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Linguistic prominence and loudness: a systematic comparison between lexical word stress, sentence accent and vocal effort

In Germanic languages, linguistic prominence is associated with an increase in duration, fundamental frequency, articulatory precision and intensity. Different types of prominence, such as word stress and sentence accent, differ with respect to the contribution of individual parameters to the production of prominence: whereas intensity or vocal effort has been shown to be more closely associated with word stress, sentence accent is signaled by rapid f0 changes (see e.g. Sluijter & van Heuven 1996) because of the association with a pitch-accent and, if the accented word is near the end of the prosodic phrase, due to the influence of boundary tones. Both prominence types can be seen as a local enhancement of syllables or words relative to their contexts produced by different means. However, a largely unresolved issue is whether word and sentence stress changes are controlled physiologically by the same types of mechanisms. A preliminary study by Mooshammer (2004) suggests that both greater word and sentence stress are accompanied by greater vocal effort and an increase in subglottal pressure. On the other hand, it is suggested by Marasek (1997) that greater subglottal pressure and an increase in vocal effort underlie only word stress whereas sentence accent is primarily controlled by vocal fold tension.
In order to explore this issue further, we analysed changes to word stress, sentence stress and changes due to increased vocal effort (by asking a subject to vary loudness) using laryngographic techniques. We reasoned that if word stress changes can be attributed to changes of vocal effort, then we should see a similar pattern of laryngographic change in both word stress and raised loudness which is different from the types of laryngographic change that accompany sentence accent. As far as supralaryngeal changes are concerned, we made the following predictions. If word stress and loudness pattern together and are both associated with a sonority expansion strategy, we should expect to see an increase in the first formant frequency as the acoustic correlate of a greater vocal tract opening in both cases.

The test words that we examined were two-syllable words in German that in traditional terms varied in whether or not there was primary lexical stress on the first syllable. These included words like ‘Lena’ with primary lexical stress on the first syllable /le:/ (henceforth +S) and ‘Lenor’ with primary lexical stress on the second syllable and hence a lexically unstressed, but full vowel /le:/ on the first syllable (henceforth –S). Words with this type of lexical-stress contrast were embedded in sentences which elicited either an accented production in a focused context (+F) associated with providing ‘new’ information; and they were also embedded in sentenced in which the word was unaccented because the information was given (-F). As a result, we had four possible lexical-stress x accent combinations: (+S, +F), (-S, +F), (-S, +F), (-S, -F) which were produced in a comfortable vocal effort level. A further condition was that all the (+S, +F) combinations were produced by the speakers in either a loud or soft voice. These 6 (lexical stress x accent in normal loudness + soft and loud levels) possible combinations were repeated nine times in randomized order. Acoustic and laryngographic signals were obtained from 4 male non-smoking subjects between 20 and 30, speaking a northern variety of Standard German.
Various parameters were derived including the formants frequencies, the fundamental frequency, RMS energy, and the first derivative of the EGG signal. The following additional parameters based on the laryngographic signal were extracted for all pitch periods during the vowel /e/: Open Quotient (OQ, computed by using a threshold criterion), Speed Quotient (SQ), slopes of glottal closing and opening (for details see Mooshammer 2004). Following Marasek (1997), we inferred subglottal pressure increase from a decrease of both the Open

Quotient (OQ) and Speed Quotient (SQ) and an increase of the opening and closing slopes. For an actively controlled pitch, Marasek (1997) predicts an increase in OQ and SQ but no changes of the slopes.

The following results were obtained:

(1) **Vowel quality:** The change from normal to loud speech resulted in an increase in F1 for all speakers, while a change from normal to soft speech produced a decrease in F1 for three speakers. The frequency of the second formant varied rather inconsistently for speakers and consonantal contexts. Word stress affected the first formant frequency only for three speakers with higher frequencies for unstressed vowels which is contrary to the predictions made above. A highly consistent effect was found for the second formant: unstressed vowels were always produced with a lower F2 independently of the focus condition and the consonantal context. Accentuation did not affect vowel quality in a consistent manner.

This result suggests that sonority expansion is not the motivation for supralaryngeal changes of vowel quality due to word stress. Instead increasing F2 frequencies of stressed front vowels gives evidence for hyperarticulation (see Lindblom 1990).

(2) **Durations:** Vowel durations were in the same direction for global vocal effort and word stress with longer vowels for loud speech and (+S), but no consistent changes for sentence accent. The initial consonant was lengthened only due to word stress but did not change for sentence accent and global vocal effort.

(3) **Voice source parameter:** Speaking louder consistently increased fundamental frequency, intensity and the opening and closing slope of the glottal pulses. The Open Quotient consistently decreased as predicted but the Speed Quotient varied less predictably. Contrary to these results word stress showed frequently smaller opening and closing slopes of the glottal pulse for stressed vowels in both accent conditions, although the energy was significantly higher in stressed vowels. Preliminary results suggest that accentuation is not simply a result of higher vocal fold tension since accentuated stressed and unstressed vowels often showed higher intensities and steeper slopes of the glottal pulse compared to deaccentuated vowels.

Even so more refined acoustical analyses and articulatory data are needed, we are tempted to conclude that lexically stressed syllables are not produced by an increase in subglottal pressure and that the higher intensity of stressed vowels is a consequence of laryngeal and supralaryngeal adjustments.

References

Lindblom, B. 1990. Explaining phonetic variation: a sketch of the H&H theory. In W.J. Hardcastle, A. Marchal, eds, *Speech production and speech modelling*, Kluwer, Dordrecht, 403-439.

Marasek, K. 1997. Electroglottographic description of voice quality. *Arbeitspapiere des Instituts für maschinelle Sprachverarbeitung*, Stuttgart, 3(2).

Mooshammer, C. 2004. An EGG study on global and local vocal effort changes in German: preliminary results. *Proceeding of the International Conference on Voice Physiology and Biomechanics*, Marseille.

Sluijter, A. & van Heuven, V. 1996. Spectral balance as an acoustic correlate of linguistic stress. *Journal of the Acoustical Society of America*, 100, 2471-2485.