Linguistic rhythm and the acquisition of language

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0. Introduction

In organisms endowed with a disposition to acquire grammar the beginnings of language learning can be detected at the onset of life, (Chomsky 1965; Chomsky 1980). Under the assumption that some universal properties of grammar are part of the human genetic endowment, we still have to explain how particular languages are acquired. One strong hypothesis that is currently under evaluation is that an essential aspect of language acquistion consists in the setting of parameters to the value that corresponds to the first language of exposure, hereafter L1. Basically, the genetic endowment can be thought of as switches that are to be set to the values that characterize the grammatical properties of L1. Whether there is an initial value of these parameters and how often they can be switched to take another value (for instance, to account for the presence of another language in the learning situation) is currently being explored. The grammars of natural languages are limited by the values that the parameters can take. There may, of course, be a noise generator as described for the expression of other biological properties (Changeux and Dehaene 1989), in which case a novel situation may arise.

We take it for granted that one version of another or the parameter setting approach is correct. Thus, we need to ask how the parameter setting account actually works. Most accounts assume that infants have somehow managed to learn the lexicon when they begin to acquire grammar. Mazuka underscored the problems that arise when one makes this assumption, see (Mazuka 1996). In this paper we assume, following Mazuka, that some physical properties of L1 determine the setting of some basic parameters thus facilitating further language learning.

What are the specific environmental stimuli that contribute to setting parameters to their values? This essential question remains unanswered. As we shall see, rhythm is an important cue that helps acquire different aspects of grammar (Gleitman and Wanner 1982; Morgan 1986; Nespor et al.

1986). That is, determining the rhythmic properties of L1 affects the acquisition of its phonology as well as of other aspects of grammar. Specifically, rhythm provides infants with information that is used to form a representation that influences continuous speech segmentation and ultimately the way in which lexical items are identified. In addition, rhythm makes it possible to determine some basic syntactic properties responsible for the variation in word order observed in natural language. That is, the rhythm of language is essential to both the acquisition of grammar and the lexicon. To understand how language learning is bootstrapped, it is essential to understand the way in which rhythm can help set parameters and to determine exactly which properties of a linguistic system may be derived from a specific rhythm.

1. Rhythm and language.

Rhythm refers to the periodicity with which certain events recur. The alternation of day and night is rhythmic, and so are the horse's trot and the beat of the heart. The modality and the nature of the events that recur with a certain periodicity are irrelevant to the definition of rhythm. Rather, it is the periodicity of their recurrence that is central to the percept we call rhythm.

If we want to understand what linguistic rhythm is, and how it contributes to the development of a linguistic system, it is necessary to identify the language specific events responsible for periodicity in speech. In other words, it is necessary to determine the properties that make speech appear as having an intrinsic rhythm. Past attempts have failed to establish the validity of any single property to account for linguistic rhythm. As we shall see below, the most influential view was that different linguistic rhythms arise because the components that recur regularly differ for each rhythm.

It has long been acknowledged that natural languages may be classified according to their rhythm. Lloyd James first noticed that some languages, Spanish among them, have a rhythm that resembles that of a machine-gun, while other languages, notably English, have a rhythm evocative of messages in Morse code (Lloyd James 1940). Pike labeled the two types of rhythm 'syllable timed' and 'stress timed', respectively (Pike 1945). Abercrombie went a step further and claimed that isochrony either of syllables or of interstress intervals is at the basis of rhythm in the languages of the world (Abercrombie 1967). The first type of language would be characterized by the isochrony of syllables and the second by the isochrony of interstress intervals. A third rhythmic class was added later (Ladefoged 1975), to account for the fact that some languages, typically Japanese, appeared to be neither syllable- nor stress-timed, but to be isochronous at a sub-syllabic level, i.e., the *mora*. The mora is a constituent established in phonological theory to distinguish light from heavy syllables: light syllables consist of one mora; heavy syllables of two (Hayes 1995). Languages whose basic rhythmic unit is the mora are labeled “mora-timed”.

Phonetic research aimed at discovering the physical properties characterizing rhythmic classes failed to find isochrony in either syllables or interstress intervals, (the latter coinciding with the notion of metrical foot in phonological theory (Liberman and Prince 1977)). Instead, the variation of their duration has been shown to be similar in syllable-timed and in stress-timed languages, (Shen and Peterson, 1962; Manrique and Signorini 1983; see however Port et al. 1987 who find isochrony at the level of the mora). This finding gave rise to two proposals: one, by Dasher and Bolinger (1982) suggesting that rhythmic classes do not result from a rhythmic distinction across languages, but rather are the byproduct of either the coexistence or the absence of different phonological phenomena, within a language. The second by Lehiste is that the rhythmic classes are due to a perceptual illusion, (Lehiste 1973; Lehiste 1977). The source of this illusion may or may not be due to the cues pinpointed by Dasher and Bolinger (1982).

The first of these two proposals finds support in the existence of phonological properties characteristic of stress timed languages. Indeed, these languages tend to have a large syllabic repertoire, vowel centralization in unstressed syllables, and quantitive sensitivity in stress location. Syllable timed languages fail to have any of these three properties (Dauer 1983). The properties that characterize the stress-timed languages which are all absent in syllable-timed ones are, *prima facie*, to be independent of each other. If so, it is natural to conjecture that some languages may have one or two of the above properties. One ought thus to find languages that are not classifiable as either syllable or stress timed because they would lie in between these. In fact, this is what actually happens. Indeed, on the one hand, there are languages with a rich syllabic repertoire, but with no vowel centralization, e.g., Polish and, on the other hand, languages with a relatively poor syllabic repertoire but with vowel centralization, e.g., Catalan or European Portuguese (Nespor 1990). This line of thinking brought Dauer (1983) and Nespor (1990) to reject the notion of rhythmic classes. They propose that languages be spread out along a continuum that would have at one extreme stress-timed languages and at the opposite extreme, syllable-timed languages.[1]

The second line of research – according to which the division of languages into rhythmic classes might be due to a perceptual illusion - stems from and is congruent with the notion that neither syllables nor interstress intervals are isochronous. Rather, Lehiste conjectures that the speech signal gives rise to perceptual processes responsible for the illusionary perception of isochronicity. To ground their hypothesis a number of investigators set out to establish whether languages are discriminated from one another only if they are not in the same rhythmic class. Language discrimination studies have been carried out, both with infants and adults and more recently with non-human animals (Ramus et al. 2000). In order to be certain that languages are discriminated on the basis of rhythmic properties rather than of phonetic or morphological cues, utterances are often delexicalized. The main outcome of these investigations is that both infants and adults can discriminate a pair of languages if they belong to different rhythmic classes but not otherwise.

A large number of experiments have been carried out to ground the aforementioned claims. Both adults and newborns are able to discriminate between two languages belonging to different rhythmic classes, but not between languages belonging to the same class, (Mehler et al. 1988; Mehler et al. 1996; Moon et al. 1993; Nazzi et al. 1998; Bahrick and Pickens 1988).[2] Interestingly, the outcome of most of these experiments is that languages appear to cluster into classes that correspond to those proposed by linguists, namely stress-timed, syllable-timed and mora-timed.

To confirm that the rhythmic class hypothesis can explain perceptual behavior, Nazzi and his colleagues carried out an experiment with sentences drawn from two languages belonging either to the same or to different rhythmic classes, (Nazzi et al. 1998). Nazzi's et al. results show that both newborns and adults discriminate stimuli of mixed Spanish and

[1] The third class, mora timed languages was not considered in these investigations.

[2] Of course, the stimuli presented to adult subjects are either low-pass filtered or resynthesized. These manipulations destroy segmental content, while preserving the different aspects of prosody.

Italian sentences from stimuli of mixed Dutch and English sentences, while they do not discriminate a mixture of Spanish and English sentences from a mixture of Italian and Dutch sentences.

The conclusion that may be drawn from the aforementioned work is that languages may form perceptually grouped rhythmic classes, rather than being spread out along a continuum. Of course, all the aforementioned studies are based upon a handful of languages and it is entirely possible that future studies will uncover more rhythmic "classes" and that in the end, what now looks as groups of languages will again appear as a continuum. Discrimination of a pair of languages would then occur between any two languages that are sufficiently distant along the continuum but not otherwise. Alternatively, the classes identified so far are not exhaustive; possibly two or three additional classes will be discovered after more languages are studied. For example, on the basis of a typological study on a variety of unrelated languages, it has been proposed that languages belong to one of five classes defined on the basis of syllable complexity (Levelt and van de Vijver 1998). It is entirely possible that investigations of more languages along the line of Ramus et al. (1999), to be discussed below, will uncover the existence of exactly two more rhythmic classes. At the moment we can't but be agnostic as to how many rhtyhmic classes there are, if there are classes at all. We pursue the notion that there are rhythmic classes because their existence presents an advantage for the language learner, as will be illustrated below.

2. Physical correlates of rhythmic classes

As was stated above, languages are perceived as belonging to one rhythmic class or another. Yet isochrony of either syllables or feet has not been found in acoustic-phonetic measurements. Hence, it becomes necessary to explore other characteristics of speech that may account for perception. Mehler et al. (1996) conjectured that infants perceive speech as a sequence of vowels, interrupted by consonants (or consonant clusters). This proposal is entirely reasonable since infants may very well pay attention to the parts of speech that have higher energy and longer duration, namely, vowels. This could give rise to the percept of rhythm underlying the discrimination performance observed in infants as well as in adults.

Ramus et al. (1999) pursued this conjecture and set out to investigate whether the way in which different vocalic intervals alternate forms the basis to our impression of speech rhythm.

Specifically, Ramus et al. (1999) propose that the representation of rhythm is computed on the basis of two measures: the proportion of utterances occupied by vowels and the variability of the consonantal intervals that separate these.

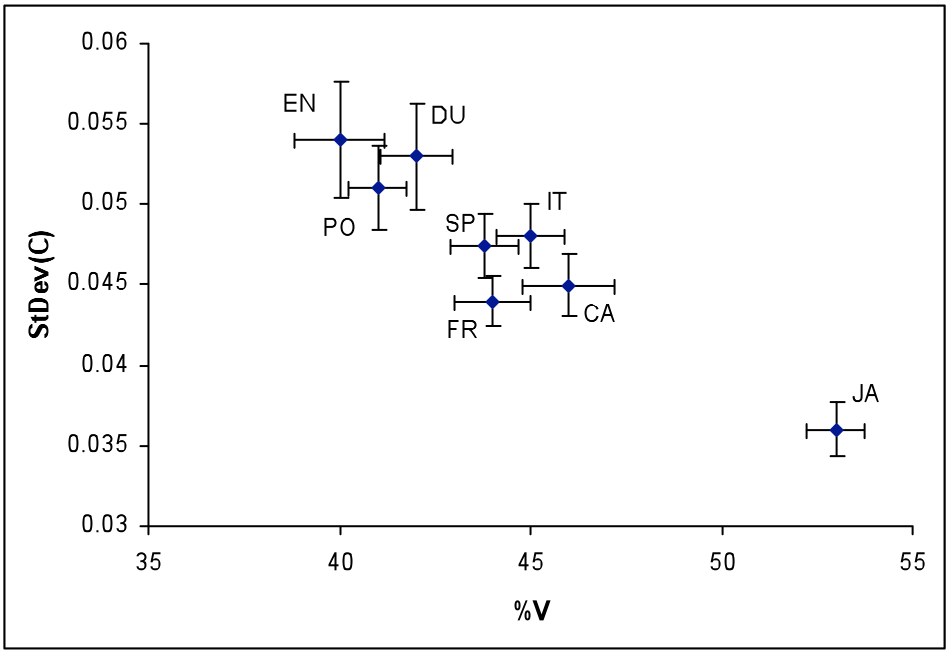

Figure 1: Results from the study by Ramus, Nespor and Mehler (1999). Distribution of languages over the percent vowel per utterance versus the standard deviation of the consonants. Error bars represent ± one standard error.

The proportion of vocalic intervals together with the regularity of their occurrence can be used to sort the eight languages studied into three groups consistent with the classes proposed by linguists. This intriguing result strengthens our conviction that some rhythmic aspects of L1 may play an important role in early language acquistion.

3. From rhythmic classes to basic phonological representations

Linguists assume that phonological units (as morae, syllables and feet) are part of the speaker's knowledge. Psycholinguists have evidence, however, that different languages highlight one or the other of these representations, to make it the basic phonological unit exploited in segmenting utterances.

Experimental studies have established that the mora is the representation that guides the behavior of Japanese speakers, the syllable that of speakers of French and the foot that of speakers of English (Cutler et al. 1986; Otake et al. 1993; Mehler et al. 1996). To illustrate one of the standard procedures used in this area, we describe one of the tests designed to discover the relevance of the syllable for native speakers of French (Mehler et al. 1981). The participants in this study were asked to respond as soon as they recognize the sequence *pa* in either *palace* or *palmier*. Reaction times were measured. Participants responded faster to *pa* in *palace* than to *pa* in *palmier*. In the first case but not in the second *pa* coincides with the first syllable. The same subjects are then asked to recognize the sequence *pal* in the same two words, and turn out to be faster in recognizing it in *palmier*, where it is a syllable, than in *palace,* where it corresponds to one syllable plus the onset of the next. The same experiment was then conducted with native speakers of English and of Japanese (Otake et al. 1993). Their reaction times turn out to be the same in all tasks. These results may be interpreted as showing that while the syllable is used as a parsing unit by native speakers of French, it is not so used by native speakers of either Japanese or English.

Let us now assume that the mora, the syllable and the foot are the representations used to parse the languages used in the experiments just mentioned, as well as all other languages of the respective rhythmic class. Under this assumption, one of the problems that must be addressed is how one goes from a representation of rhythm, understood as the proportion of vowels and the regularity with which these are produced, to a representation in terms of moras, syllables or stress periodicity.[3] This is a difficult question to answer and one that is not usually addressed in the psycholinguistic literature.

Is it possible to make some conjecture that would link the rhythmic classes, as illustrated in Ramus (1999) with one of the three phonological units mentioned above? We will risk making one conjecture even though

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[3] Cutler and here colleagues have argued that strong syllables are the segmentation unit that is used by speakers of English and languages in that class (Cutler,1992). If so, speakers of Japanese would use morae, speakers of Romance languages syllables, and speakers of stress-timed languages strong syllables, to segment the speech signal.

the exact details have not yet been worked out. Consider speakers of Hawaian or Japanese. It is likely that infants will rapidly discover that their L1 is mainly composed by CVs. In some of these languages, codas may exist, e.g. post-vocalic nasals or geminate consonants in Japanese. This however may not be too problematic for the infant. Indeed, given that the majority of the units they hear are actually CVs (the infant may be able to figure this out from the fact that the standard deviation of Cs (ΔC) is very low) the codas may be rated as having a special status. In due time, the infant might even notice that their average duration is not that different from CVs and assimilate codas to moraic units. Notice, moreover, that Japanese codas are quite different from codas in languages belonging to other rhythmic groups.

Consider the other extreme case, that in which the infant's L1 is a stressed-timed language. In this case, infants may discover that these are languages that have a very high ΔC. Given that L1 has a high ΔC, a salient regularity may become apparent, namely, that besides word primary stress also secondary stress is clearly marked. This gives rise to the percept of an alternation of stressless and stressed vowels and thus of strong and weak syllables. What happens when the infant's L1 is a syllable-timed language? In all likelyhood this is a property that is correlated with an intermediary value of ΔC. In this case, the syllable will become the representational unit that will be most highlighted, a fact that becomes clear in adult psycholinguistic experiments with speakers of Romance languages, as shown above.

4. Syllabic repertoires and expectations for segmentation

The preceding sections can lead one to conclude that rhythm may help determine how many syllable types a language has, i.e. the size of the syllabic repertoire of the language the infant is acquiring. This is a hypothesis that Ramus et al. (1999) mention explicitly. In fact, languages appear to have syllabic repertoires that jump quantically. Some languages, like Japanese or Hawaiian, have a small syllabic repertoire consisting of two or three syllable types. Other languages, like Greek, Spanish and Italian, have six to eight syllable types while English and Dutch have a syllabic repertoire of sixteen or even more syllable types (Dauer 1987; Nespor 1990). Sorting languages according to the size of their syllabic repertoire coincides with the previously mentioned rhythmic classes. Determining the rhythmic class to which a language belongs is, however, not sufficient to determine exactly which syllable types the language has.[4] It may, however, provide some information about the level of complexity of syllabic structure.

Is there some additional information besides the rough estimate of the syllabic repertoire in L1 that the pre-linguistic infant can gain from paying attention to rhythm? This is a hard question to answer without further research. However, we are willing to venture the hypothesis that rhythm may bias the infant to segment signals into smaller or larger chuncks. In other words, the rhythmic class to which a language belongs may provide some information about the mean size of the more frequent words in L1. Indeed, low frequency words are very often long in most languages, (Zipf 1936; Dehaene and Mehler 1992).

Indeed, it seems reasonable to conjecture that languages with a small repertoire of syllables, i.e., mora-timed languages, will tend to have long frequent words, like Japanese or Hawaiian, while the languages with the richests syllablic repertoire, i.e, stress-timed languages will be rich in monosyllables, like Dutch or English. Syllable-timed languages will, of course, fall in between, as is the case for Spanish, Italian or Greek.

The above conjecture makes intuitive sense. Indeed, in a language with a very poor syllabic repertoire, the number of monosyllables is insufficient to express even the most frequent concepts. Conversely, in a language with a rich syllabic repertoire, there are enough monosyllables to cover the basic vocabulary, rendering the use of polysyllables unnecessarily costly. Of course, this assumes that languages have a similar tolerance for polysemy.

Given the connections between rhythmic class and syllable types and between syllable types and minimal word size, it is indeed plausible that through the identification of the rhythmic class of L1, infants will tend to postulate possible word units of different sizes.

In addition to the above conjucture about the possible function of rhythm in language acquisition, others have proposed that higher levels of the rhythmic organization can help the acquisition of syntax. The representation of rhythm, in fact, in language as in music, is hierarchical in nature. While at the basic level, the elements that recur in time to make speech rhythmic

[4] For example, one language with two syllable types, may have CV, V, like Cayuvava; another language with the same number of syllable types may have CV, CVC, like Thangari and yet another might have CV, CCV, like Arabela (cf. Blevins 1995).

are vowels, at higher levels, it is prominent vowels, that is, vowels characterized by different suprasegmental properties that, alternating with less prominent vowels, establish the rhythmic flow (Liberman and Prince 1977; Selkirk 1984).

The two levels of phonological - and rhythmic organization - relevant to syntax are the phonological and the intonational phrase. In both cases, the relative prominence of their elements has been proposed as a specific signal to some properties of syntax (Nespor and Vogel 1986; Hayes and Lahiri 1991 for the first and the second constituent, respectively). If this proposal is right, then these cues may be essential to the prelexical setting of basic syntactic parameters governing word order (Nespor 1995; Nespor et al. 1996; Nespor and Guasti 2002).[5] Future research will uncover whether the different cues to phrasal prominence are actually used by infants. In a first experiment, the sensitivity of infants to the phonological phrase prominence makes plausible the idea that at least the Head-Complement parameter could be set through prosody (Christophe et al. 2002).

5. **Conclusions**

In this paper, we have suggested that on the basis of the specific rhythmic class of their L1, infants might be able to highlight the phonological representation that they will eventually come to use to segment speech. Moreover, infants may also obtain information about the size of the syllabic repertoire of the language they hear. Indeed, we have speculated that the size of the syllabic repertoire might give a bias as to mean word length. Finally, we mentioned that basic syntactic parameters might also be set through the signal conveyed by the prosody of utterances.

The idea that rhythm may provide an initial perspective into the structure of language is fascinating. However, how exactly an infant derives phonological knowledge from rhythmic information remains to be studied in greater detail.

Future research will clarify exactly the ways in which the rhythmic properties of the speech signal contribute to learn the language specific aspects L1. The appeal we see in the hypothesis that rhythm is directly responsible for part of the knowledge necessary to learn grammar, is that the child could start quite early to work on segmentation. According to our proposal, the infant starts to learn grammar with the onset of life. The signal

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[5] See also C. Donati and M. Nespor, From Focus to Syntax (submitted).

could set parameters in an automatic fashion, without requiring the postulation that the infant adopts an intentional stance or engages in ***heavy*** computations. Those two assumptions seem to us incompatible with what is otherwise known about the infant's brain.

Finally, further research will also have to clarify where language specific learning starts and general learning stops. We know that tamarins behave similarly to babies as to some linguistic discrimination (Ramus et al. 2000). At least one part of the task involved in the identification of rhythm might thus not be language specific.

Abercrombie, D. (1967). Elements of general phonetics. Chicago, Aldine.

Bahrick, L. E. and J. N. Pickens (1988). "Classification of bimodal English and Spanish language passages by infants." Infant Behavior and Development **11**: 277-296.

Changeux, J. P. and S. Dehaene (1989). "Neuronal models of cognitive functions." Cognition **33**: 63-109.

Chomsky, N. (1965). Aspects of the theory of syntax. Cambridge, MIT Press.

Chomsky, N. (1980). Rules and Representations. Oxford, Basil Blackwell.

Christophe, A., M. Nespor, M.T. Guasti and B. van Ooyen (2002) "Prosodic structure and syntactic acquisition: the case of the head-complement parameter. Developmental Science.

Cutler, A. (1992). "The Production and Perception of Word Boundaries." Speech Perception Production and Linguistic Structure. Y. Tohkura, E. Vatikiotis-Bateson and Y. Sagisaka. Tokyo and Amsterdam, Ohmsha and IOS PRESS.

Cutler, A., J. Mehler, D. Norris and J. Segui (1986). "The syllable's differing role in the segmentation of French and English." Journal of Memory and Language **25**: 385-400.

Dasher, R. and D. Bolinger (1982). "On pre-accentual lengthening." Journal of the International Phonetic Association **12**: 58-69.

Dauer, R. M. (1983). "Stress-timing and syllable-timing reanalyzed." Journal of Phonetics **11**: 51-62.

Dehaene, S. and J. Mehler (1992). "Cross-linguistic regularities in the frequency of number words." Cognition **43**: 1-29.

Donati, C. and M. Nespor (2002) "From focus to syntax". submitted.

Gleitman, L. R. and E. Wanner (1982). "Language acquisition: The state of the state of the art." Language Acquisition: State of the Art. Wanner and G. E. L. R. New York, Cambridge University Press.

Hayes, B. (1995). Metrical Stress Theory. Chicago and London, The University of Chicago Press.

Hayes, B.and A.Lahiri (1991). Bengali intonational phonology. *Natural Language and Linguistic Theory* 9:47-96.

Ladefoged, P. (1975). A course in phonetics. New York, Harcourt Brace Jovanovich.

Lehiste, I. (1973). "Rhythmic units and syntactic units in production and perception." Journal of the Acoustical Society of America **54**: 1228-1234.

Lehiste, I. (1977). "Isochrony reconsidered." Journal of Phonetics **5**: 253-263.

Levelt, C. and R. van de Vijver (1998). "Syllable types in cross-linguistic and developmental grammars." Third Biannual Utrecht Phonology Workshop, Utrecht.

Liberman, M. and A. Prince (1977). "On stress and linguistic rhythm." Linguistic Inquiry **8**: 240-336.

Lloyd James, A. (1940). Speech signals in telephony. London.

Manrique, A. M. B. d. and A. Signorini (1983). “Segmental Durations and rhythm in Spanish.” Journal of Phonetics **11**: 117-128.
Mazuka, R. (1996). "How can a grammatical parameter be set before the first word?" Signal to Syntax: Bootstrapping from speech to grammar in early acquisition. J. L. Morgan and K. Demuth. Mahwah, NJ, Lawrence Erlbaum Associates**:** 313-330.
Mehler, J., J., Y. Dommergues, U. Frauenfelder and J. Segui (1981). “The syllable's role in speech segmentation.” Journal of Verbal Learning and Verbal Behavior **20**: 298-305.
Mehler, J., E. Dupoux, T. Nazzi and G. Dehaene-Lambertz (1996). "Coping with linguistic diversity: The infant's viewpoint." Signal to syntax: Bootstrapping from speech to grammar in early acquisition. J. L. Morgan and K. Demuth. Mahwah, NJ, Lawrence Erlbaum Associates**:** 101-116.
Mehler, J., P.W. Jusczyk, G. Lambertz, N. Halsted, J. Bertoncini and C. Amiel-Tison (1988). “A precursor of language acquisition in young infants.” Cognition **29**: 143-178.
Moon, C., R. Cooper and W. Fifer (1993). “Two-day-olds prefer their native language.” Infant Behavior and Development **16**: 495-500.
Morgan, J. L. (1986). From simple input to complex grammar. Cambridge Mass, MIT Press.
Nazzi, T., J. Bertoncini and J. Mehler (1998). “Language Discrimination by Newborns: Towards an understanding of the role of rhythm.” Journal of Experimental Psychology: Human Perception and Performance. **24**(3): 756-766.
Nespor, M. (1990). "On the rhythm parameter in phonology." Logical issues in language acquisition. I. M. Roca. Dordrecht, Foris**:** 157-175.
Nespor, M. (1995). "Setting syntactic parameters at a prelexical stage." Proceedings of the XXV ABRALIN Conference, Salvador de Bahia.
Nespor, M., M. T. Guasti and A. Christophe (1996). Selecting word order: the Rhythmic Activation Principle. Interfaces in Phonology. U. Kleinhenz. Berlin, Akademie Verlag**:** 1-26.
Nespor, M. and M.T. Guasti (2002) "Stress-to-Focus alignment." *Lingue e Linguaggio*. 1.
Nespor, M. and I. Vogel (1986) *Prosodic Phonology*. Dordrecht. Foris
Otake, T., G. Hatano, A. Cutler and J. Mehler (1993). “Mora or syllable? Speech segmentation in Japanese.” Journal of Memory and Language **32**: 258-278.
Pike, K. L. (1945). The intonation of American English. Ann Arbor, Michigan, University of Michigan Press.
Port, R. F., J. Dalby and M. O'Dell (1987). “Evidence for mora-timing in Japanese.” Journal of the Acoustical Society of America **81**(5): 1574-1585.
Ramus, F., M. D. Hauser, C. Miller, D. Morris and J. Mehler (2000). “Language Discrimination by Human Newborns and by Cotton-Top Tamarin Monkeys.” Science **288**: 349-351.
Ramus, F., M. Nespor and J. Mehler (1999). “Correlates of linguistic rhythm in the speech signal.” Cognition **73**(3): 265-292.
Selkirk, E. O. (1984). Phonology and Syntax: the Relation between Sound and Structure., Cambridge Mass.: MIT Press.
Shen, Y. and J. J. Peterson (1962). “Isochronism in English.” University of Buffalo Studies in Linguistics. Occasional Papers. **9**: 1-36.
Zipf, G. K. (1936). The psycho-biology of language. London, George Routledge.