

COMPARISON OF FUNDAMENTAL FREQUENCY IN WELSH AND ENGLISH IN BILINGUAL SPEECH

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ABSTRACT

The study presents the results of cross-linguistic differences in speaking fundamental frequency in Welsh and English in bilinguals' speech. The findings established significant cross-linguistic differences between pitch profiles of Welsh and English. Welsh is produced with wider pitch span. The increase in F0 span is achieved by higher F0 maxima in tone units. This result is not dependent on differences in anatomical constitution of the speakers. These differences are consistent across female bilinguals. The detected within-speaker differences in pitch profiles can be attributed to sociolinguistic factors.

Keywords: bilingual speech, speaking fundamental frequency, pitch, pitch range, pitch level.

1. INTRODUCTION

A number of recent studies have focused on comparing speaking fundamental frequency between languages [14, 16, 10], regional linguistic varieties [8, 7], social groups [19, 2, 12] and confirmed significant and substantial differences in pitch use¹ between linguistic communities. A few studies also concentrated on comparing F0 profiles in first (L1) and second (L2) language speech [15, 18]. Mennen et al. [15] studies pitch use in L2 German produced by native English learners and L2 English produced by native German learners. They found that L2 learners approximated the target features of pitch range at the beginning of the intonational phrases (IPs) – the location of the most substantial cross-linguistic differences between German and English pitch profiles. In the later parts of the IPs more deviations from the target were observed in L2 speech.

Ulbrich [18] found that the differences in pitch profiles between L1 and L2 utterances are

¹ Strictly speaking, the terms fundamental frequency and pitch are not equivalent. Pitch is a perceptual property of frequency. However, in this publication, like in other papers that focus on comparing speaking fundamental frequency between languages and speakers, we used the terms interchangeably.

determined not only by differences in the phonetic realization of pitch accents. Swiss German, Northern German and southern English speakers also reveal phonological differences in inventory and distribution of pitch accents. These phonological differences are transferred to the L2 and are found to affect the accentedness of L2 speech.

Cross-linguistic differences in speaking fundamental frequency in bilinguals' speech still represent an underresearched area of enquiry. We are aware of only one study that compared pitch use in bilingual and monolingual speech, and in the two languages spoken by bilinguals [1]. The authors compared pitch profiles in English spoken by monolingual English speakers and by Russian/English and Cantonese/English female bilinguals. Pitch range in English did not differ between these three groups of speakers. English/Cantonese bilinguals did not differ in pitch use when they switched languages. However, Russian/English bilinguals exhibited higher mean F0 in Russian than in English, thus indicating that bilinguals might have different pitch profiles for the languages in their repertoire. It is not quite clear why bilinguals with certain but not all language pairs have different pitch profiles for the languages, and this issue needs further investigation. The reported study is an initial stage to investigate pitch use by simultaneous Welsh-English bilinguals in an attempt to answer the following research questions: 1) Do Welsh-English bilinguals realize pitch range differently when they use different languages? 2) If so, what dimension(s) of pitch range (i.e. level/span) is/are language-specific?

2. METHOD

2.1. Participants and speech material

We recruited 14 female Welsh-English bilinguals who had been exposed to both languages from birth and reported to have used them on a daily basis in private life as well as in professional activities. All participants were fluent readers both in technical and colloquial styles in both languages. To monitor reading fluency, we asked the participants to read a

specialized text on history of the Welsh (for technical style in Welsh) or English (for the technical style in English) languages. We also asked the participants to read a selection of colloquial sentences in both languages. We recorded them reading the texts and sentences. The participants were randomly assigned to one of the two groups. The first group of the speakers first read the text and sentences in Welsh followed by English. The other group first read English text and sentences, followed by Welsh. The recordings were made in a quiet place at 44kHz, 16 bit, in PCI format, using a condenser microphone attached to a handheld Marantz PMD 660 Solid State Recorder.

Thirty sentences were read in English and in Welsh by each participant. We excluded from the acoustic analysis the last sentence and the first 9 sentences, and left only 20 sentences per speaker per language. This was done to remove a possible effect of pitch lowering on the last sentence toward the end of the list of sentences, and a possible effect of pitch range readjusting when switching into a different language.

2.2. Acoustic measures of F0 range

The definition of pitch range is not precise, and researchers have applied different measures to capture the cross-linguistic, between- and within-speakers differences in speaking fundamental frequency. In our study we analyzed pitch range along two different dimensions: pitch level and span. Three measures for pitch level were defined: 1) speaker's F0 maximum peaks on each tone unit², 2) speaker's F0 minimum valley (excluding creaky intervals) on a tone unit; 3) mean pitch on a tone unit as measured by Praat [6] using autocorrelation algorithm, 0.01 sec. time step, default settings for voicing threshold. Pitch span on each tone unit was determined as the difference in semitones (ST) between the speaker's F0 maximum and F0 minimum.

For the initial analysis of pitch range in bilingual speech, we decided to limit our investigation to purely phonetic measures. Welsh and English intonation systems reveal a number of consistent differences. For example, pitch accents in English are aligned with the syllables that bear lexical stress. Accented syllables increase in duration and intensity. Syllables that carry lexical stress in Welsh exhibit shorter durations and lower intensity than in English [22].

² Tone unit is defined as an utterance that is produced on a continuous airstream. Each of the recorded sentences consisted of at least two tone units. Tone units in the recorded speech material correspond to the syntactic and prosodic constituents.

Besides, we have detected differences in the local F0 events. H* or H*+L accents are predominant in English material we have recorded and analysed, while Welsh accents are better labeled as L+H*. We cannot be certain at the moment whether this is a systemic difference that refers to the inventory and distribution of structural elements in Welsh and English, or whether we are merely dealing with different phonetic realizations of the same phonological primitive. Taking these differences and uncertainty into consideration, we decided to concentrate on the analysis of phonetic F0 maxima and minima to measure pitch span and level, assuming that absolute F0 peaks and valleys are less affected by intonation than many other measures of pitch range.

2.3. Statistical analysis

We wanted to compare pitch profiles between languages within speakers. At first, we verified whether distributions of these measures were normal for each speaker. Some samples revealed significant deviations from normality. Thus we applied non-parametric statistical tests. This also complied with the common recommendations to apply non-parametric tests to study cross-linguistic differences in pitch range [16].

3. RESULTS

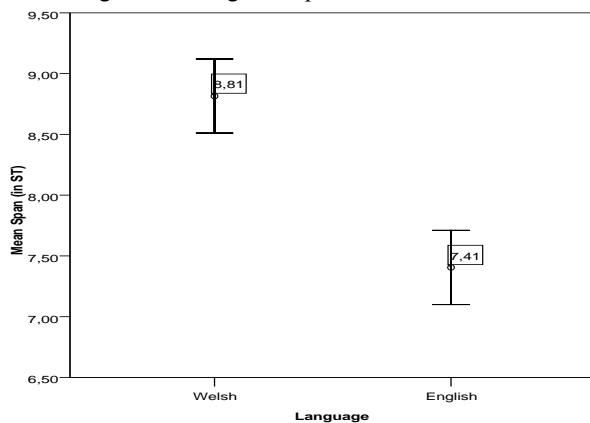
3.1. Overall results

We averaged the measures of F0 span and level across all tone units for each speaker, and used Wilcoxon signed rank test to investigate whether the differences in pitch range in Welsh and English are significant. The test revealed that Welsh-English bilinguals exploit higher pitch span in Welsh compared to English, $z = -3.17$, $p = 0.002$, $r = 0.6$ (Fig. 1). The mean cross-linguistic difference is 1.4 ST. F0 maxima are also higher in Welsh than in English, $z = -3.233$, $p = 0.001$, $r = 0.61$ (Fig. 2). The average difference is 1.37 ST.

F0 minima reveal significant differences between Welsh and English sentences, $z = -2.166$, $p = .03$. However, regardless of the medium effect size, $r = .41$, the difference of .23 ST is neither substantial nor perceptually relevant. Average F0 minimum in Welsh is 164 Hz, and 166Hz in English, which is 1.2% difference in frequency, or 0.02 Barks. For this difference to be perceptually discriminable, the duration of two sequentially presented tones should be at least 500 msec [11: 185-187]. Speech intervals with minimum F0 values are shorter and are not presented sequentially. Moreover, such small differences can also be caused by random variation

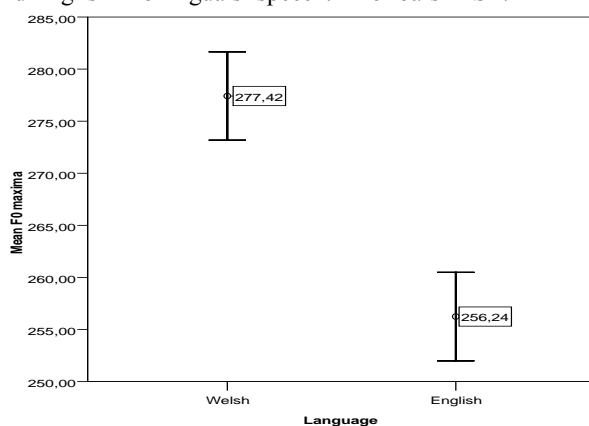
of vowels with different intrinsic F0 in the syllables aligned with F0 minima [21, 17]. Differences in vowel intrinsic F0 far exceed those we have determined for mean F0 local minima in Welsh and English. Absolute minimum F0 in tone units is most likely physiologically determined and does not have a linguistic function [3], unlike local F0 valleys, or relative F0 minima, that are used for L tones.

Figure 1: The difference between F0 span in Welsh and English in bilinguals' speech. Error bars $\pm 2SE$.



The difference in mean F0 is not significant, $z = -1.852$, $p = .064$ and only amounts to 0.5ST or 0.07 Barks, which is 2.76% (217Hz in Welsh and 211 Hz in English). Although this difference will be perceptually relevant for two consecutively presented 500ms long pure tones, it is hardly perceivable as the mean difference in F0 between two tone units.

Figure 2: The difference between F0 max. in Welsh and English in bilinguals' speech. Error bars $\pm 2SE$.



3.2. Individual results

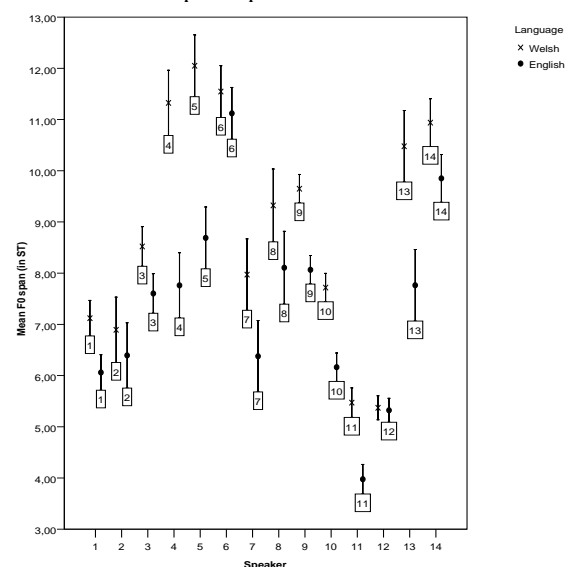
The measurements averaged across languages and speakers show that Welsh and English pitch profiles of bilinguals differ in F0 span and level. The difference in level lies in the difference of absolute F0 maxima on tone units. As F0 span on each tone

unit was measured as the difference between F0 absolute minimum and maximum, and F0 minima do not differ within speakers between languages, we can conclude that span in Welsh is wider due to higher F0 peaks. In further analysis, we wanted to see whether the detected trend is also valid for each individual bilingual. For this, we performed tests for the data from each individual bilingual.

Table 1: Significance of cross-linguistic differences in pitch profiles between Welsh and English. One star stands for significance at $p < .05$, two stars stand for significance at $p < .001$.

SPEAKER	F0span	F0max	F0mean	F0min
1	*	**	**	n/s
2	n/s	n/s	n/s	n/s
3	*	**	**	n/s
4	**	**	**	n/s
5	**	**	**	n/s
6	n/s	n/s	n/s	n/s
7	**	**	n/s	n/s
8	*	**	**	n/s
9	**	**	**	n/s
10	**	**	**	n/s
11	**	**	n/s	*
12	n/s	n/s	n/s	n/s
13	**	**	n/s	n/s
14	*	n/s	n/s	n/s

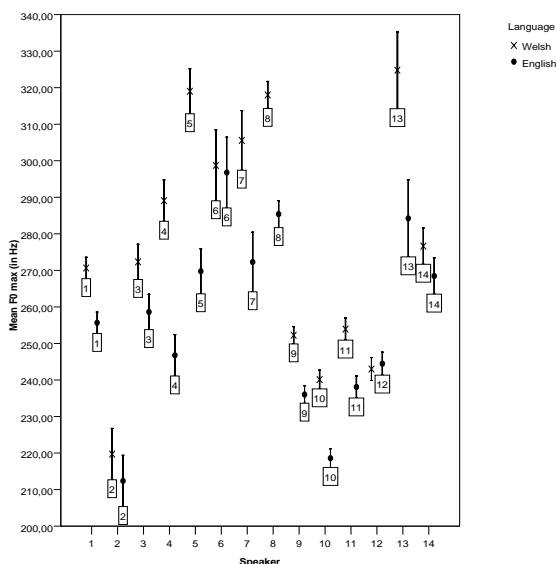
Figure 3: Individual differences between F0 span in Welsh and English in bilinguals' speech. Numbers on the bars mean participant numbers. Error bars $\pm 2SE$.



The analysis showed that the trend is consistent across most speakers. F0 span in Welsh is significantly wider in productions of 11 out of 14 speakers (table 1). In productions of the other three speakers, pitch span in Welsh is also wider than in English, but the difference does not reach significance (Fig. 3). The difference between F0

maxima in Welsh and English did not reach significance in productions of these three bilinguals, either. However, this difference in F0 peak values was significant for the other 11 speakers (Fig. 4). Individual Welsh and English pitch profiles do not differ in terms of F0 minima, with the exception of speaker 11, who has slightly (0.4ST) higher F0 minima in English than in Welsh. Mean F0 differs cross-linguistically in the speech of 7 bilinguals, 6 bilinguals have higher mean pitch in Welsh, and speaker 9 reveals a higher mean pitch in English. As F0 minima values do not reveal cross-linguistic differences, we believe that the differences in mean F0 are the consequences of higher F0 maxima and wider F0 span in Welsh compared to those in English. Bilinguals enhance pitch span by increasing the F0 peaks, and the other differences between pitch profiles arise from that.

Figure 4: Individual differences between F0 maxima in Welsh and English in bilinguals' speech. Numbers on the graphs stand for the participant's number. Error bars $\pm 2SE$.



4. DISCUSSION

The differences in pitch range can be explained 1) by differences in intonation systems of languages in terms of inventory, distribution and realization of pitch accents [16]; 2) by differences in anatomical constitution of speakers [3, 20, 5, 12]; 3) by typological characteristics of tone vs. intonational languages [10, 14]; 4) stylistic variation [4]; and 5) social factors [19, 20, 9, 12].

Considering the type of measurements we made, it is hardly possible that the detected differences in Welsh and English pitch profiles are determined by intonational phonology of the languages under investigation. We measured absolute F0 maximum and minimum on each tone unit. This approach is

different from the one undertaken by Mennen et al. [15, 16]. We did not measure relative F0 peaks and valleys associated with intonational primitives. We measured absolute values of F0, which are determined by language-specific settings for the voice profile, not by intonational structures. Our investigation shows that the settings are different for the absolute maxima, and not for absolute minima. Mean F0 values for each tone unit that were calculated by averaging F0 every 0.01 sec are more likely to be influenced by differences in inventory and distribution of pitch accents. We indeed found that mean F0 is higher in Welsh in speech of 6 bilinguals, but this higher mean F0 is not systematic because 7 bilinguals in our samples do not reveal cross-linguistic differences in mean F0, and one bilingual exhibited higher mean F0 in English. Differences in absolute F0 maxima and span are consistent across most speakers in our sample.

The differences in anatomical constitution also do not account for the detected cross-linguistic differences in speaking fundamental frequency because we used a within-subject design. All subjects performed the same task in the same environment, therefore we believe that stylistic and situational factors are unlikely to have influenced the obtained results. Both Welsh and English are intonational languages, and the typological characteristics that are known to influence pitch range do not differ between the languages under study. Thus we think that the most likely factors accounting for the differences in F0 range between English and Welsh in bilingual speech are social.

There are two possible social factors that might explain wider pitch span and higher maxima in Welsh in bilinguals' speech. Welsh in Northern Wales is a language of prestige, and people are proud to be able to speak it, to emphasize the national identity by using the native language. Thus they might specifically enhance F0 span when they switch into the language to which they feel emotional attachment.

It is also possible that Welsh is a likely home language for most bilinguals in Northern Wales, and parents speak Welsh to their children more readily than English. Child-directed speech usually exhibits higher F0 maxima [13]. This, in turn, might lead to spoken Welsh acquiring some phonetic features of "motherese", including higher F0 maxima.

Further study is deemed necessary to establish the role of social factors when comparing speaking fundamental frequency in different languages. Social factors should be considered alongside with phonological, typological, phonetic, individual and stylistic effects.

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