A Review of Timing Factors in Speech

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ABSTRACT

Timing in speech is determined by many factors. In this paper, we introduce and discuss some factors that have generally been regarded as important in speech timing. They include stress, syllable structure, consonant insertion or deletion, tempo, lengthening at clause, phrase and word boundaries, preconsonantal vowel shortening, and compensation between segments or within phonological units (e.g., word, foot), compression due to the increase of syllables in word or foot level, etc. and each of them may play a crucial role in the structuring of speech timing in a language. But some of these timing factors must interact with each other rather than be independent and the effects of each factor on speech timing will vary from language to language. On the other hand, there could well be many other factors unknown so far. Finding out and investigating new timing factors and reinterpreting the already-known timing factors should enhance our understanding of timing structures in a given language or languages.

Keywords : speech, timing factors, timing structures

1. Introduction

As is well known, the conventional theories of speech rhythm (timing) were based on the assumption of isochrony between stresses (stress-timed) and between syllables (syllable-timed) or moras (mora-timed). But many observers of speech rhythm (timing) have not been able to find out physical evidence for isochrony and have agreed with the idea that rhythm (timing) of speech does not stem from the isochrony between stresses or between syllables/moras, but from the phonological and phonetic characteristics concerning timing in a given language. Hence they have suggested a variety of timing factors in speech. The possible factors that can influence speech timing include stress (stress induced syllable lengthening, unstressed syllable reduction), syllable structure, consonant insertion for maintaining CV syllabic structures, tempo, lengthening at clause, phrase and word boundaries, preconsonantal vowel shortening, and compensation between segments or within phonological units (e.g., word, foot), compression due to the increase

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of syllables at word or foot level, etc. Of course, some of them are closely related to each other and are not independent. In this study, we will discuss some factors that have generally been regarded as important in speech timing. In order to properly establish timing structures in a language and to highlight similarities and differences between languages, it is prerequisite that factors in speech timing should be found out and investigated in each language and across languages.

2. Factors in speech timing

2.1 Stress

In general, stress can cause changes in fundamental frequency, duration, intensity, or the formant structure of the vowel (quality), although the extent of variation in each acoustic correlate due to stress, depends upon language. Among them, especially the durational change should be the main concern with regard to acoustic timing. It is known that in many languages, stressed syllables lengthen, whereas unstressed syllables shorten. But this contrast is remarkable in the so-called stress-timed languages, most of which are Germanic languages (Ladefoged, 1993). In the experiments of perception of stress in English, Fry (1955, 1958) found that apart from the fundamental frequency whose effect was strongest despite some inconsistency, duration was a more effective cue for judgements of stress than intensity, even if both duration and intensity could be correlated with stress. According to Klatt (1976), at the phrase final position the duration of an unstressed unreduced vowel is about 65 % compared to that of a stressed unreduced vowel in English. Furthermore, when a reduction to schwa occurs in an unstressed vowel, the duration of the vowel becomes even shorter than the normal duration of schwa.

As already mentioned, however, the degree of lengthening due to stress could be different from language to language. In addition, stress may not always induce significant lengthening. This point is worth noting with reference to differences in timing between languages.

Delattre (1966) carried out a comparative investigation into the syllable length conditioning between four languages (English, German, French and Spanish) and observed that different languages showed different degrees of syllable lengthening with reference to syllable weight (stressed (primary) *vs.* unstressed), syllable position (final (in sense-groups) *vs.* non-final) and syllable type (closed *vs.* open). Independent of lengthening, it was also found that the variation of vowel intensity due to the presence or absence of stress varied according to languages (highest in English, lowest in French). In the experiments regarding the three acoustic correlates of accent (F0,

amplitude, duration) in English and Japanese, Beckman (1986) found highly significant variations of F0 due to accent (stress) in both English and Japanese. However, the differences in amplitude and duration were generally insignificant in Japanese unlike in English where all three acoustic correlates showed significant differences between stressed syllables and unstressed syllables. On the other hand, Fónagy (1966) reports many Hungarian words in which an unstressed second syllable has longer duration, higher F0 and greater intensity than a stressed syllable (see also Lehiste, 1970). In consequence, it is strongly suggested that the different temporal characteristics caused by stress in different languages, should be taken into account when we investigate the timing pattern of a language. Of course, stress effect on timing will have to be considered with regard to position, and inherent vowel/consonant duration, etc.

2.2 Vowel reduction (vowel centralization)

Vowel reduction can be an independent timing factor, although it is often regarded as being closely related to stress effect. In another study (1969), Delattre compared the same four languages (English, German, Spanish, French) as in the previous study (1966), concerning vowel reduction. Before starting experiments, he recalled the major causes of vowel reduction (pp. 297-300), which seem to be worth noting.

First, *monosyllabic rhythm*, in which each syllable has similar stress (e.g., French) shows less vowel reduction than *polysyllabic rhythm*, in which strongly and weakly stressed syllables are easily distinguished (e.g., English). He stated that Spanish and German are situated between the two types. Second, languages using muscular tenseness in articulation (e.g., French) tend to show less vowel reduction than those using muscular laxness (e.g., English). Third, weakly stressed vowels produce more reduction than strongly stressed ones. Fourth, vowel duration is another cause. That is, the shorter the vowel, the more reduced it is (Lindblom (1963) claims that duration is more related to vowel reduction than stress in Swedish). In particular, Delattre (1969, p. 298) contends that the subjective impression of vowel obscuration can be produced by shortening the duration alone, without modification of formant frequencies. Fifth, tempo influences vowel reduction. Sixth, a vowel with lower intensity is more reduced. Delattre remarks that in languages of polysyllabic rhythm, weaker stress correlates regularly with lower intensity whereas it does not always correlate with reduced duration in *hurry, city, picture*, ... the final unstressed vowel is as long or longer, but much less intense (loud), than the initial stressed vowel. (p. 299). Finally, vowel reduction is affected by contextual assimilation.

As stated above, vowel reduction is not always accompanied by durational decrease, and it does not necessarily relate to stress. Delattre (1969) observed the differences of formants 1 and 2 between stressed vowels and unstressed vowels in the four languages.

The percentage combining variations in formants 1 and 2 was greatest in English (17.78 %), followed by French (8.69 %), German (6.39 %) and Spanish (3.65 %). It is notable that German, reputedly one of the stress-timed languages, showed relatively small reduction. This fact is likely to confirm that vowel reduction (centralization) due to weak stress does not necessarily coincide with shortening in unstressed syllables, if shortening due to stress effect is larger in German than in French. Thus, vowel reduction must be language-specific, and it is likely to be considered independent of simply stress effect on duration, even if a high positive correlation is observed in some languages (e.g., English and Swedish).

On the other hand, despite vowel reduction, an unstressed syllable generally retains its syllabicity in English,[1] while in French vowel reduction often results in the complete elimination of syllables, e.g., chez le garcon /ʃel.gar.sõ/ (Dauer, 1983, p. 57). These differences seem to contribute to causing different temporal patterns (or different perceptual impressions) between English and French or Spanish.

2.3 Syllable structure

Syllable structure as a timing factor is well described by Dauer (1983). Firstly, languages can be substantially different in the variety of syllable structures, which in turn may be one reason to induce different temporal patterns from language to language. In general, stress-timed languages are remarkable in the variety of syllable structures they have, compared to those that are syllable-timed (e.g., English can have as many as four consonants in a syllable, while Spanish has "at most one consonant word-finally and two consonants medially" (Dauer, 1983, p. 55)). Secondly, open syllables are dominant in the so-called syllable-timed languages (cf. Delattre, 1966; Smith, 1976; Roach, 1982). For instance, some data suggested by Dauer (1983, p. 56) showed the percentage of open syllables is 44 % in English, 70 % in Spanish and 74 % in French (French data are cited from Smith, 1976)). Thirdly, heavy syllables tend to be stressed more often than light syllables in stress-timed languages (e.g., English, Arabic and Thai). Fourthly, in English most stressed CV syllables have inherently long vowels and diphthongs, whereas most unstressed CV syllables have short vowels. The opposite tendency is shown in Spanish. On the other hand, according to a study regarding syllable structure in Korean (Jin, 1992), open syllables (CV or V) predominate (i.e., 50-78 %).

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1) In a fast rate of speech, unstressed syllables in English may lose their syllabicity-vowels are deleted, remaining consonants only (e.g., Roach (1999) indicates that "She looked particularly interesting" could be pronounced as /ʃi lʊk pətkli ɪntrstɪŋ/ in a rapid speech.).

2.4 Final lengthening as one of the boundary marking phenomena

In many languages, *final-syllable lengthening* (*prepausal lengthening*) has been observed (e.g., English: Oller, 1973; Klatt, 1975; French: Crompton, 1980; Fletcher, 1991; Swedish: Lindblom, 1968; Japanese: Hoequist, 1983; Spanish: Delattre, 1966; German: Delattre, 1966; Italian: Farnetani & Kori, 1990; Korean: Yun, 1992). But the seemingly language universal phenomenon reveals substantial differences in its degree and mechanism between languages. That is, English, Swedish and German generally show high lengthening ratios (Delattre, 1966; Oller, 1973), Spanish intermediate ratios (Delattre, 1966; Oller, 1979), and Finnish low ratios (Oller, 1979). With regard to different mechanisms, Oller (1979) suggests a good example: in Finnish the average final vowel lengthening ratio is low (1.16), penultimate consonant lengthening ratios are also low (1.12) and final consonant lengthening ratios are comparatively high (1.66). (p. 337), and furthermore, some Finnish speakers may not lengthen final vowels at all. (p. 336). Thus we need to consider the mechanism as well as the degree of final lengthening. On the other hand, Farnetani & Kori (1990) observed the absence of word boundary lengthening in their Italian reiterant speech materials, and they interpreted it as contributing to the perception of Italian as syllable-timed. Considering these differences between languages, therefore, final-syllable lengthening could, eventually, be incorporated into the factors characterising the temporal pattern of a given language.

2.5 Consonant and vowel duration, and compensation between them

It has been known that in general, English shows relatively high durational variation between the preceding vowel and the following consonant (Chen, 1970; Mack, 1982; Munhall, Fowler, Hawkins & Saltzman 1992). But the variation has been observed mainly within monosyllables. The magnitude of the variation, however, substantially decreases in English when it is considered across syllable boundaries (Barnwell, 1971; Klatt, 1973; Port, 1981). Although many languages show the preconsonantal vowel shortening phenomenon as a function of the feature of the following consonant, the extent of shortening is known to be different from language to language (Chen, 1970; Mack, 1982). This kind of inter-language differential could also be observed between voiced (lax) and voiceless (tense) consonant durations, and the whole durations of the neighbouring syllables between which the durational compensation occurs (Fledge, 1979; Fledge & Port, 1981; Port, et al., 1980; Keating, 1985; Sato, 1993). Accordingly, the compensatory phenomena associated with the distinctive feature (voicing or tenseness) in the following consonants can be interpreted as being linguistically significant (phonological), especially with reference to timing in a given language.

For example, Port, Al-Ani & Maeda (1980) and Port, Dalby & O'Dell (1987) suggested the two contrastive terms *temporal microstructure* of speech, which indicates

the level of phoneme, and *temporal macrostructure* of speech, which has larger units (e.g., syllable, word) than a phoneme. In particular, with regard to the temporal macrostructure in Japanese, Port, et al. (1980, 1987), Homma (1981) and Sato (1993) claimed that the durational compensation within two-syllable words has some linguistic significance for mora-timing in Japanese. But Otake (1989) rejected their claim suggesting counter-evidence obtained from his experiment. That is, he cross-linguistically tested the speech materials used by Port, et al. (1980) and Homma (1981), etc. (i.e., five speakers of each of English, Spanish and Chinese read the same materials: e.g., *basa, bata, tabasaka, tabaraka*), and found no significant differences from Japanese (i.e., the evidence for mora-timing suggested by Port, et al. (1980) and Homma (1981) is seen in the other languages as well). Therefore, he concluded that "the temporal compensation effect is a universal phenomenon rather than a language specific phenomenon, so that it may not be evidence for mora-timing." (p. 19).

Of course, the compensatory phenomenon between neighbouring vowels and consonants would not always be linguistically significant. Rather, some other timing factors such as stress would be more influential in some languages. Yet, it is likely that we need to take into account the possibility that the compensatory phenomenon could be one of the crucial timing factors according to languages. In addition to that, some possible inter-language differences concerning the phenomenon would be worth observing in relation to speech timing.

2.6 Compression and incompressibility

In a number of languages (e.g., English, Swedish, Spanish, Czech, Hungarian, Lappish, Dutch, Estonian), compression of segments (vowels and consonants) has been observed due to the increase of the number of segments or syllables composing a phonological unit, i.e., syllable, word, foot (Fischer-Jørgensen, 1987). However the compression (shortening) effect would be different between languages. Hoequist (1983) compared three languages (English, Spanish, Japanese) with reference to the compression effect, and final lengthening, etc. He could find significant anticipatory and backward compression effects in English, whereas only backward compression effect in Spanish, and no compression effect in Japanese. From her French speech materials, Fletcher (1991) also observed a positive linear correlation between word duration and the number of syllables. In the aspect of temporal compression, Vayra, Avesani & Fowler (1983) tested the hypothesis that Italian, one of the Romance languages, is syllable-timed. Before starting experiments, they predicted two things: (1) strong syllable-level compression (2) very weak foot-level compression in Italian. Unexpectedly, however, syllable-level and foot-level compression effects were all weak. In conclusion, they presumed two reasons why Italian is reported as syllable-timed: (1) little foot-level

shortening (2) less reduction of unstressed vowel in Italian than in stressed-timed languages.

Interestingly, even in English, conflicting claims exist concerning the compression of segments due to the increase of syllables. In an investigation into the effect of speaking mode [vowel duration in carrier phrases *vs.* connected text] on speech timing, Harris and Umeda (1974) found that while significant compression of the target vowel /æ/ was observed in carrier phrases as the number of syllables increased (from one to four), no negative correlation was found between vowel duration and the number of syllables in connected speech (a 30-minute essay read by one subject). That is, the mean vowel durations in non-prepausal situations were virtually identical. Nakatani, O'connor & Aston (1981) also claimed that in their English speech materials there was a linear or sometimes even positive relationship between foot size and foot duration. In a study to investigate vowel duration in polysyllabic words in American English, Umeda (1972) concluded that the number of syllables in a word did not directly influence the duration of each vowel.

Furthermore, Fischer-Jørgensen (1987) observes that some Danish vowels in monosyllabic words lengthen when another syllable is followed. Consequently compression effect due to the addition of syllables could be language-specific, if we acknowledge its existence despite the negative opinions above. Thus, it will be another important factor with regard to speech timing. On the other hand, Klatt (1973) noted *incompressibility*. That is, he assumed that incompressibility is relative to the inherent duration of a phonetic segment and reflects a minimum time of execution of the required articulatory program. (p. 1103). The incompressibility must be taken into account together with compressibility when timing structures are investigated in a language.

2.7 Tempo

Speech rate could be another important timing factor. The tempo effect can be considered in two aspects: *macro effect* and *micro effect*. That is, changes in speech rate yield temporal changes in pauses and segments (vowel and consonant), among which the former will be the macro effect and the latter the micro effect (Fletcher, 1987, 1988).

It is known that slowing down of speech rate causes mainly extra duration in pauses (Goldman-Eisler, 1968). But Fletcher (1987, 1988) reported that according to speakers, tempo changes caused variations in either pause length or frequency, or both. So she assumed that the different pausing strategies would come from speaker-dependent strategies more than the language-specific strategies.

On the other hand, an increase in speech rate is accompanied by differential shortening of vowels and consonants as well as phonological and phonetic simplifications (Klatt, 1976). That is, in general, vowels show more shortening than consonants when

tempo changes from normal to fast. For instance, Port (1981) observed that in his English speech materials the post-stress stops revealed a fast/slow ratio of 0.79, whereas for the stressed vowels 0.74. This phenomenon is likely to be supported by Gay, Ushijima, Hirose & Cooper's (1974) observation of articulatory movements of American English. They found that for consonant production, the pertinent muscle (orbicularis oris) and lip movements became more active due to the increase of speech rate, while for vowel production, the activity of the genioglossus muscle weakened. In general, it is more complex to articulate consonants than vowels, since the articulation of consonants includes closures or constrictions at some points in the vocal tract. Therefore, at fast speech, execution time for consonant articulations seems to be more likely maintained, as compared to that for vowels (Fletcher, 1987, 1988).

What is of interest is that in English or Dutch speeding up tempo does induce significantly differential ratios in vowel/consonant duration, whereas slowing down tempo does not (e.g., Nooteboom, 1972; Pickett, 1980; Port, 1981). On the other hand, the extent of durational variations of French consonants and vowels was similar between from normal to slow tempo and normal to fast tempo (Fletcher, 1987, 1988). The differences between languages might be attributed to a tendency to maintain vowel quality in French despite tempo variations. Hence it would be worthwhile to observe temporal variations due to the change of speech rate, in an effort to find out some possible characteristics of timing structures in a given language.

2.8 Some other factors

Speech mode could be suggested as one of timing factors. As introduced earlier, Harris & Umeda (1974) reported significant differences in vowel compression due to the increase of syllables according to the speech mode (i.e., isolated words or carrier phrases *vs.* connected text). The result was attributed not to individual speaking characteristics but to different speaking modes. They remarked "what matters is not the length of the sentence, but the nature of the sentence." (p. 1018). And it was speculated that the role of prosody varies depending on the situation.

Glottalization (glottal stop) might be another timing factor especially in English. Roach (1980) investigated stop closure durations in English bilabial, alveolar, velar and glottal stops after voiced [a] and voiceless [h]. The results showed that the glottal closure durations were markedly longer than the others, irrespective of voicing in the preceding phoneme. That is, glottal stops were on average 68 % longer than bilabials, 49 % longer than alveolars, and 21 % longer than velars. He went on to measure stop closures in some language speakers other than English (i.e., Spanish, Kikongo and Sudanese colloquial Arabic). Even if the glottal stops manifested longer durations than supraglottal stops in these languages as well, English, in general, appeared to be

remarkable in the durational difference between the glottal and supraglottal stops. Furthermore, glottal stops do not occur in Spanish and Kikongo. On the other hand, Arabic that has phonological glottal stop [ʔ] did not reveal a significant level of differences. Roach (1980, p. 313) states "glottal stop is common in syllable final position in conjunction with /p, t, k, tʃ/ in the speech of many English speakers." In addition, this phenomenon seems more striking in the younger generation of English speakers. Many foreigners have a strong impression of glottal stop from English speakers, which is likely to be as strong as the impression of stress in English. They frequently indicate "English speakers say [Vʔ][Vʔ][Vʔ]...." Considering the above discussion, however, glottalization (glottal stops) could be taken into account as a timing factor in English at least, not simply as a perceptual impression. The significant differences between languages concerning glottal stop durations, and its frequent occurrences in English may encourage this idea.

3. Conclusion

It is surprising that though no physical evidence has been found, the theories of speech rhythm (timing) are still based on the assumption of isochrony between stresses and between syllables or moras. Especially, the typology of speech rhythm in a language is generally decided according to the perceptual timing that is liable to be subjective. But in order to give objectivity to the theories and to generalize them across languages, we ought to surmount the limit of the conventional theories of speech timing. To investigate timing factors in speech must be a good way for it. As indicated earlier, however, timing factors will often be associated with each other rather than be independent. Therefore, it would be valuable to observe relationships and interactions between factors as well as the effect of individual factors on timing. On the other hand, there could well be many other factors not listed above that would influence the timing of speech either across languages or in a specific language. They must wait to be discovered by linguists and phoneticians, if they have so far remained unknown. Eventually, we hope that they will be incorporated into theories about timing structures in a given language or languages.

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