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Jan Gauffin

On January 16, 2008, Jan Gauffin passed away after a long battle with cancer.

In the 1960s, after getting his degree in electrical engineering, Jan became a member of the research team directed by Gunnar Fant at the Speech Transmission Laboratory of the Royal Institute of Technology (KTH), Stockholm. There he played a key role applying his engineering skills to provide solutions to various instrumentation needs. He constructed a number of special devices for making aerodynamic, acoustic and psychoacoustic measurements of voice and speech.

Among his first projects was building an inverse filter to be used for extracting the glottal component from speech waveforms. The finished product was an unwieldy ana-



logue device in a 6-foot rack with control knobs for manually adjusting the frequencies and bandwidths of five formants. The analyses required an FM recording of a vowel, a tape loop with a pulse on one channel and the vowel sample on the other. The pulse triggered an oscilloscope, which displayed the inverse filtered waveform once per revolution of the tape loop.

Jan's inverse filtering work paved the way for the long and fruitful collaboration between the KTH speech group and the Department of Logopedics and Phoniatrics at the Karolinska University Hospital, Huddinge. The aim of this interaction was developing clinical applications of acoustic methods in the study of normal and pathological voice function. During the 70s and 80s Jan worked with ENT doctors and logopedists at Huddinge on the clinical application of acoustic voice analysis developing an integrated set of tools that would perform computerized inverse filtering and measure F_0

perturbation, noise components, fundamental frequency distribution as well as the overall slope and level of the fundamental in long-term average spectra. These techniques laid a foundation for quantitative assessments of voice function and gave Jan a key role in the supervision of several doctoral dissertations in both logopedics [Hammarberg, 1986] and phoniatrics [Hertegård, 1994].

Jan was strongly committed to finding practical applications of his research. For instance to facilitate speech training for hard-of-hearing children he constructed pronunciation aids, such as the 's-indicator' and the 'nasal indicator', simple, yet highly effective devices that provide real-time visual feedback to children whose speech is strongly nasalized, or who have trouble pronouncing voiceless fricative consonants (http://www.specialinstrument.se/horselhjapm.htm).

Alongside his attempts to apply speech research to practical needs Jan also pursued questions of a more fundamental nature. One area that he acquired significant knowledge about was the neuromechanics of hearing. No doubt his awareness of 'phase-locking' in physiological systems was at the back of his mind when he decided to make use of speech-wave zero-crossings in his design of the 's-indicator'. Another example is his work on the laryngeal mechanisms in speech, most of which he published in his doctoral dissertation [Gauffin, 1972]. This research appears of particular interest to phoneticians, so we will summarize it here in some detail.

While working on the extraction of glottal waveforms by means of inverse filtering Jan is likely to have mulled over the processes underlying speech phonation. He must have asked himself a lot of questions about how these processes had come about and had been 'engineered': 'How does the source mechanism do what it does in speech?' As we shall see below, as a result of his collaboration with Osamu Fujimura, he got an opportunity to pursue such questions further.

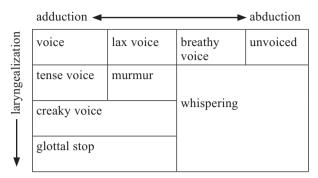
As a guest researcher at KTH, Fujimura worked with Jan to develop a new approach to measuring the transfer characteristics of the vocal tract. Their method used an external sweep-tone excitation applied by putting a vibrator on the subject's pharyngeal sidewall. The contribution of the transmission characteristics through the vocal tract tissues was taken into account and automatically corrected for by means of a device invented and built by Jan. This allowed direct measurement of formant frequencies and bandwidths during silent vowel articulation. This collaboration resulted in a now classic *JASA* article [Fujimura and Lindqvist, 1971] and marked the beginning of a long and close friendship between the two researchers.

Jan continued his collaboration with Fujimura during a subsequent visit to the Research Institute of Logopedics and Phoniatrics at the University of Tokyo. Interacting with Fujimura, Sawashima and Hirose, Jan returned to his interest in laryngeal mechanisms. He used his stay to make films of the vocal folds using fiber optics and began collecting data that he would later include in his dissertation.

What he saw in the laryngoscopic images surprised him given how the phonation types of the world's languages were then described in phonetics. Ladefoged [1967] views them as glottal states differing in terms of abduction vs. adduction along a one-dimensional continuum: glottal stop \rightarrow creak \rightarrow creaky voice \rightarrow tense \rightarrow lax voice \rightarrow murmur \rightarrow breathy \rightarrow voiceless.

Jan found Ladefoged's [1967] proposal too simple. To him the most striking thing about the laryngoscopic images was that there was more going on than merely adjustments of vocal folds along a single adduction-abduction continuum. He realized that laryngeal behavior in speech involves anatomical structures not only at

Table 1. Jan Gauffin's two-dimensional model for classifying phonation types [Gauffin, 1972]



the glottal level but also above it. He was stimulated to dig more deeply into the literature.

He discovered Negus [1949, 1957] and other works on evolution and comparative anatomy [Pressman, 1954]. Important biological functions of the larynx, he learned, are protective closure, respiration and phonation. He became convinced that the protective closure mechanism – the aryepiglottic sphincter (AES) – is also used in speech and concluded that 'the traditional view of the function of the larynx in speech' needed modification [Lindqvist, 1969, 1972; Gauffin, 1977; see references for note on name change]. He claimed that in speech the larynx can be constricted in two ways: at the vocal folds and at the aryepiglottic folds and that the two levels 'are independent at a motor command level and that different combinations of them may be used as phonatory types of laryngeal articulations in different languages' [Lindqvist, 1972].

Table 1 summarizes Jan's proposal for revising the classification of phonation types. The dimension of 'laryngealization' recruits the complex of muscles of the AES. Activating this 'purse-string' mechanism constricts the top of the larynx tube. It narrows the inlet of the larynx. Jan noted that it also reduces the distance between arytenoids and the tubercle of the epiglottis thereby making the vocal folds shorter and thicker. This process when combined with adducted vocal folds should result in lower and irregular glottal vibrations, in other words, in lower pitch and creaky voice. Consequently Jan argued that glottal stop \rightarrow creaky voice \rightarrow F₀ lowering form a continuum. In drawing attention to the AES mechanism and suggesting that it is recruited both in phonation and articulation, Jan contributed two new hypotheses:

(i) The AES plays a significant role shaping both phonation and articulations in the world's languages. For instance, this mechanism is involved in the production of creaky voice. Its mechanical properties suggest an explanation why creaky voice occurs with lower F₀.

The activation of AES shortens and thickens the vocal folds. Along with this activity there is contraction of the vocalis muscle adding glottal adduction to the protective closure. In Jan's conception, creaky voice would thus result from the vocal folds being pressed together more and more so as to change the open quotient and make the vibration irregular and eventually stop it completely.

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Is there empirical support for this suggestion? Yes, for instance there is evidence for this interpretation in studies showing that creaky voice tends to be associated with lower fundamental frequency values than modal voice [Monsen and Engebretson, 1977] and that, in many languages, it often occurs in connection with the falling F₀ contours at the end of utterances [Redi and Shattuck-Hufnagel, 2001].

(ii) Since its original function is to protect, the AES is fast. This fact made Jan hypothesize that it may therefore provide the F₀ lowering mechanism underlying rapidly falling F₀ contours.

Using laryngoscopic data on Swedish word accents Jan proposed that 'laryngealization in combination with low vocalis activity' [vocalis contraction tends to increase F₀] 'is used as a mechanism for producing a low pitch voice' and that 'this is the normal gesture for producing low pitch and accordingly a part of the pitch control mechanism.' The reader might object: What about the role of vertical larynx position in F_0 control? Jan was aware that such a relationship had been proposed and had done an investigation of the topic [Lindqvist et al., 1973]. He found no correlation between larynx height and F₀ in continuous speech, but for sustained phonation a clear relationship was obtained. This conclusion is compatible with the more recent MRI findings of Honda et al. [1999] on sustained vowel production.

The world's sound patterns lend some indirect support to Jan's description of F₀ lowering. We know for instance that there is a close link between creaky voice and tonal phenomena. Examples are found in Swedish and Norwegian dialects with the falling tones of their word accents and in the Danish use of 'stød' [Riad, 2006]. The phonetic realization of the Danish stød varies from a weaker or stronger degree of creak to a full-blown glottal stop. In keeping with Jan's predictions the stød has been reported to be preceded by significant F₀ lowering [Fischer-Jørgensen, 1989].

In Jan's reports quantitative experimental findings supporting his theory are quite limited. The evidence published in the Speech Transmission Laboratory QPSR reports (http://www.speech.kth.se/publications/) is presented mostly as a verbal commentary on his laryngoscopic observations. He never got around to writing up his work on laryngeal mechanisms in the form of refereed journal articles. As time went by he found himself devoting more and more time to managing Specialinstrument, the company he had founded.

It is therefore not surprising that his work on laryngeal mechanisms has had a limited impact in phonetics. In 2001 Gordon and Ladefoged published an update on classifying the world's phonation types. The authors did not consider the possibilities suggested by Jan. Their overview retains the one-dimensional model of Ladefoged [1967].

However, the empirical validity of Jan's laryngoscopic observations has more recently been strengthened by the findings of John Esling and his colleagues [Esling, 1996; Esling and Harris, 2005; Moisik, 2008] which strongly support Jan's claim that the AES system for protective closure is reused in articulation and phonation to an extent that is not yet acknowledged in current standard phonetic frameworks.

While the evidence for Jan's account of laryngeal mechanisms is still incomplete, it certainly appears sufficient to encourage further exploration of his hypotheses. His quest took him onto domains that are not normally in the central focus of an electrical engineer, such as the evolution and comparative anatomy of man's vocal structures, which helped him to make observations and gain new insights.

When the full spectrum of Jan's contributions is considered we find that he was much respected and appreciated among researchers around the world. In 1995, the Voice Foundation awarded him the prestigious Quintana Award in recognition of his use of technology engineering principles to promote a better understanding of the human voice.

In the fall of 2008 the Jan Gauffin Memorial Symposium was arranged in his honor. A special issue of the journal of *Logopedics Phoniatrics Vocology* contains articles based on the papers presented on this occasion on a range of Jan's favorite topics: voice source analysis, laryngeal function, language learning and speech training, to name a few [Sundberg et al., 2009].

Jan Gauffin was a lively, cheerful and deeply original person. A fun-to-be-with colleague and friend whose witty comments and sense of situation comedy could break the ice at even the most formal gatherings. His warmth, his sharp intellect and wild associations never failed to enrich the everyday lives of his friends. His interests were broad. He had a strong interest in music and vocal art. In the 1970s, he designed one of the world's best singing machines, the KTH Music and Singing Synthesis Equipment, MUSSE. He was also an ardent collector, a passion that he indulged in with happy devotion and much humor. The objects of his interest would vary over the years, starting with clocks, then turning to square pianos, with which he generously decorated his house, and finally vintage cars. As an engineer not only limited to a mastery of computer technology, Jan passionately collected all these items, but he also took pleasure in being a tinkerer, and restoring and repairing them.

We his friends and colleagues deeply mourn losing him and feel a deep gratitude for the privilege of having known him.

Björn Lindblom, Stockholm, Sweden Johan Sundberg, Stockholm, Sweden

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Jan Lindqvist changed his name to Jan Gauffin in mid career. He published under both names. We here refer to his papers either as Gauffin [...] or Lindqvist [...] depending on his own choice as author of the publication. See http://www.speech.kth.se/publications/

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