) and/or mellow constrictives. For example, German and Czech have beside /s/ and /t/ the corresponding affricate /ŝ/, cf. German reissen "to tear", reiten "to ride", reizen "to tease". Moreover, beside /f/ and /p/ German includes /f̂/; and Czech has /ʃ̂/ beside the strident constrictive /ʃ/ and the mellow stop /c/. On the other hand, beside /s z/ and /t d/ English possesses the mellow constrictives /θ ð/, both spelled th:

When, beside strident constrictives and mellow stops, a language possesses either corresponding strident stops as German or mellow constrictives as Arabic, this state may be interpreted in terms of one single opposition: optimal constrictive vs. optimal stop. Should we symbolize the former by a "plus" and the latter, correspondingly, by a "minus", such a complex unit as a strident stop or mellow constrictive would be "±". The same device is applicable also in the case when, as in English, one pair of optimal constrictive and optimal stop (e.g. /s/ - /t/) is supplemented by a mellow constrictive (/θ/) and another pair (/ʃ/ - /k/) by a strident stop (/ʃ̂/): both of these complex units could be designated by the same symbol ±. In the relatively few languages with all four members in one series, e.g. those North Caucasian languages which have the strident constrictive /χ/, the mellow stop /k/, the mellow constrictive /x/ and the strident stop /χ̂/, we must operate with two autonomous oppositions - constrictive vs. stop and strident vs. mellow. Furthermore, insofar as it is preferable to deal with simple two-choice situations and to exclude complexes, the two oppositions might be treated separately in the case of ternary series as well, e.g. in English.

In addition to consonants proper, liquids may participate in the opposition strident vs. mellow. A few languages, e.g. Czech, have a strident counterpart of the phoneme /r/. This sibilant variety of trill is spelled r̆ : cf. r̆ada "row",

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rada "council". Some American Indian, African and Caucasian languages contain strident counterparts of the /l/ phoneme - lateral affricates and/or constrictives (9). Despite the high damping of their formants all these phonemes retain manifest acoustic traces of their relation to liquids. They are liquids with superposed stridency (cf. below 2.441).

2.33 Supplementary Source: Voiced vs. Voiceless

2.331 Stimulus. The voiced or "buzz" phonemes as /d b z v/ vs. the voiceless or "hiss" phonemes are characterized by the superposition of a harmonic sound source upon the noise source of the latter (10). For the voiced consonants this means a joint presence of two sound sources. The spectrum of voiced consonants includes formants which are due to the harmonic source. The most striking manifestation of "voicing" is the appearance of a strong low component which is represented by the voice bar along the base line of the spectrogram (11).

2.332 Production. Voiced phonemes are emitted with concomitant periodic vibrations of the vocal bands and voiceless phonemes without such vibrations.

2.333 Occurrence. The use of the distinctive consonantal opposition voiced vs. voiceless is widespread in the world; e.g., in Europe it is found in all Slavic languages as well as in Hungarian: cf. Russian /don/ "Don" - /ton/ "tone". The extension of this feature to liquids is extremely rare; e.g. in Gaelic voiced /r l/ and the corresponding voiceless /r̬ l̬/ may occur in the same positions. (On the nasal consonants see 2.443).

Vowels are normally voiced. It is still questionable whether there are languages in which parallel to the consonantal opposition voiced vs. voiceless, there actually is a similar distinctive opposition of voiced and murmured vowels, as reported about a few American Indian languages, e.g., Comanche. Either the vocal murmur is not a distinctive feature and functions merely as a border mark, or it may be a concomitant of the tense-lax opposition (Fig. 12).

In languages lacking an autonomous opposition of voiced and voiceless consonants, the latter is either used as a mere concomitant of the opposition of lax and tense consonants, as in English (cf. 2.434), or oral consonants are normally voiceless, as in Finnish dialects. Here the difference between "hiss" and "buzz" acts as a concomitant factor of the consonant-vowel opposition. In some of these languages an automatic voicing of consonants takes place in certain phonemic contexts.

2.4 RESONANCE FEATURES

This class includes:

1) three types of features generated in the basic resonator: a) the compactness feature, b) three tonality features, c) the tenseness feature,
2) the nasalization feature due to a supplementary resonator.

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