Attractor Dynamics in Speech Production: Evidence from List Reading

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Abstract

To date, the vast amount of research done on the isochrony of English speech rhythm has not accounted for the emerging organization of rhythmicity. Our observation that speech rhythmicity is naturally occurring and even preferred as a strategy for optimizing the production and perception of a language-related task has been left untested. A set of experiments were devised to simulate list reading, i.e., a finite set of word tokens that a speaker must convey to hearers. Three lists were used that differed in prosodic structure to investigate the effect of stress pattern on isochrony. The results are analyzed as a low-dimensional dynamical system in which stress determines the cycle of an oscillator. The subjects show consistency in their speech rhythm across all list conditions. There is evidence of attractor dynamics in list reading.

Discussion

In many studies of isochrony and speech rhythmicity in English, subjects are asked to listen to, produce, and/or manipulate utterances so as to make their rhythm regular (Rapp, 1971; Allen, 1972; Morton, Marcus, & Frankish 1976; Tuller & Fowler, 1980; Hoequist, 1983; Howell, 1984; Fox & Lehiste, 1987). Despite this vast amount of research done on isochrony in speech, our observation that speech rhythmicity is naturally occurring and even preferred as a strategy for simplifying specific language-related tasks has been left untested. Thus, our question is, "Do subjects naturally, with minimal instruction, fall into a speech rhythm when asked to read a list of randomly ordered items?" Further, "Can this speech rhythm be defined by a low-dimensional dynamical system?"

A set of experiments were carried out on a group of four native speakers (NSs) of American English in which subjects were asked to read three different lists containing letters (i.e., "A" "B" "C" "D") (List 1), monosyllabic words (List 2), and bisyllabic words with alternating stress (List 3). The timing between vowel onsets was measured for each speaker across all three lists using Bex and hand measurements. Phase angles were measured by averaging the three previous inter-stress intervals (ISIs) of any particular ISI and then dividing the current ISI by the average of the previous three. This manner of measurement could be thought of as a simulation of the process by which auditory perceptual oscillators use short-term memory to make phase adjustments in rhythmic speed (McAuley 1995). In strictly-defined, task-specific systems such as the reading of a list for hearer verification, the establishment of isochronous rhythm may act as one oscillator in a coupled system to which the second oscillator, the internal perceptual oscillator of the hearer (McAuley, 1998), may be entrained in a 1:1 ratio.

In the reading of all of these lists, across four NS subjects, we observed an isochronous rhythm. Specifically, we conclude that:

1) the subjects naturally, with minimal instruction, fall into a regular, resting speech rhythm when asked to read a list of randomly ordered items;
2) the subjects showed consistency in their phase (.8-1.1 msec) across all three lists;
3) there is evidence for a low-dimensional dynamical system falling out of list reading;
4) regression plots of phase:phase-1 indicate the presence of a weak attractor for all three lists(List 1: $R=.09$ $R^2=.008$; List 2: $R=.05$ $R^2=.002$; List 3: $R=.20$ $R^2=.041$ respectively) (Figures 1-3.), with the bisyllabic word lists showing the largest difference between mean phase and current phase ($F=2.68$ $p<.11$);
5) simple meter is implicated as a temporal object that is used to regulate the ISIs in list reading.

The observed simple meters of 2:1 and 3:1 suggests that perhaps speakers adjust the timing of their list reading to line up onsets of stressed syllables with preferred points in the auditory oscillator. Thus, an effect similar to a Harmonic Timing Effect (Cummins & Port 1996) is suggested. Also, as phase is biased in multiples of 500 and 600 ms units, it is possible that the preferred rhythm of our subjects corresponds to the resting perceptual oscillatory rate suggested by McAuley (1995).

Thus, we find evidence in a simple speech rhythm task for attractor dynamics and view isochrony as a product of a dynamical system and not a segment manipulation on the part of the speakers.

Figure 1.

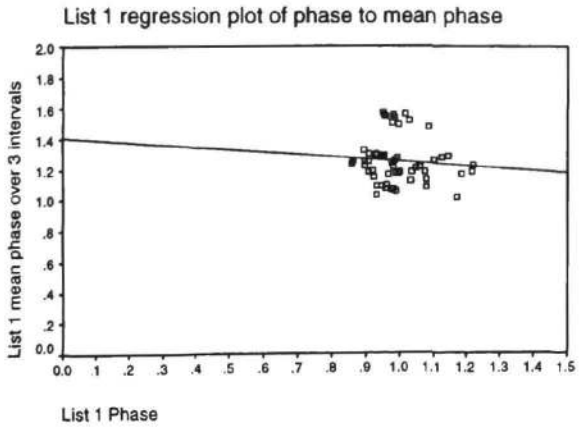


Figure 2.

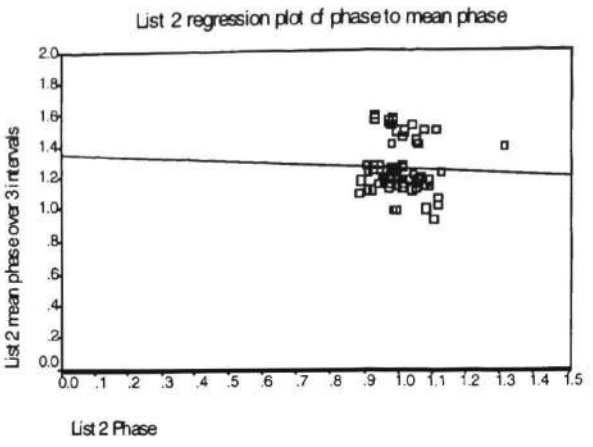
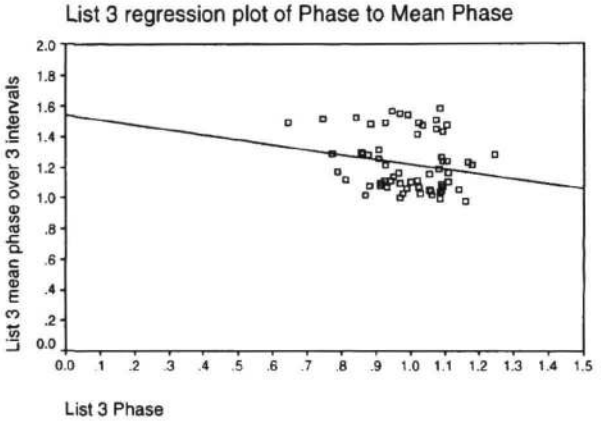


Figure 3.



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