Spracherwerb

Speech Rhythm in the Pronunciation of German and Spanish Monolingual and German-Spanish Bilingual 3-Year-Olds

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Abstract

Recent linguistic research suggests that reliable acoustic cues underlie the rhythmic classification: stress versus syllable timing. We utilized the Pairwise Variability Index (PVI) to examine the rhythmic patterns of six monolingual (3 German; 3 Spanish) and six bilingual German-Spanish children (3 growing up in Germany; 3 growing up in Spain), aged 3;0 years. Our aim was to determine whether the rhythmic patterns (stress- vs syllable-timing) of German and Spanish could be distinguished in the speech of three-year-old children, and whether bilingual children differed from monolingual children in this respect. Results indicated that the PVIs of monolingual German and Spanish children were significantly different from each other; however, bilingual children displayed similar rhythmic patterns in both languages, tending towards less vocalic variability in German and greater consonantal variability in Spanish than the monolinguals. These findings show that child production reflects the prosody—here rhythm—of their target language at a very early age, and are consistent with "phonetic compromise" in the bilingual development of the acoustic patterns that underlie rhythm.

1 Introduction

Rhythm is an area of prosody that has to do with the timing or temporal organization of speech. Discussions of rhythm in the literature have frequently dealt with a dichotomy of rhythm types. Some languages are said to have a temporal organization based on stress, the so-called stress-timed languages, whereas other languages are said to have a temporal organization based on syllables, namely, the so-called syllable-timed languages (Pike, 1945; Roach, 1982; Dauer, 1983, 1987; Auer and Uhmann, 1988).[1] Ever since the original coining of these terms by Pike in the 1940's, many linguists and some foreign language teachers alike have been committed to the idea of a rhythmic distinction between languages. Attempts to quantify this distinction, however, have frequently met with failure, leading many researchers to question whether it was appropriate to speak of different types of rhythmic organization in the world's languages (Roach 1982). In the first section of this paper, we review various approaches to rhythm and present two more recent approaches, based on the measurement of vocalic and consonantal intervals, which empirically support a rhythm dichotomy (Ramus, Nespor and Mehler, 1999; Grabe and Low, 2002). We then go on to discuss how we have applied one of these approaches to the measurement of rhythm in young monolingual and bilingual German and Spanish speakers, German being a classic example of a "stress-timed" language, and Spanish, a classic example of a "syllable-timed" language (Berg, 1991; Marks, Bond and Stockmal, 2003).

The aim of this study is two-fold. Our first aim is to determine whether the syllable-timed pattern of Spanish can be distinguished from the stress-timed one of German in the speech of young monolingual children. Studies suggest that cross-linguistic differences in rhythmic patterns are evident in children by four years of age (Bunta and Ingram, 2007; Grabe, Gut, Post and Watson, 1999a; Grabe, Post and Watson, 1999b), but no studies have examined rhythmic patterns in children as young as three-years. Thus, we wish to examine rhythmic development in a younger age group than has been previously studied in the literature, in order to find out whether children are able to produce the rhythmic characteristics of their target language at an early age. Such rhythmic properties have been shown to be distinguished very early in perception (Jusczyk, 1997; Ramus, Dupoux and Mehler, 2003).

Our second aim is to examine the rhythmic patterns of bilingual children and to compare them to those of monolingual children. This goal touches on an important topic in bilingual research, namely whether the two languages of bilingual children influence each other or whether they develop independently. The term cross-linguistic interaction is often used to refer to a certain degree of convergence between the two languages of bilingual children, leading to qualitative or quantitative differences between their linguistic systems and those of monolingual children (Paradis, 2000; Kehoe, 2002b; Lleó, 2002, 2006; Lleó, Kuchenbrandt, Kehoe and Trujillo, 2003). Documenting interaction patterns in bilingual children is important because it provides information not only on the nature of bilingual development but also on the nature of different linguistic domains. Studies suggest that certain linguistic domains may be more susceptible to interaction effects than others due to factors such as structural ambiguity, markedness, and frequency (Müller and Hulk, 2000; Paradis, 2000; Lleó, 2002). We believe that rhythm is an important linguistic domain to search for cross-

[1] We acknowledge that the terms stress- and syllable-timed are imperfect labels but will continue to use them for the sake of simplicity. When these terms are used to refer to a given language, the reader should understand that the language is "usually described as stress- or syllable-timed".

linguistic interaction, because it responds to linguists' intuitions that certain languages, such as Spanish and French, on the one hand, and English and German, on the other hand, can be grouped into contrastive perceptual categories based on rhythm. The rhythmic properties of the two languages should be salient to the bilingual child and, thus, should be acquired very early. Furthermore, in the case of young German-Spanish bilinguals, rhythm is a good starting point to study interaction effects because the adult systems are very different, thus increasing the chances that clear differences between languages will be observed (Grabe and Low, 2002).

1.1 Various Approaches to Studying Rhythm

Approaches to studying rhythm can be broadly classified into three main groups: the first approach is based on the search for isochrony of time intervals (Abercrombie, 1967); the second approach claims that rhythmic differences between languages are the result of specific phonological phenomena (Dasher and Bolinger, 1982; Dauer, 1983; Auer and Uhmann, 1988; Nespor, 1990; Auer, 2001); and the third approach proposes that the perception of rhythm classes results from differences in the measurements of vocalic and consonantal intervals (Ramus et al., 1999) and in their variability (Ramus et al., 1999; Low, Grabe and Nolan, 2001; Grabe and Low, 2002). Each of these approaches will be discussed in turn.

Isochrony Theory

Isochrony theory is based on time interval equivalence in speech. Languages, in which the intervals between stressed syllables are roughly of equal length, are called stress-timed, and languages, in which all syllables are roughly of equal length, are called syllable-timed. Many experiments have measured the length of interstress intervals and the lengths of syllables in a variety of the world’s languages, yet none has confirmed the notion of isochrony. Instead they show that the duration of interstress intervals is not always equal in “stress-timed” languages (Lehiste, 1977) and the length of syllables is not always constant in “syllable-timed” languages (Delattre, 1966; Roach, 1982), thus revealing no physical reality for the rhythmic distinction of stress and syllable timing based on isochrony.

Phonological Approach

In the phonological approach, rhythm types are not viewed as phonological or phonetic primitives but rather as derivatives (Ramus et al., 1999). That is, they are the by-product of the phonological properties of the respective languages, of which the three most important are:

Syllable structure: "Stress-timed" languages have a greater variety of syllable types and more complex syllable structure than "syllable-timed" languages. For example, English syllables (English, being a "stress-timed" language) may contain from one to seven elements resulting in 16 syllable types, whereas Spanish syllables contain from one to five elements resulting in nine syllable types (Nespor, 1990). A greater variety of syllables, as in "stress-timed" languages, clearly leads to potentially larger durational differences between syllables.

Vowel reduction: "Stress-timed" languages, as e.g. English and German, contain reduction processes that lead to the centralization or reduction of unstressed vowels. In German, unstressed syllables in words such as Elephant and Aspirin are assumed to have underlying full vowels but they may surface as reduced vowels, depending upon factors such as speech style and speech rate (e.g., El/e/fant → El[ə]fant; Asp/i/rin → Asp[ə]rin) (Vennemann, 1991). In contrast, "syllable-timed" languages tend not to contain such reduction processes; they may contain deletion processes instead, that result in the complete elimination of syllables. In Spanish, two unstressed non-high vowels are reduced to one, as in *del monte* 'from the mountain' or *al mar* 'to the sea', comprised of *de+el* and *a+el*, respectively. The main difference between the two types of processes is that reduction processes lead to the presence of uneven lengths of syllables, whereas deletion processes eliminate unstressed vowels, thereby maintaining the even lengths of syllables.

Word stress: Most "stress-timed" languages have word stress (Dauer, 1983), in which a variety of acoustic correlates (e.g., duration, loudness, and pitch contour) reinforce the difference between stressed and unstressed syllables. "Syllable-timed" languages do not necessarily have word stress (e.g., French) or when they do, the acoustic manifestation of stress in these languages is not as extreme. For example, stressed syllables in Spanish are on average 1.3 times longer than unstressed syllables, whereas in English and in German, they are about 1.5 and 1.6 times longer, respectively (Delattre, 1966). These differences may be, in part, due to differences in syllable structure and vowel reduction, and they clearly lead to larger duration differences in "stress-timed" than in "syllable-timed" languages.

Variability of Consonantal and Vocalic Intervals

The third approach is an implementation of the phonological account but it also assumes an acoustic component to rhythm. Ramus and colleagues developed a measurement technique, in which an utterance is segmented into a succession of vocalic and consonantal intervals. An interval refers to either one vowel or to one consonant, or to a sequence of vowels and consonants, regardless of whether they belong to the same syllable or not. The segmentation of the phrase *next Tuesday on* (phonetically transcribed as [nɛkstjuzdeiɔn]) is shown in Figure 1 (adapted from Ramus et al., 1999: 272).

n	ɛ	kstj	u	zd	eiɔ	n

Fig. 1. The phrase 'next Tuesday on' segmented into vocalic and consonantal intervals. Shaded intervals refer to consonants.

The duration of each vocalic and consonantal interval is measured and then submitted to two calculations:[2]

- the proportion of vocalic intervals within the sentence (%V),
- the standard deviation of the duration of consonantal intervals (ΔC).

Applying these two calculations to the sentence productions of speakers from eight different languages, Ramus et al. (1999) were able to distinguish well-known rhythm classes. Languages typically considered stress timed (e.g., English, Dutch, and also Polish) clustered together with low %V and high ΔC. They were statistically differentiated from languages typically considered syllable timed (e.g., Spanish, Italian, French, and Catalan), which were characterized by having high %V and lower ΔC values. Finally, Japanese, a language, which is often referred to as mora timed, unlike both stress- and syllable-timed languages, was distinguished from them all with very high %V and very low ΔC scores.

It should be noted that these measurements may reflect the phonological account of rhythm. The proportion of vocalic intervals and the standard deviation of consonantal intervals within a sentence should in part relate to the vowel reduction and syllable structure characteristics of a given language. The fact that a "stress-timed" language contains reduced vowels and complex syllable types implies that it will contain lower proportions of vocalic intervals and higher consonantal variability than a "syllable-timed" language. Thus, a higher %V will combine with low ΔC scores in so-called syllable timing and a lower %V will combine with high ΔC scores in so-called stress timing.

Grabe and Low (2002) have developed a rhythmic measurement technique similar to that of Ramus et al.'s (1999). Like Ramus et al. (1999), they advocate dividing up the speech stream into intervals of consonants and vowels. However, instead of subjecting these absolute duration measures to the two calculations proposed by Ramus et al. (1999), they compute a Pairwise Variability Index (nPVI-V), as shown in (1). The "V" at the end of the formula refers to the fact that this form of the PVI is computed on vocalic intervals.

[2] Ramus et al. (1999) measured three variables – %V, ΔV, ΔC – but found that the combination of %V and ΔC best fitted the standard rhythm classes.

(1) Pairwise Variability Index (normalized version).[3]

$$nPVI-V = 100x\left[\sum_{k=1}^{m-1}\left|\frac{d_k - d_{k+1}}{(d_k + d_{k+1})/2}\right| /(m-1)\right]$$

Where m = number of vocalic intervals in utterance
d = duration of the kth vowel

This equation expresses the average amount of difference between adjacent intervals. According to Grabe and Low (2002: 520), the index "is compiled by calculating the difference in duration between each pair of successive measurements, taking the absolute value of the difference and dividing it by the mean duration of the pair." (PVIs are calculated both for vocalic intervals (nPVI–V) and for consonantal (i.e., intervocalic) intervals (rPVI-C). When the duration of successive intervals is relatively similar, low variability indices will be obtained. This should be the case in syllable-timed languages, due to the presence of simple syllable structure and absence of vowel reduction, which lead to sequences of syllables of even length. When the duration of successive intervals is highly variable, high variability indices should be computed, as in the case of "stress-timed" languages, which contain complex syllable structure and reduced vowels.

After comparing the PVI and Ramus et al.'s (1999) measures, Low et al. (2001) argue that the PVI is a better indicator of rhythmicity because it contains an articulation rate normalization component. This avoids picking up spurious variability due to speaker rate variation within phrases. For this reason, we adopt the PVI in the current study (see, however, Ramus, 2002).[4] We turn to findings on the acquisition of rhythm in young children's speech.

1.2 Acquisition of Rhythm

No discussion of rhythmic development would be complete without reference to the seminal work of Allen and Hawkins (1978, 1980), who observed three decades ago that the rhythm of children's speech, regardless of target language, tends to be syllable-timed. Learning phrase rhythm, in their view, involves learning to reduce heavy syllables with full vowels.

[3] We discuss the difference between the normalized (n) and non-normalized (r) versions of the PVI later in the article.

[4] A further rhythm measure has been proposed, which also incorporates normalization of speech rate, namely VarcoV. Results reported by means of this measure are comparable to nPVI-V results (White and Mattys, 2007a, 2007b; Wiget, White, Schuppler, Grenon, Rauch and Mattys, 2010). Here, we will focus on Grabe and Low's (2002) PVIs, because they have also shown robust results, and they are the most widely used measurement in studies of L1 acquisition (but see Kohler, 2009, for objections to the method and some alternative proposals).

While many researchers have frequently observed that children's first utterances contain vowels with full articulation, very few studies have actually documented or measured vowel reduction processes in early speech. A few exceptions are works by Allen and Hawkins (1978), Kehoe (2002a) and Kehoe and Lleó (2003). Allen and Hawkins (1978) investigated how often children reduced syllables in function words and multisyllabic content words; they calculated percentages of deletion and vowel reduction in a group of six English-speaking children, aged 2;2 – 3;9. They found that this group of children reduced target syllables on average only 50% of the time. In contrast, Kehoe (2002a) observed a higher production rate of reduced syllables by German-speaking children. She compared the vowel productions of German and Spanish-speaking monolingual and bilingual children, focusing particularly on the presence of reduced vowels. As mentioned above, German is traditionally described as a stress-timed language containing reduced vowels, whereas Spanish is considered a syllable-timed language containing only full vowels. Based on phonetic transcription, Kehoe (2002a) found that two-year-old German-speaking children often substituted full vowels for schwas, but still produced reduced syllables with a mean accuracy rate of 64%. Their vowel productions differed greatly from two-year-old Spanish-speaking children's, which rarely contained reduced vowels. Thus, it is important to note that the speech of children acquiring "stress-timed" languages, while tending towards syllable-timing, may still differ from the speech of children acquiring "syllable-timed" languages.

A comparison of the rhythmic patterns of children acquiring traditionally considered stress- and syllable-timed languages has been conducted by Grabe and colleagues (Grabe et al., 1999a, 1999b). They measured the rhythm indices (using the nPVI-V described above) of four-year-old English-, German- and French-speaking children and compared the scores of these children with those of their mothers. At the outset, they hypothesized that the syllable-timed rhythm of French should be less complex than the stress-timed rhythm of English and German. The lower degree of complexity of syllable timing would be due both to not having to compress or lengthen different numbers of syllables and to the predictability of accent location. Their findings confirmed their hypothesis in that the rhythmic patterns of French children did not differ significantly from those of their mothers, whereas the rhythmic patterns of English children did, tending more towards syllable timing. Interestingly, the German results patterned differently from the English results. The mothers' rhythm index fell in between the French and English ones and the rhythmic patterns of the German-speaking children did not differ significantly from their mothers', thus displaying a pattern more like French. English and German, although considered to be stress-timed languages, do differ in vowel reduction patterns and this may explain the varied findings (Delattre, 1966; Kaltenbacher, 1997).

Thus in the end, Grabe et al.'s (1999a, 1999b) results support the general view that the "stress-timed" rhythm of English is more difficult to acquire than the "syllable-timed" one of French (Vihman, 1996). Nevertheless, one other important finding from Grabe et al.'s (1999a, 1999b) studies is that cross-linguistic differences in rhythmic patterns were clearly evident in the data: Four-year-old English- and German-speaking children received higher rhythm scores (greater vocalic variability) than the French-speaking children, a pattern consistent with the rhythmic patterns of the ambient languages. In this study, we will examine whether three-year-old German-speaking children receive higher rhythmic scores than Spanish-speaking children, as would be expected given the rhythmic patterns of German and Spanish.

1.3 Acquisition of Rhythm in Bilingual Children

Studies that have investigated the rhythmic development of bilingual children include Whitworth's (2002) investigation of six bilingual German-English children (aged 5–13 years) and Bunta and Ingram's (2007) study of bilingual English-Spanish four- to five-year-olds. Whitworth (2002) did not find any rhythmic differences between German and English, using the rhythm indices nPVI-V and rPVI-C in the speech of the bilingual children, with the exception of one child who produced higher nPVI-Vs in English than in German. She also did not find any significant differences between the rhythmic scores of the parents speaking their native languages (German in the case of the mothers and English in the case of the fathers). The PVI values (vowel and consonant intervals) of children and adults for both languages tended to cluster together. However, German and English, being both stress-timed languages, may not be sufficiently different to serve as a valid test of interaction effects in bilingual development.

In contrast to Whitworth's (2002) findings, Bunta and Ingram (2007) did find a statistically significant difference between the PVI-Vs and PVI-Cs (referred to as intervocalic intervals in their study) of the two languages of English-Spanish bilingual children. Both, older bilingual children (aged 4;6 to 5;2) as well as younger bilingual children (aged 3;9 to 4;5) did have different PVIs in the two languages, exhibiting lower variability values in Spanish than in English. They also found statistically significant differences between the PVI-Vs of bilingual English as compared to monolingual English, the former showing lower variability than the latter, but not between the PVI-Vs of bilingual Spanish as compared to monolingual Spanish. Collectively, these findings suggest that although the rhythm of bilingual children tends towards syllable timing, 4-year-old bilingual children are still capable of differentiating their languages.

An important methodological finding of Bunta and Ingram's study (2007) is that the vocalic PVI scores appeared to be more robust and accurate in differentiating the speech rhythm of monolingual and bilingual speakers than the consonantal PVI scores. For example, only the vocalic PVIs and not the consonantal PVIs distinguished the speech rhythm of the younger monolingual English and bilingual English speakers. Similarly, only the vocalic PVIs indicated a significant difference between younger monolingual English and monolingual Spanish speakers; the consonantal PVIs indicated no significant differences. Thus, the consonantal PVIs appeared to be more variable and less sensitive in detecting cross-linguistic differences, leading the authors to cautiously question their utility as a measure of speech rhythm. This finding should be kept in mind when interpreting the current results which include vocalic as well as consonantal PVIs.

Bunta and Ingram (2007) observed a bias towards syllable timing in the speech of their bilingual children. As mentioned above, the variability scores of the younger bilingual English children were lower than those of the monolingual English whereas the variability scores of the bilingual Spanish approximated those of monolingual Spanish. This is consistent with syllable timing being linguistically less marked from a developmental standpoint than stress timing. Interestingly, Kehoe and Lleó (2005) observed the opposite effect when examining the speech rhythm patterns of monolingual and bilingual German and Spanish children. The rhythm scores of monolingual and bilingual children (aged 3;0 years) did not differ in German but they did in Spanish suggesting that Spanish was the language particularly affected in the bilingual situation. The syllable-timed pattern of Spanish seemed to have moved towards the stress-timed pattern of German. A drawback of Kehoe and Lleó's (2005) study was the small subject numbers, consisting of only two bilingual subjects, two monolingual German subjects and only one monolingual Spanish subject. It is possible that differences reflected patterns of an idiosyncratic nature rather than true population differences. Another factor that could have accounted for their finding was the fact that the bilingual subjects were growing up in Germany and may have been exposed to German on a more continual basis than to Spanish. Ambient language effects may be particularly important in the development of rhythm. In order to determine whether the findings could be generalized to all German-Spanish bilingual children or only to bilingual children growing up in Germany, one would need to conduct a similar study in Spain. That is, one would need to test bilingual German-Spanish children growing up in Spain.

In this study we will examine the speech rhythm of monolingual and bilingual German and Spanish children utilizing two populations of bilingual children: bilingual German-Spanish children growing up in Germany and bilingual German-Spanish children growing up in Spain. We will also try to alleviate the drawback of low subject numbers by increasing the number of subjects to three in each condition (i.e., three monolingual German subjects; three monolingual Spanish subjects; three bilingual subjects growing up in Germany; three bilingual subjects growing up in Spain). Admittedly, the numbers of subjects are still on the low side but it must be recognized that acoustic measures of rhythm are very time intensive, making the desired aim of increased subject numbers a difficult one to obtain.

In the following section, we describe the study and its goals in more detail.

1.4 Description and Goals of Current Study

In the current study, we measure speech rhythm employing the methodology described above, in which the variability of vocalic and consonantal intervals is computed using a Pairwise Variability Index: nPVI-V, rPVI-C (Grabe and Low, 2002). Our first goal is to determine whether monolingual children display cross-linguistic differences in rhythmic patterns, consistent with the distinction of stress- and syllable-timing. We test children at around three years of age (2;9–3;1), a younger age-range than the subjects in Bunta and Ingram's (2007) study (e.g., children aged 3;9–4;5 and 4;6–5;2) because we are interested in knowing whether children can differentiate speech rhythm from the earliest stages of phonological development. In fact, three-year old children may be considered to be at a relatively advanced stage of phonological development; however, methodological restrictions, such as the requirement of analyzing utterances of at least 5 syllables, necessitated choosing children around this age.

Our second goal is to examine the rhythmic patterns of bilingual children and to compare them with those of monolingual children. If our bilingual children behave like the bilingual Spanish-English children in Bunta and Ingram (2007)'s study, we may expect them to already display significant differences between the rhythmic scores of German and Spanish, consistent with the distinction stress- and syllable-timing. They may, however, display some differences when compared to monolingual children as well, such as manifest lower rhythmic scores in the case of the stress-timed language (in their case English; in our case, German), suggestive of a delay in rhythmic development and a bias towards syllable-timing in children's speech. This is one possible pattern in the data; however, other patterns are also likely. Our bilingual children are younger than those studied in Bunta and Ingram's study; thus, they may not yet display significant differences between the rhythmic scores of German and Spanish. Alternatively, they may manifest significant differences in their Spanish rhythmic scores when compared to monolinguals, as observed by Kehoe and Lleó (2005). In short, we aim to document patterns of cross-linguistic interaction or independence (no cross-linguistic interaction) in the rhythmic development of this group of young bilinguals.

As mentioned above, we study two groups of bilingual children: bilingual German-Spanish children growing up in Germany and bilingual German-Spanish growing up in Spain because we wish to examine whether the ambient language in which the children are growing up also has an influence on their rhythmic development. If the two groups pattern similarly in terms of rhythm then the findings would suggest that it was the constellation of languages (i.e., German and Spanish) rather than the language environment itself, which has an influence on rhythmic development. If the two groups pattern differently in terms of rhythm then the findings would suggest that ambient language influences rhythmic patterns.

2 Method

The data stem from a bilingual project in which children acquiring German and Spanish in Hamburg (Germany) were followed longitudinally from the onset of word production. In addition, cross-sectional data on bilingual children acquiring Spanish and German in Madrid were recorded. Monolingual data are taken from a previously conducted project, in which German children in Hamburg (Germany), and Spanish children in Madrid (Spain) were recorded longitudinally in similar data collection conditions to the bilingual project carried out in Hamburg. In all cases, children were audio- and, in some cases, video-recorded in their homes (fortnightly until two years, and monthly after two years; the Spanish monolinguals monthly at all ages), while playing and interacting with one parent and one experimenter, or with two experimenters. In the recording sessions children were encouraged to talk spontaneously; they were not required to imitate adult productions. On the contrary, imitations or immediate repetitions of adults' utterances were excluded from analysis. The bilingual children in Hamburg were visited by two separate teams: a German- and a Spanish-speaking team. If one of the parents was present, he/she had to be a native speaker of the language in which the recording session was taking place. The bilingual children growing up in Spain were audio- and video-recorded in the *Kindergarten of the Madrid German School*, under similar circumstances to the German children. Following testing, all sessions were glossed and phonetically transcribed.

2.1 Subjects

For purposes of the current study, productions of three monolingual German (Thomas, Marion and Britta), three monolingual Spanish (Miguel, José and María), three bilingual German-Spanish children (Simon, Jens and Manuel) growing up in Hamburg (Germany) and three bilingual Spanish-German children (Eva, Inés and Carla) growing up in Madrid (Spain), aged approximately 3;0 years (2;9 to 3;1), were selected for data analysis.[5] The bilingual children in Hamburg were children of Spanish-speaking mothers and German-speaking fathers, whereas the bilingual children in Madrid were children of German-speaking mothers and Spanish-speaking fathers. The parents followed the "une personne, une langue" rule by addressing the child in his/her respective language. The parents' language of communication was German in the case of Jens and Manuel, and Spanish in the case of Simon and also in the case of the bilinguals from Madrid. The main care person during the first three years of life for the bilingual children was the mother, who was the main provider of input for the

[5] The names of the children are research names, which, except for two cases, do not match their real names.

other language, not spoken in the larger environment. Information based on the percentage of German and Spanish utterances produced in the recording sessions and Mean Length of Utterances (MLUs) suggested that the children were balanced bilinguals (see section 3.1).

2.2 Procedure

From the recorded data, 20 intonation phrases were selected for each child. An intonation phrase was defined roughly as a sense group, separated by a pause and forming a prosodic whole. Utterances of minimally five syllables were required to calculate the PVI, because, based on recommendations by Grabe et al. (1999a, 1999b), the final syllable of each phrase should be excluded from analysis, to avoid possible confounds of phrase-final lengthening that may operate differently in German and in Spanish. Note that Bunta and Ingram (2007) did not find that final syllable lengthening had a significant impact on the vocalic PVI score; however, we have taken the more conservative stance of excluding them.

Intonation phrases were selected if they were "acoustically clean" productions, without obvious hesitations and noise overlay. Examples of intonation phrases are given in (2).

(2) Examples of intonation phrases in German and Spanish, produced by the children.

German utterances	English gloss
Da gehe ich immer rein	'I always go inside there'
Hast du mich dann wieder abgeholt	'Did you pick me up again?'
Andere passt so darein	'another one fits in there'
Da ist Hosentasche	'There is (the) trouser pocket'

Spanish utterances	English gloss
Eso es una locomotora	'That is a locomotive'
y va a la piscina	'and (he/she) goes to the swimming-pool'
y otro camión también	'and another truck, too'
no se puede abrirse ahí	'it cannot be opened, there'

Note that children's utterances were still accepted even when they were not accurate renditions of the adult target utterances. For example, children occasionally deleted consonants as in Miguel's simplification of the cluster /tɾ/ in *otra* 'other' in the Spanish phrase *y tiene otra boca* 'and (it) has another mouth' (adult form [i tjene otɾa βoka]; Miguel (3;0)'s production [i dɛne utaː vokaː]). Children also produced simplifications typical of fast speech forms as in Thomas's production [hɐbm̩] for *haben* 'to have' in the German phrase *Wir* *haben das bei Frau Schnell gesungen* 'We sung that at Mrs Schnell's place' (Standard adult form [vɪɐ hɐbn̩ das baɪ̯ fʀaʊ̯ ʃnɛl ɡɛzʊŋn̩]; Thomas (3;0)'s production [vɪɐ hɐbm̩ das baɪ̯ fʀaʊ̯ ʃnɛl ɡzʊŋɣ]).

Using the acoustic program, Soundscope for the MacIntosh, utterances were digitized at 44.100 Hz sampling rate and segmented using a commercial software package (SoundScope, GW Instruments, Somerville, Mass.). The duration of successive consonantal and vocalic intervals was measured, left to right, with the aid of both visual (time waveform and spectrogram) and auditory cues. Following the method presented in Grabe and Low (2002: 524), "Vocalic intervals were defined as the stretch of signal between vowel onset and vowel offset, [...] regardless of the number of vowels" that intervened. Consonantal or "intervocalic" intervals were defined as the stretch of signal between vowel offset and vowel onset, regardless of the number of consonants included." Periods of silence which did not belong to the articulation of a consonant were not counted in the analysis. These periods ranged from 50 to 500ms. Vowels and consonants were identified using standard segmentation criteria (Peterson and Lehiste, 1960). An example of the duration measurements of one Spanish phrase (produced by Jens, age 3;0) is provided in Figure 2. The 2nd row contains the child's pronunciation in phonetic characters.

c	e	r	d	i	t	o	s	t	a	m	b	i	é	n
T	e	d		i	t	o	s	t	a	m		I	e	n
C	V	C		V	C	V	C		V	C		V		C
149	102	95		177	103	99	232		120	205		245		78

Fig. 2. Example of duration measurement (in ms) of vocalic and consonantal intervals for one Spanish production *cerditos también* "little pigs too" (Jens, 3;0).

Vocalic variability was computed using the normalized version of the PVI (nPVI-V) whereas consonantal variability was computed using the raw PVI (rPVI-C). Grabe and Low (2002) argue that normalization is desirable for vocalic intervals, which generally consist of a single vowel that may be subject to speech rate effects. However, in their opinion it is less desirable for consonantal intervals, which may consist of several segments, each of which may be subject to different speech rate effects. Thus, we adopt their recommendation of only normalizing in the case of vocalic intervals (see also Ramus, 2002). The vocalic and consonantal intervals of 10 intonation phrases were re-measured by a second examiner. Inter-examiner re-measures produced Pearson r correlation coefficients of .84 and .83 for nPVI-V and rPVI-C respectively and a mean difference of 2.3 and 2.9 respectively between the PVIs (vowel and consonant) measured by both examiners (e.g., Examiner 1: nPVI-V=43.0; rPVI-C=81.6; Examiner 2: nPVI-V=40.7; rPVI-C=78.7). T-tests indicated no significant differences between the two sets of PVIs, a finding consistent with acceptable inter-examiner reliability.

In sum, 20 nPVI-Vs and 20 rPVI-Cs were computed for each monolingual child, one for each intonation phrase, and 40 nPVI-Vs and 40 rPVI-Cs were computed for each bilingual child, one for each intonation phrase of the two languages (20 x 2).

3 Results

Before we proceed to an analysis of the rhythm scores, we first provide an indication of language dominance (i.e., the relative competence of one language versus the other) in our bilingual children, since this factor has been shown to play a role in the phonological development of bilingual children (Law and So, 2006).

3.1 Language Dominance

Language dominance was determined by two measures: 1) the percentage of utterances corresponding to the target language in a recording session, and 2) Mean Length of Utterance (MLU, based on words). The first provides an indication of language preference, the second, an indication of syntactic proficiency. Results are presented in Table 1 for the analysis period 2;8 through to 3;0.

Table 1. Information on language dominance in the bilingual subjects: percent utterances and MLU

Child	Age	German %Utterances[a]		MLU	Spanish %Utterances[a]		MLU
Bilingual (Germany)							
Simon	2:8	95%	(172/182)	3.01	98%	(188/192)	2.82
	2;9	98%	(126/128)	3.10	98%	(164/167)	3.10
	2;10	98%	(105/107)	3.86	97%	(111/115)	2.59
	2;11	87%	(13/15)	2.85	100%	(126/126)	3.40
	3;0	96%	(171/178)	3.07	96%	(121/125)	3.20
Jens	2:8	89%	(66/74)	2.82	97%	(68/70)	2.10
	2;9	88%	(105/120)	2.53	96%	(182/189)	2.05
	2;10	91%	(70/77)	2.77	98%	(84/86)	1.88
	2;11	82%	(46/56)	2.44	98%	(50/51)	2.66
	3;0	96%	(69/72)	3.11	98%	(40/41)	2.62
Manuel	2:8	84%	(70/83)	2.21	99%	(113/114)	3.32
	2;9	100%	(198/199)	3.45	100%	(196/196)	2.75
	2;10	100%	(200/200)	3.70	100%	(151/151)	3.94
	2;11	100%	(238/238)	4.33	99%	(112/113)	3.24
	3;0		Not tested		99%	(168/170)	4.81

Bilingual (Spain)							
Eva	3;0	99%	(234/236)	3.07	100%	(341/341)	2.59
Inés	3;1	100%	(151/151)	2.58	96%	(201/210)	3.00
Carla	2;9	99%	(141/142)	4.37	100%	(183/184)	3.66

[a] Refers to the percentage of utterances representing the target language, that is, German utterances in a German session, Spanish utterances in a Spanish session.

In the case of the bilinguals growing up in Germany, the table indicates that they all produced the target languages most of the time in the recording sessions. That is, they produced predominantly Spanish utterances in a Spanish session and German utterances in a German session. When the children occasionally introduced the non-target language, it was usually in favor of Spanish (e.g., Jens, Manuel and Simon occasionally introduced Spanish into their German sessions, between 10% and 20% of one of the sessions in each case). The MLU results do not indicate any major differences in syntactic proficiency between the two languages.

Something similar could be said for the bilinguals growing up in Spain. They all produced predominantly Spanish utterances in their Spanish sessions and German utterances in their German sessions. Their MLU values, however, differed slightly between languages: Carla and Eva had slightly higher MLUs in German as compared to Spanish whereas Inés had a slightly higher MLU in Spanish as compared to German. Nevertheless, given the results that we will present below, we consider that overall the findings support the subjective impression of the investigators that all bilingual children could be characterized as "balanced" bilinguals.

3.2 Mean Length of Vocalic and Consonantal Intervals

Before presenting the pairwise variability indices of vocalic and consonantal intervals, we report two additional measures: the mean values of interval duration in the two languages, which do not necessarily reflect rhythm per se. The results (means and standard deviations) are shown in Tables 2 and 3, respectively. Table 2 shows differences in the mean length of vocalic intervals across children. In the monolingual condition, there was a tendency for the mean vocalic intervals to be longer in Spanish than in German, although, the mean interval of one of the monolingual Spanish children (Miguel) approximated that of the German children, suggesting there was also considerable variability among monolingual children. In the bilingual condition, the mean vocalic intervals of German and Spanish were very similar.

Table 2. Mean length of vocalic intervals (ms) for all children

	German			Spanish	
Children	Mean	SD	Children	Mean	SD
Monolingual					
Thomas	127	62	Miguel	119	54
Marion	129	74	José	195	107
Britta	114	73	María	157	94
Bilingual (Germany)					
Simon	133	56	Simon	132	53
Jens	143	68	Jens	134	49
Manuel	144	99	Manuel	149	103
Bilingual (Spain)					
Eva	174	96	Eva	171	65
Inés	154	100	Inés	149	96
Carla	127	52	Carla	131	59

Table 3 shows differences in the mean length of consonantal intervals across children. In contrast to the measurement of vocalic intervals, the measurement of consonantal intervals did not display any difference between the Spanish and the German of the monolinguals. There were, however, some isolated differences between the mean intervals of bilingual children (e.g., Inés and Carla). As Bunta and Ingram (2007) noted, consonantal intervals may be a less appropriate measure of rhythm than vocalic intervals. We keep this in consideration throughout our analysis.

Table 3. Mean length of consonantal intervals (ms) for all children

	German			Spanish	
Children	Mean	SD	Children	Mean	SD
Monolingual					
Thomas	120	88	Miguel	104	59
Marion	125	74	José	118	54
Britta	148	87	María	157	94
Bilingual (Germany)					
Simon	129	87	Simon	121	53
Jens	135	90	Jens	126	78
Manuel	157	122	Manuel	135	68
Bilingual (Spain)					
Eva	155	110	Eva	137	80
Inés	150	123	Inés	113	83
Carla	146	95	Carla	116	57

3.3 Speech Rhythm – PVI Scores

Monolingual Analyses

The PVI scores for the monolingual German and Spanish children are plotted in Figure 3. Each point represents the intersection of nPVI-V and rPVI-C indices for each of the 20 intonation phrases spoken by each child. Vocalic variability (nPVI-V) is indicated on the Y-axis and consonantal variability (rPVI-C) on the X-axis. As can be observed, there is a great deal of overlap between the PVI results for the Spanish and German monolingual children. Nevertheless, the PVI results for the Spanish children tend to cluster in the lower left hand corner of the graph, with low vocalic and consonantal variability scores, and the PVI results for the German children tend to be dispersed towards the extremes of the graph with higher vocalic and consonantal variability scores. Table 4 presents the mean values for each individual child. T-tests revealed significant differences between German and Spanish for both the nPVI-V and the rPVI-C (nPVI-V: $t(118)=2.849$, $p<.01$; rPVI-C: $t(118)=6.062$, $p<.001$). No significant differences were obtained between the PVIs of the individual children within the German group on the one hand, and between the individual children within the Spanish group on the other, except for the significantly lower nPVI-V of Miguel as opposed to that of José ($t(38)= 2,853$, $p<0.01$).

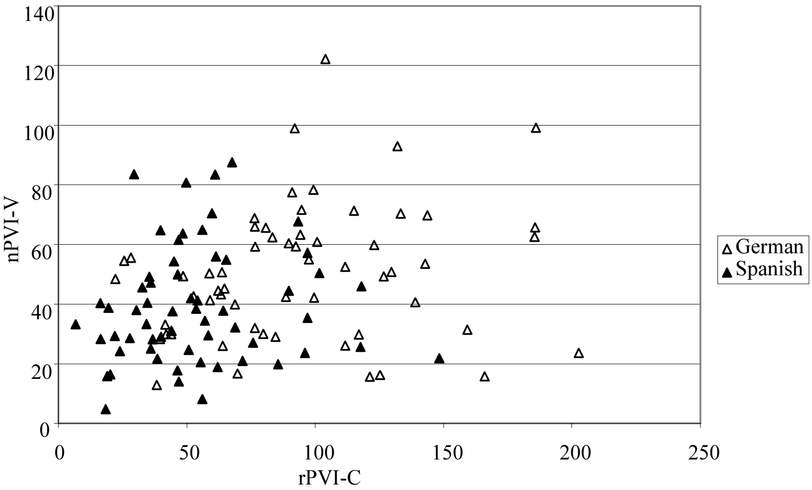


Fig. 3. PVI scores for the monolingual German and Spanish children.

Table 4. Means and standard deviations of Pairwise Variability Index scores (PVIs) for German and Spanish monolingual children.

	German					Spanish			
Children	nPVI-V	SD	rPVI-C	SD	Children	nPVI-V	SD	rPVI-C	SD
<u>Monolingual</u>									
Thomas	48	23	104	40	Miguel	31	11	50	25
Marion	49	26	85	45	José	46	19	57	26
Britta	55	17	93	43	María	41	14	55	25

In sum, our results revealed significant rhythmic differences between German and Spanish monolingual subjects, based on measures of vocalic and consonantal variability. In spite of much variation within the two groups, the three Spanish and the three German children manifested differing values. The variability values of the Spanish group were lower than the German values, the highest value in Spanish being lower than the lowest value in German, both for vocalic as well as for consonantal indices. This finding is consistent with the rhythmic distinction: stress- versus syllable-timing. Nevertheless, it should be noted that the mean nPVI-V score of one of the Spanish children, José, was not very different from the German childrens' values (particularly Thomas and Marion – compare 46 vs. 48 and 49), suggesting that rhythmic development is still not complete at three years of age, and that cross-linguistic differences are only just emerging. It is also interesting to note that the Spanish child Miguel, who has the lowest nPVI-V scores, corresponding to the expectations of syllable timing, is the most advanced phonetically and phonologically, based on other phonetic and phonological data (syllable structure: Kehoe, Hilaire-Debove, Demuth and Lleó, 2008; Lleó et al., 2003; prosodic constituents, especially the Phonological Phrase: Lleó, 2006; Place of Articulation: Lleó, 1996). The German child Britta, who has the highest nPVI-V scores, which thus correspond to stress timing, is also the most advanced phonetically and phonologically in the German group (syllable structure: Lleó et al., 2003; VOT: Kehoe, Lleó and Rakow, 2004; schwa and syllabic consonants: Kehoe and Lleó, 2003). This could raise the suggestion that rhythmic development is characterized by a reduction of vocalic variability in the case of syllable-timed languages and an increase of vocalic variability in the case of stress-timed languages.

Bilingual Analyses

The mean PVI scores for the two groups of bilingual children are presented in Tables 5 (nPVI-V) and 6 (rPVI-C) respectively. As can be observed, the expected pattern of greater vocalic variability in German versus Spanish was evident in the scores of only three of the bilingual children (Jens and Manuel growing up in Germany; Eva growing up in Spain). The other children displayed similar vocalic variability in both languages (Inés and Carla growing up in

Spain) or even displayed greater variability in Spanish than in German (Simon growing up in Germany). T-tests revealed that none of the bilingual children showed statistically significant differences between the vocalic PVIs of their Spanish and German. In contrast, the expected pattern of greater consonantal variability in German versus Spanish was evident in the scores of all the bilingual children (see Table 6). However, the results tended to be more centralized than seen in the monolinguals. The rPVI-Cs were generally higher in the Spanish of the bilingual children than in the monolingual children (compare range 62–82 versus 50–55) and in some cases lower in the German of the bilingual children than in the monolingual children (compare Simon's result of 77 versus monolingual range of 85–104). T-tests revealed that two of the children, Manuel (growing up in Germany) and Inés (growing up in Spain) obtained higher consonantal rhythm indices for German than for Spanish; the other children displayed no significant differences between their consonant rhythm indices in German and Spanish.

Table 5. T-test and mean values of the nPVI-V scores in German and Spanish bilingual children

	Spanish		German				
	Mean	SD	Mean	SD	df	t	sig.
Germany:							
Simon	44	23	40	19	38	0.571	n.s.
Jens	36	22	46	15	38	1.734	n.s.
Manuel	50	23	56	18	38	0.831	n.s.
Spain:							
Inés	47	18	46	22	34	0.147	n.s.
Eva	36	17	45	20	38	1.400	n.s.
Carla	37	15	36	13	42	0.192	n.s.

Table 6. T-test and mean values of the rPVI-C scores in German and Spanish bilingual children

	Spanish		German				
	Mean	SD	Mean	SD	df	t	sig.
Germany:							
Simon	62	36	77	36	38	1.257	n.s.
Jens	82	51	92	41	38	0.652	n.s.
Manuel	62	25	104	65	38	2.710	**[a]
Spain:							
Inés	80	42	126	54	34	2.891	**
Eva	64	45	90	55	38	1.674	n.s.
Carla	65	33	81	42	42	1.325	n.s.

a ** $p<.01$

In order to provide a graphic representation of the data, the mean PVI scores for the bilingual children are shown alongside those of the monolingual children in Figures 4 and 5: Figure 4 presents the mean PVI scores for the bilingual children growing up in Germany and Figure 5 presents the mean PVI scores for the bilingual children growing up in Spain. The PVI scores of the bilingual children are indicated by the letters ‘J’, ‘S’ and ‘M’ for Jens, Simon and Manuel in Figure 4 and by the letters ‘E’, ‘I’ and ‘C’ for Eva, Inés and Carla in Figure 5. These graphs illustrate the main findings, namely that the mean PVI scores of the bilingual children tend to be located between the two extremes of the monolingual children, with the exceptions of Manuel in Figure 4 and Inés’ PVI-C in Figure 5.

Fig. 4. Mean PVI scores for the monolingual and the bilingual children growing up in Germany. In the diagram ‘J’ refers to Jens, ‘S’ to Simon and ‘M’ to Manuel.

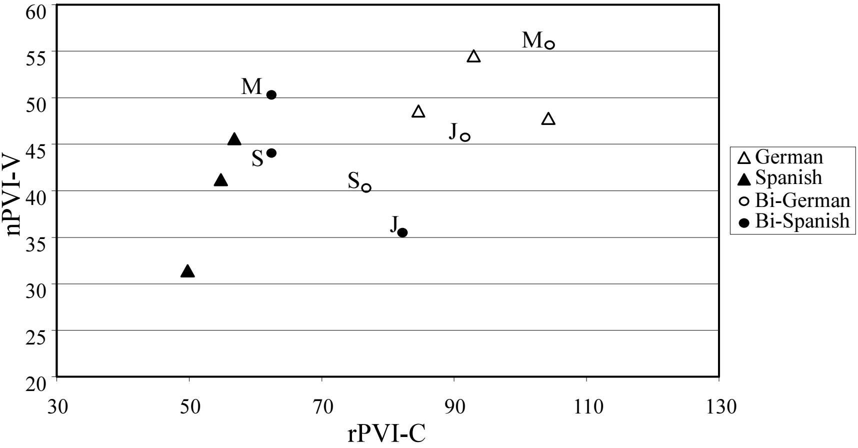
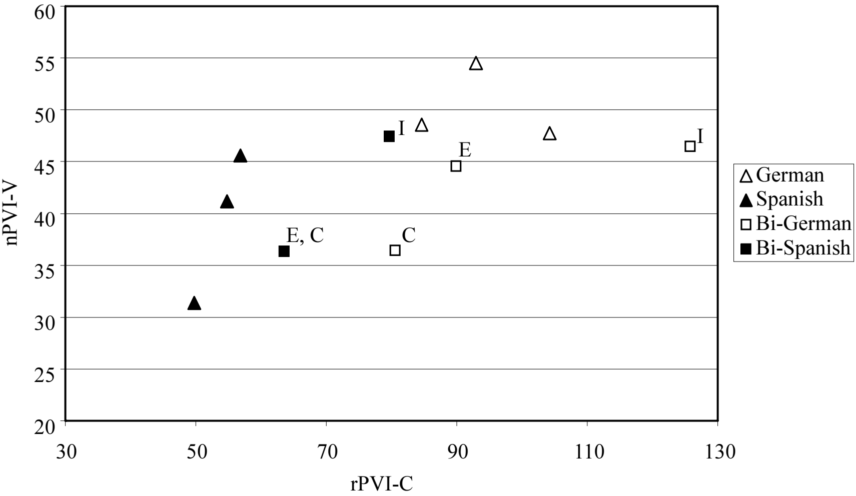


Fig. 5. Mean PVI scores for the monolingual and the bilingual children growing up in Spain. In the diagram 'E' refers to Eva, 'I' to Inés and 'C'refers to Carla.



An ANOVA was used to test differences between the rhythm scores of monolingual and bilingual children. It indicated that vocalic rhythm indices were significantly different between groups ($F(5,354) = 2.684$, $p=.021$); however, multiple comparison tests (Bonferroni) revealed that only the vocalic PVIs of monolingual German were significantly higher than those obtained for monolingual Spanish (p=.042), as was reported in the previous section. The vocalic rhythm indices obtained for bilingual German both in Germany and in Spain were not significantly different from those obtained for monolingual German and the vocalic PVIs of monolingual Spanish were not significantly different from those obtained for bilingual Spanish either in Germany or in Spain (see Table 7). Moreover, no statistically significant difference was found between the bilingual children's German and Spanish PVI-Vs.

As far as consonantal rhythm indices are concerned, an ANOVA revealed that there were significant differences between groups ($F(5,354) = 9.981$, $p<.001$). Multiple comparison tests (Bonferroni) indicated that the consonantal PVIs of monolingual German were significantly higher than those obtained for monolingual Spanish ($p<.001$), as was reported previously. The consonantal rhythm indices obtained for bilingual German both in Germany and in Spain were not significantly different from those obtained for monolingual German. The Bonferroni test led to equivalent results in Spanish: There were no significant differences between monolingual Spanish and bilingual Spanish, either in Spain or in Germany. There were several significant differences, however, which were less pertinent to the main research questions since they involved comparisons between monolingual groups in one language and bilingual groups in the other language, or they involved a comparison across language and country of upbringing. The main relevant result was that bilingual German was significantly different from bilingual Spanish in Spain, a finding probably related to the extreme score of Inés (see Table 8).

Table 7. Bonferroni test and mean values of nPVI-V scores in German and Spanish monolingual and bilingual groups.

					Monolingual		Bilingual Germany		Bilingual Spain	
			Mean	SD	G.	S.	G.	S.	G.	S.
Monolingual		G.	50	22	-	*[a]	n.s.	n.s.	n.s.	n.s.
		S.	39	19	-	-	n.s.	n.s.	n.s.	n.s.
Bilingual	Germany	G.	47	18	-	-	-	n.s.	n.s.	n.s.
		S.	43	23	-	-	-	-	n.s.	n.s.
	Spain	G.	42	19	-	-	-	-	-	n.s.
		S.	40	17	-	-	-	-	-	-

a * $p<.05$; G: German, S: Spanish

Table 8. Bonferroni test and mean values of rPVI-C scores in German and Spanish monolingual and bilingual groups

					Monolingual		Bilingual Germany		Bilingual Spain	
			Mean	SD	G.	S.	G.	S.	G.	S.
Monolingual		G.	94	43	-	***[b]	n.s.	*[a]	n.s.	*
		S.	54	28	-	-	***	n.s.	***	n.s.
Bilingual	Germany	G.	91	49	-	-	-	n.s.	n.s.	n.s.
		S.	69	39	-	-	-	-	***	n.s.
	Spail	G.	96	53	-	-	-	-	-	*
		S.	70	40	-	-	-	-	-	-

a * p<.05; b *** p<.001; G: German, S: Spanish

3.4 Summary of the Bilingual Analyses

In sum, analyses of vocalic PVIs revealed similar vocalic PVI-scores in the two languages of the bilingual children and no significant differences between the vocalic PVI-scores of monolingual and bilingual groups growing up in either Germany or Spain respectively. Analyses of consonantal PVIs revealed higher consonantal PVI-scores in German than in Spanish, a result that was significant in the case of two children (Manuel and Inés). There were, however, no differences between monolingual and bilingual groups growing up in either Spain or in Germany respectively.

4 Discussion

This study examined rhythmic development in monolingual German, monolingual Spanish and bilingual German-Spanish children at about 3 years of age, using measures based on the mean duration of vocalic and consonantal intervals, as well as on their variability (Grabe and Low, 2002). The first aim of the study was to determine whether there were cross-linguistic differences between the rhythm scores of monolingual German- and monolingual Spanish-speaking children. Consonantal and vocalic variability scores were significantly greater in German than in Spanish, a pattern consistent with the different rhythmic classifications of the two languages (stress- vs. syllable-timing). We note, however, that this finding should be "tempered" to a certain degree since one of the Spanish children had values not very different from those of the German children, suggesting that cross-linguistic differences are still emerging at three-years of age.

The second aim of the study was to compare the rhythmic patterns of bilingual children with those of monolingual children to determine whether they displayed cross-linguistic interaction in rhythmic development. In the case of interaction, we anticipated several different types of patterns, for example, significant differences between the two languages of the bilinguals and between the bilinguals and one of their respective monolingual controls, as seen by Bunta and Ingram (2007) with bilingual Spanish-English children. Non-significant differences between the two languages of the bilinguals was another expected pattern, in case there was a delay in rhythmic development. The study provided evidence for the latter only: bilingual children displayed similar rhythm scores in both German and Spanish with the exception of two children (Manuel and Inés) who obtained different scores with regard to the consonantal indices. There were no differences between the monolingual and the bilingual groups in their respective languages, however.

There were trends in the data, nevertheless, which appeared to support interaction effects. The German PVI-V results of the bilingual children tended to be lower than those of the monolingual German children, a finding consistent with delay in development of stress-timed rhythm, or changes in rhythmic patterns due to the influence of Spanish. The Spanish PVI-C results of the bilingual children were higher than those of the monolingual children, a finding consistent with changes in rhythmic patterns due to the influence of German.

When comparing the two groups of bilingual children, the findings were essentially the same across group. The mean vocalic rhythm scores of monolingual and bilingual children did not differ in German or in Spanish, regardless of country of upbringing. Nevertheless, there was a tendency for the German vocalic rhythm scores to be lower for those children growing up in Spain compared to those growing up in Germany, a phenomenon that may relate to ambient language effects. The consonantal rhythm scores, however, showed some differences in the bilingual condition, as there were significant differences between the two languages of the bilinguals growing up in Spain, but not of those growing up in Germany. However, the significant result of the bilinguals from Spain appears to be influenced by the extreme score of one child, Inés (see Figure 5). Furthermore, these effects go in the opposite direction as one would expect. The German consonantal rhythm scores were greater in Spain than in Germany, but if the ambient language was exerting an effect, the German consonantal rhythm scores should have been less. It thus seems that there is only weak support for the claim that ambient language may influence interaction in bilingual development.

Our findings are consistent with interaction in the rhythmic systems of bilingual children. As mentioned above, this is suggested particularly by the nonsignificant differences between the vocalic variability scores of the two languages of the bilingual speakers. How can this interaction be characterized? Bunta and Ingram (2007) observed an interaction effect in which the stress timing of English tended towards more equal timing, a pattern consistent with either influence from Spanish or with the linguistically less marked pattern of syllable-timing. Kehoe and Lleó (2005) observed the opposite effect in which the syllable timing of Spanish moved towards more variable timing, a pattern consistent with the influence of German. The present study documented a different type of interaction in which there seemed to be a merging of rhythmic patterns. The syllable-timed pattern of Spanish moved towards stress-timing and the stress-timed pattern of German moved towards syllable-timing resulting in a rhythmic pattern that was neither stress- or syllable-timing but rather a compromised pattern. We explore the notion of phonetic compromise later in this paper.

An interesting question is why these findings differ from Bunta and Ingram's (2007) who found that young bilingual children were able to distinguish the rhythmic patterns of their two languages, Spanish and English. One possibility is age. Our subjects were approximately one year younger than Bunta and Ingram's (2007) youngest children (2;9 – 3;1 vs. 3;9 – 4;5). Perhaps, three-year-old children are not yet capable of distinguishing rhythmic patterns, either due to insufficient language exposure or limited phonetic/phonological skills. Bunta and Ingram (2007) observed that vocalic rhythm scores changed significantly between the younger (4;0 – 4;5) and older (4;9 – 5;2) age groups suggesting that age may play an important role in the separation of languages. In addition, we observed that cross-linguistic rhythmic differences were not even fully established in the monolingual children, and the most phonetically and phonologically advanced of the monolingual children were the ones who exhibited the most prototypical rhythmic values (high variability in the case of German; low variability in the case of Spanish). Thus, both the monolingual and bilingual findings are consistent with the fact that three-year-old children may not have developed sufficient control of the timing parameters that make up the perceptual distinction stress- versus syllable-timing.

Another possibility is the constellation of languages. On the continuum of stress-timed languages, British English can be considered an even more extreme example than German because of its increased tendency for vowel reduction (Delattre, 1966; Kaltenbacher, 1997; but see Grabe & Low, 2002). Thus, bilingual children may distinguish rhythmic patterns more easily in the case of extreme differences rather than less extreme differences. Support for this possibility comes from Whitworth's (2002) findings with bilingual children acquiring German and English, two languages with less extreme differences. Despite the fact that the children in her study were relatively "old" (aged 5 to 13 years), they displayed similar rhythm scores in the two languages.

As mentioned in the introduction, an analysis of rhythm based on the variability of vocalic and consonantal intervals is also an implementation of the phonological account of rhythm (Ramus et al., 1999). Therefore, it might be useful to relate the current findings to some previous analyses we have conducted comparing the phonological development of monolingual and bilingual children. In particular, we would like to explain why we measured higher consonantal variability in the productions of Spanish bilingual children as compared to monolingual Spanish children. Some insight might be gleaned from studies conducted on the presence of resyllabification in Spanish, specifically resyllabification occurring between a word ending in a consonant followed by a word beginning with a vowel, as in *balcón alto* 'high balcony'. These studies show that monolingual Spanish children produce high rates of resyllabification, approaching the values of the target language, whereas bilingual children produce much lower rates of resyllabification in Spanish (Munz, 2003; Oltmanns, 2007; Saceda and Lleó, 2009). Thus, the sequence *balcón alto* 'high balcony' is produced as [bal.ko.nal.to] by monolingual Spanish children, whereby the final consonant /n/ is postlexically reanalyzed as the onset of the following syllable, whereas bilingual children tend to produce a glottal stop or a short pause between the two words: [bal.kon./al.to]. Such missing resyllabifications, often combined with glottal stop insertion, might result in more variability in the consonant intervals. This may explain the higher PVI-C scores in the Spanish of some bilinguals.

One further factor we should exclude is the selection of target sentences, in the sense that we (unintentionally) might have selected sentences with uneven complexity of syllable structure for the monolingual or bilingual group of children. For that purpose, we measured the average number of consonant clusters per sentence (normalized for the numbers of syllables per sentence). Results of these measurements showed that there were equivalent numbers or even slightly more of these sequences in the target set for the monolingual Spanish children (Miguel 0.24; José 0.268; María 0.144; Mean = 0.217) than for the bilingual children (Jens 0.269; Manuel 0.171; Simon 0.145; Eva 0.195; Inés 0.178; Carla 0.128; Mean = 0.181) We could thus be reassured that no bias as far as complexity of consonant clusters had creeped into the Spanish data.

It is plausible that the bilingual and monolingual German differed from the bilingual and monolingual Spanish children in the finer temporal aspects, which underlie syllable structure and other phonological structures. These aspects include the way stress and vowel reduction are realized acoustically. These minor phonetic changes may explain why we registered a "compromise" or centralization of values in the bilingual children. We propose that the PVI-V measures are the ones that reflect rhythm per se, whereas the PVI-Cs reflect phonological differences like syllable structure, and resyllabification. Like Bunta and Ingram (2007) we posit that the PVI-V may be a more appropriate measure of rhythm than the PVI-C. Moreover, as we noted above (in section 2.2), PVI-Cs are more influenced by speech rate effects than the PVI-Vs.

In Voice Onset Time (VOT) research, it has been commonly noted that individuals who begin learning a second language as adults often produce "compromise" VOT values, which are intermediate to the VOT values of the two languages (Williams, 1980; Flege and Port, 1981; Flege, 1991). An analogous situation has been reported for rhythm using PVIs. Second language learners of English whose native language is Spanish displayed rhythm values in their English that were intermediate between the low indices of L1 Spanish and the high indices of L1 English (White and Mattys, 2007a). Another example of phonetic compromise, this time in bilingual children, comes from Whitworth's (2000) study of the acquisition of phonological vowel length in two bilingual German-English children (aged 9;11 and 12;5 years). Both children produced tense vowels longer than lax vowels in German and in English; however, the cross-linguistic differences in vowel length ratios were averaged in the speech of the two children. Whereas German lax vowels are half as long as tense vowels (ratio = 0.46) and English lax vowels are two-thirds as long as tense vowels (ratio = 0.70 according to House, 1961), the short-to-long vowel ratio was about .60 in both languages of the bilingual children, a value falling in between the German and English ratios. We speculate that bilingual children may be employing phonetic compromise on a more widespread basis than has been previously documented, that is, they may be applying it in their temporal realizations of consonantal and vocalic intervals, thus leading to similar rhythmic patterns in German and Spanish. Lleó, Rakow and Kehoe (2004) have also found a great deal of overlap between the non-final pitch accents of Spanish and German in the bilingual children, a finding which seems to point in the direction of such phonetic compromise values.

The current findings underscore the need to conduct follow-up testing with the same population of bilingual children during the course of childhood to document changing patterns of rhythmic development. At the moment, we do not know whether the rhythmic patterns of these children remain "overlapping" or become distinct in later childhood, although Bunta and Ingram's (2007) findings would seem to suggest that rhythm values separate early in childhood.

5 Conclusion

Our analysis of the vocalic and consonantal interval timing patterns of bilingual German-Spanish children suggests that the rhythm patterns of bilingual children do not remain separate but interact. Whereas monolingual German and Spanish children displayed different rhythmic patterns, bilingual children tended to display similar rhythmic patterns in their German and Spanish productions. We interpret this pattern as one of phonetic compromise, akin to previous findings in VOT research with bilingual subjects. When comparing bilingual children's results to those of monolingual children, the main differences were the tendency to less vocalic variability in German and greater consonantal variability in Spanish. The first result most clearly evidences rhythmic interaction between the two languages of the bilingual child. The second finding may be related to phonological factors such as syllable structure development and resyllabification. Taking into consideration a certain correlation between PVI-C and phonological factors, and the fact that the main rhythmic differences obtained between rhythmic types in Grabe and Low (2002) pertain to PVI-V, it is reasonable to suggest that the rhythmic measurement directly related to stress-timed vs. syllable-timed languages is the PVI-V rather than the PVI-C. These findings, although preliminary, suggest genuine variation in rhythm of an acoustic-phonetic nature, and point to the vulnerability of prosodic phenomena.

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References

Abercrombie, D. (1967). *Elements of general phonetics*. Edinburgh: University Press.

Allen, G. & Hawkins, S. (1978). The development of phonological rhythm. In A. Bell & J. Hooper (eds.), *Syllables and segments*, pp. 173–185. Amsterdam: North-Holland.

Allen, G. & Hawkins, S. (1980). Phonological rhythm: definition and development. In G. H. Yeni-Komshian, J. F. Kavanagh & C.A. Ferguson (eds.), *Child phonology. Volume 1: Production*, pp. 227–256. New York: Academic Press.

Auer, P. (2001). Silben- und akzentzählende Sprachen. In M. Haspelmath, E. König, W. Oesterreicher & W. Raible (eds.), *Language Typology and Language Universals. An International Handbook*, Vol. 2, pp. 1391–1399. Berlin: de Gruyter.

Auer P. & Uhmann, S. (1988). Silben- und akzentzählende Sprachen. Literaturüberblick und Diskussion. *Zeitschrift für Sprachwissenschaft,* 7, 214–259.

Berg, T. (1991). Phonological processing in a syllable-timed language with pre-final stress: Evidence from Spanish speech error data. *Language and Cognitive Processes*, 6, 265–301.

Bunta, F. & Ingram, D. (2007). The acquisition of speech rhythm by bilingual Spanish- and English-speaking 4- and 5-year-old children. *Journal of Speech, Language, and Hearing,* 50, 999–1014.

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

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

Dauer, R. (1987). Phonetic and phonological components of language rhythm. *Proceedings of the 11th International Congress of Phonetic Sciences*, pp. 447–450. Tallinn, Estonia.

Delattre, P. (1966). A comparison of syllable length conditioning among languages. *International Review of Applied Linguistics*, 4, 183–198.

Flege, J. (1991). Age of learning affects the authenticity of voice-onset time (VOT) in stop consonants produced in a second language. *The Journal of the Acoustical Society of America,* 89, 395–411.

Flege, J. & Port, R. (1981). Cross-linguistic phonetic interference: Arabic to English. *Language and Speech*, 24, 125–146.

Grabe, E. & Low, E. (2002). Durational variability in speech and the rhythm class hypothesis. In C. Gussenhoven & N. Warner (eds.), *Papers in Laboratory Phonology 7*, pp. 515–546. Berlin: Mouton de Gruyter.

Grabe, E., Gut, U., Post, B. & Watson, I. (1999a). The acquisition of rhythm in English, French, and German. In I. Barrière, G. Morgan, S. Chiat & B. Woll (eds.), *Current research in language and communication: Proceedings of the child language seminar*, pp.157–163. London: City University.

Grabe, E., Post, B. & Watson, I. (1999b). The acquisition of rhythm in English and French. *Proceedings of the 14th International Congress of Phonetic Sciences*, *2*, pp. 1201–1204. San Francisco, USA.

House, A. (1961). On vowel duration in English. *The Journal of the Acoustical Society of America*, 33, 1174–1178.

Jusczyk, P. W. (1997). *The discovery of spoken language*. Cambridge, MA: MIT Press.

Kaltenbacher, E. (1997). German speech rhythm in L2 acquisition. In J. Leather & A. James (eds.), *New sounds '97*. *Proceedings of the Third International Symposium on the Acquisition of Second-Language Speech,* pp. 158–166. University of Klagenfurt, Klagenfurt.

Kehoe, M. (2002a). The acquisition of unstressed syllables in bilingual children with a particular focus on vowel reduction. Paper presented at the *Deutsche Gesellschaft für Sprachwissenschaft (DGfS)*. Mannheim, Germany.

Kehoe, M. (2002b). Developing vowel systems as a window to bilingual phonology. *International Journal of Bilingualism*, 6, 315–334.

Kehoe, M. & Lleó, C. (2003). A Phonological Analysis of Schwa in German First Language Acquisition. *Canadian Journal of Linguistics,* 48 (3/4), 289–327.

Kehoe, M. & Lleó, C. (2005). *The emergence of language specific rhythm in German-Spanish bilingual children*. Arbeiten zur Mehrsprachigkeit: Working Papers in Multilingualism 58. Hamburg: SFB 538.

Kehoe, M., Lleó, C. & Rakow, M. (2004). Voice onset time in bilingual German-Spanish children. *Bilingualism: Language and Cognition*, 7, 71–88.

Kehoe, M., Hilaire-Debove, G., Demuth, K. & Lleó, C. (2008). The structure of branching onsets and rising diphthongs: Evidence from the acquisition of French and Spanish. *Language Acquisition*, 15, 5–57.

Kohler, K. (2009). Rhythm in speech and language. A new research paradigm. *Phonetica*, 66, 29–45.

Law, N. & So, L. (2006). The relationship of phonological development and language dominance in bilingual Cantonese-Putonghua children. *International Journal of Bilingualism*, 10, 405–428.

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

Lleó, C. (1996). To spread or not to spread: different styles in the acquisition of Spanish phonology. In B. Bernhardt, J. Gilbert and D. Ingram (eds.), *Proceedings of the UBC International Conference on Phonological Acquisition*, pp. 215–228. Somerville: Cascadilla Press.

Lleó, C. (2002). The role of markedness in the acquisition of complex prosodic structures by German-Spanish bilinguals. *International Journal of Bilingualism*, 6, 291–313.

Lleó, C. (2006). The acquisition of prosodic word structures in Spanish by monolingual and Spanish-German bilingual children. *Language and Speech*, 49 (2), 205–229.

Lleó, C., Kuchenbrandt, I., Kehoe, M. & Trujillo, C. (2003). Syllable final consonants in Spanish and German monolingual and bilingual acquisition. In N. Müller (ed.), *(Non)Vulnerable Domains in Bilingualism*, pp. 191–220. Amsterdam: John Benjamins.

Lleó, C., Rakow, M. & Kehoe, M. (2004). Acquisition of language-specific pitch accent by Spanish and German monolingual and bilingual children. In T. Face (ed.), *Laboratory Approaches to Spanish Phonology*, pp. 3–27. Berlin, New York: Mouton.

Low, E., Grabe, E. & Nolan, F. (2001). Quantitative characteristics of speech rhythm: Syllable-timing in Singapore English. *Language and Speech*, 43, 377–401.

Marks, E., Bond, Z. & Stockmal, V. (2003). Language experience and the representation of phonology in an unknown language. *Revista Española de Lingüística Aplicada*, 16, 23–31.

Müller, N. & Hulk, A. (2000). Crosslinguistic influence in bilingual children: object omissions and root infinitives. In S.C. Howell, S.A. Fish & T. Keith-Lucas (eds.), *Proceedings of the 24th Annual Boston University Conference on anguage Development*, pp. 546–557. Somerville, Mass.: Cascadilla Press.

Munz, N. (2003). *Resilbifizierung im L1-Erwerb des Spanischen*. M.A. Thesis, Universität Hamburg.

Nespor, M. (1990). On the rhythm parameter in phonology. In I. Roca (ed.), *Logical issues in language acquisition*, pp. 157–175. Dordrecht: Foris Publications.

Oltmanns, S. (2007). *Resilbifizierung im L1-Erwerb eines bilingualen deutsch/spanischen Kindes*. M.A. Thesis, Universität Hamburg.

Paradis, J. (2000). Beyond "One System or Two?" Degrees of separation between the languages of French-English bilingual children. In S. Döpke (ed.), *Cross-linguistic structures in simultaneous bilingualism*, pp. 175–200. Amsterdam/Philadelphia: John Benjamins.

Peterson, G. & Lehiste, I. (1960). Duration of syllable nuclei in English. *Journal of the Acoustical Society of America*, 32, 693–703.

Pike, K. (1945). *The intonation of American English*. Ann Arbor, MI: University of Michigan Press.

Ramus, F. (2002). Acoustic correlates of linguistic rhythm: Perspectives. In B. Bel & I. Marlin (eds.), *Proceedings of the Speech Prosody 2002 Conference,* pp. 115–120. Aix-en-Provence: Laboratoire Parole et Langage.

Ramus, F., Nespor, M. & Mehler, J. (1999). Correlates of linguistic rhythm in the speech signal. *Cognition*, 73, 265–292.

Ramus, F., Dupoux, E. & Mehler, J. (2003). The psychological reality of rhythm classes: perceptual studies. In M. Solé, D. Recasens & J. Romero (eds.), *Proceedings of the 15th International Congress of Phonetic Sciences*, pp. 337–342. Barcelona: Universitat Autònoma de Barcelona.

Roach, P. (1982). On the distinction between "stress-timed" and "syllable-timed" languages. In D. Crystal (ed.), *Linguistic controversies*, pp. 73–79. London: Edward Arnold.

Saceda, M. & Lleó, C. (2009). Prosodic transfer of a demarcating language into a grouping language in the development of German-Spanish bilingual phonology. Poster to *PaPI 2009 (Phonetics and Phonology in Iberia)*. Las Palmas de Gran Canaria, Spain.

Vennemann, T. (1991). Syllable structure and syllable cut prosodies in Modern Standard German. In P. Bertinetto, M. Kenstowicz, & M. Loporcaro (eds.), *Certamen Phonologicum II: Papers from the Cortona Phonology Meeting*, pp. 211–243. Turin: Rosenberg and Sellier.

Vihman, M. (1996). *Phonological development: the origins of language in the child*. Oxford: Blackwell.

White, L. & Mattys, S. L. (2007a). Calibrating rhythm: First language and second language studies. *Journal of Phonetics*, 35, 501–522.

White, L. & Mattys, S. L. (2007b). Rhythmic typology and variation in first and second languages. In P. Prieto, J. Mascaró & M.-J. Solé (eds.), *Segmental and Prosodic issues in Romance Phonology. Current Issues in Linguistic Theory series*, pp. 237–257. Amsterdam/Philadelphia: John Benjamins.

Whitworth, N. (2000). Acquisition of VOT, and vowel length by English-German bilinguals: A pilot study. *Leeds Working Papers in Linguistics and Phonetics*, *8* (online publication).

Whitworth, N. (2002). Speech rhythm production in three German-English bilingual families.

Wiget, L., White, L., Schuppler, B., Grenon, I., Rauch, O. & Mattys, S.L. (2010). How stable are acoustic metrics of contrastive speech rhythm? *Journal of the Acoustical Society of America,* 127, 1559–1569.

Williams, L. (1980). Phonetic variation as a function of second-language learning. In G. Yeni-Komshian, J. Kavanagh & C. Ferguson (eds.), *Child Phonology, Vol. 2 Perception*, pp. 185–216. New York: Academic Press.

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