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Between- and Within-Speaker Effects of Bilingualism on F0 Variation

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Abstract

To what extent is prosody shaped by cultural and social factors? Existing research has shown that an individual bilingual speaker exhibits differences in framing, ideology, and personality when speaking their two languages. To understand whether these differences extend to prosody we study F0 variation in a corpus of interviews with German-Italian and German-French bilingual speakers. We find two primary effects. First, a *between-speaker* effect: these two groups of bilinguals make different use of F0 even when they are all speaking German. Second, a *within-speaker* effect: bilinguals use F0 differently depending on which language they are speaking, differences that are consistent across speakers. These effects are modulated strongly by gender, suggesting that language-specific social positioning may play a central role. These results have important implications for our understanding of bilingualism and cross-cultural linguistic difference in general. Prosody appears to be a moving target rather than a stable feature, as speakers use prosodic variation to position themselves on cultural and social axes like linguistic context and gender.

Index Terms: bilingualism, F0, prosody, cross-cultural differences, sociophonetic variation, speaking fundamental frequency

1. Introduction

Fundamental frequency (F0) is used differentially by speakers to convey emotion [1, 2, 3], focus [4, 5, 6], engagement [7, 8, 9], and discourse structure [10, 11, 12]. This variation is typically assumed to be relative to some speaker-specific baseline, referred to as a "speaking fundamental frequency" or SF0 [13, 14]. Across speakers, SF0 has been correlated with physiological attributes such as vocal tract length [15] as well as relatively stable social attributes of a speaker such as gender [16], age [17], and personality [18, 19]. Indeed, the relevance of these factors is confirmed in part by the fact that prosodic features have often been successfully used to improve the performance of speaker recognition systems [20, 21, 22].

Nevertheless, a variety of recent research has called into question the idea that SF0 depends on attributes of the talker alone; in particular, SF0 varies across languages or cultures. For example, speakers of English tend to use higher F0 mean and variance compared with speakers of German [23], and native speakers of English tend to use a higher F0 mean and variance compared to English second-language (L2) speakers whose native language (L1) is Italian [24].

It follows to ask whether such cultural or social variation can take place within the same speaker, and if so how it takes place. Bilinguals provide a natural source of data to pursue this question. Psychological studies suggest that bicultural individuals are able to gain independent competence in both cultural contexts [25], and linguistic research on bilinguals has confirmed this analysis, identifying differences within individual speakers in expressed culturally-specific ideology [26] as well as "cultural frame switching" of personality traits concordant with the speech community of the language being spoken [27].

In the case of prosody, within-speaker variation for bilinguals by language has also been demonstrated in several cases. Comparing Japanese-English bilinguals, [28] found that women (but not men) use a higher F0 mean in Japanese than in English, and [29] showed bilinguals to exhibit more F0 variability when speaking English than Japanese. [30] found that Welsh-English bilinguals use more F0 variability when speaking Welsh. [31] compared Russian-English and Cantonese-English bilinguals to English monolinguals, finding some within-speaker effects (Russian-English bilinguals used higher F0 mean in Russian), but no differences between groups when speaking English.

These findings, however, leave important open questions. For one, we need to explore a much wider variety of bilingual language pairs, and consider languages other than English. Prior studies were done with relatively small datasets – both in terms of the number of speakers and the quantity of speech observed – and in relatively controlled experimental conditions such as reading lists of sentences: do these results generalize to naturalistic speech across larger numbers of speakers?

Furthermore, the role of gender in particular is understudied. Most studies only look at a single gender; those that study gender have found gender differences only between very different languages (e.g., Japanese and English, which may be very distant culturally as well as in linguistic aspects like stress- vs. syllable-timing [28]). Would we find gender differences in more similar languages?

Lastly, although [31] found no effect across groups of bilingual speakers in F0 usage while speaking a shared language (Russian-English and Cantonese-English bilinguals speaking English), does this always hold, or do some groups of bilinguals display differences when speaking a shared language?

In this study we address these questions by examining F0 variation in a corpus of naturalistic interviews with German-Italian and German-French bilingual speakers. The corpus is much larger than the datasets examined in previous studies, and is balanced by gender and bilingual group, allowing us to systematically examine the interaction between gender and bilingualism with regards to within-speaker F0 variation. Since the two groups share a language in common (German), we can also explore between-speaker variation across groups when they are all speaking a common language.

2. Data

For this study, we use the Hamburg Adult Bilingual Language (HABLA) corpus of interviews with German-Italian and German-French bilingual speakers [32]. The interactions are loosely structured interviews touching on personal topics like

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place of origin, languages spoken in the family, books and movies, and cultural stereotypes.

The collection of this dataset was originally driven by acquisition-related questions related to syntax, attrition, and so on; however, in many ways it is ideal to be adapted for our purposes. The interviews are relatively casual, akin to sociolinguistic interviews, so we anticipate speakers to gravitate towards a more naturalistic speaking style. The topics are somewhat constrained, so we have no reason to suspect a systematic bias in topic across speakers.

Though the dataset contains some L2 speakers, we use only the 2L1 speakers: that is, those who natively acquired German and either French or Italian from birth, with at least one parent speaking each language, and spoke both languages in the home until at least the age of six. This results in 45 speakers, well balanced for gender and language: our sample contains 23 women and 22 men, of whom 25 are German-French bilinguals and 20 are German-Italian bilinguals.

For each speaker the dataset contains two interviews, one for each language, collected on different occasions. Each interview is approximately 20-30 minutes long, and the subset of the corpus we are working with is more than 42 total hours in length.

2.1. Preprocessing

We preprocess all the data into a usable format for the analyses to follow. The data is annotated with transcripts, aligned throughout to turn-sized chunks of speech which we will refer to as “phrases.”

All data is recorded in mono, with both the interviewer and the participant on the same track. The transcripts, however, are aligned on separate tiers for each speaker, so we use all phrases from the participant, but adopt a conservative approach by removing all phrases in which the interviewer’s annotated phrase had any overlap with the participant. We then use *Praat* to extract F0 measurements for all voiced segments of each phrase using the autocorrelation method. [33]

In this study, we adopt simple measures of F0 height and span from the existing literature. For F0 height we use the mean F0 in a phrase [23], and for F0 variance we use the standard deviation of F0 in a phrase [34]. All statistical models to be presented aim to predict these two measurements from contextual elements like the speaker’s current language, and control for the log duration of the phrase in which they were spoken.

After preprocessing, we obtain measurements for 19,849 phrases which we treat as observations in our statistical models. The phrases have a median length of 3.7 seconds, and in total represent 23.95 hours of speech from participants. In the following experiments, since we are interested in whether particular features are relevant to F0 usage, we will primarily be concerned with the statistical significance of particular predictors rather than the overall predictiveness of the models, which will naturally be tied to many of the other linguistic and paralinguistic functions mentioned in the introduction.

3. Within-speaker Differences

We first aim to expand upon prior work by asking whether our two groups of bilinguals exhibit within-speaker differences in the use of F0 when speaking each of their different languages. A null hypothesis would suggest speakers use F0 similarly when speaking either language.

For the experiment in this section we divide the data into two sets: 10,703 phrases spoken by German-French speakers and 9,146 phrases spoken by German-Italian speakers.

3.1. Statistical Models

We model these questions with linear mixed-effects regressions [35] predicting our two dependent variables of interest, F0 mean and F0 variance. We model speakers as a random effect, so each speaker has their own intercept in the model, and all variation is taken to be relative to a given speaker’s mean.

As independent variables we include the log duration of the phrase, the gender of the speaker, which of their two languages they are speaking for a given phrase, and an interaction effect between gender and language.

3.2. Results: F0 Mean

Model outputs are given in Table 1.

Looking first at F0 mean models for German-French bilinguals, all effects were significant. German-French bilinguals overall used a higher F0 mean when speaking French as opposed to German, but a significant negative interaction effect between gender and language means that in fact this trend is driven by women. As seen in Figure 1, when German-French men and women speak French their F0 means are more distant from each other than when they speak German.

Table 1: Within-speaker results for F0 mean comparing German-French and German-Italian speakers to themselves when speaking German or French. Reference levels are female and phrases spoken in German.

	German-French	*German-Italian*
Phrase Duration	-3.303^{***}	-12.612^{***}
Gender (Male)	-83.322^{***}	-56.625^{*}
Current Language (French)	2.848^{*}	
Current Language (Italian)		-18.281^{***}
Gender * Language	-12.539^{***}	28.981^{***}
Constant	240.181^{***}	259.129^{***}
Observations	10,703	9,146

$^{\bullet}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$, $^{***}p<0.001$

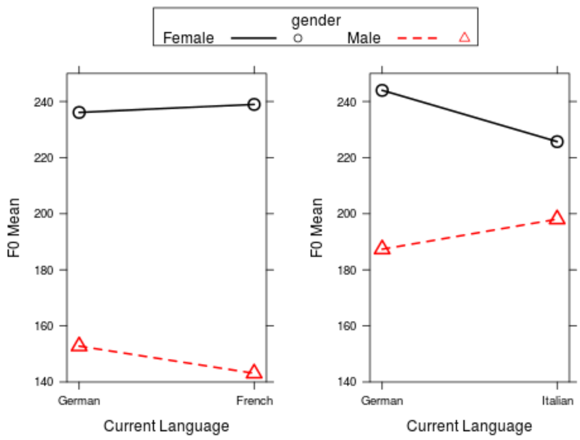

Figure 1: Within-speaker F0 mean for German-French and German-Italian bilinguals; effect display [36] showing interaction between current language of the phrase and gender.

Considering German-Italian bilinguals, again all effects were significant. These bilinguals tend to use a lower F0 mean when speaking Italian as opposed to German, but again the interaction effect indicates this main effect is driven by women. As Figure 1 shows, men actually use a higher F0 mean in Italian. In this case, German-Italian men and women speak with a more similar F0 mean to each other when speaking Italian than when speaking German.

3.3. Results: F0 Variance

Model outputs are given in Table 2.

With the F0 variance model, considering German-French speakers, language was not a main effect, but there was a strong negative interaction effect between language and gender. Figure 2 makes clear that for German-French bilinguals, interestingly men "cross over" women in terms of F0 variance when moving from German to French: while women's F0 variance does not change across languages, in German men have a higher F0 variance than women while in French it is lower.

Considering German-Italian speakers, all effects were significant. Overall these speakers used less F0 variance in Italian than in German, but a strong interaction effect with gender shows a "cross over" effect like for German-French speakers but with a trend in the opposite direction. In German women use slightly higher F0 variance than men, but in Italian the situation is reversed.

Table 2: Within-speaker results for F0 variance comparing German-French and German-Italian speakers to themselves when speaking German or French. Reference levels are female and phrases spoken in German.

	German-French	*German-Italian*
Phrase Length	8.770***	7.899***
Gender (Male)	13.200	−9.654
Current Language (French)	0.293	
Current Language (Italian)		−14.543***
Gender * Language	−30.763***	35.074***
Constant	68.359***	87.859***
Observations	10,703	9,146

•p<0.1; *p<0.05; **p<0.01, ***p<0.001

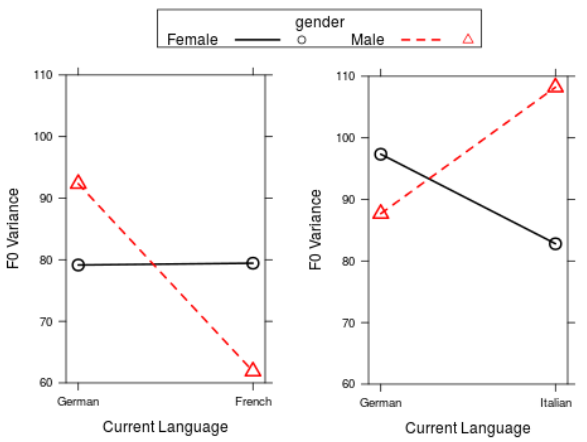

Figure 2: Within-speaker F0 variance for German-French and German-Italian bilinguals; effect display showing interaction between current language of the phrase and gender.

4. Group Differences in German

Having observed within-speaker differences, we now ask whether distinct groups of bilingual speakers may display differences to baseline SF0 even when they are speaking the same language. Given existing results on the cultural specificity of F0 usage, a null hypothesis would suggest that since all these bilingual speakers natively speak German from birth, when speaking German – the same linguistic and cultural context – these two groups would display no difference.

Because this dataset contains two distinct groups of bilinguals with an overlapping language (German), it provides a unique opportunity for us to investigate this hypothesis by comparing these groups' F0 usage only in phrases in which they are speaking German.

4.1. Statistical Model

We model this question with a linear regression at the phrase level predicting our two variables of interest, F0 mean and variance. As independent variables we include the log duration of the phrase, the gender of the speaker, the speaker's bilingual group (German-Italian or German-French), and an interaction effect between gender and group.

Unlike the models in Section 3, this model does not control for within-speaker variation. Because we are interested in whether these differences are consistent across speakers, and speakers have varying numbers of phrases in the dataset, we subsample our dataset by randomly selecting a number of observations for each speaker equal to the lowest number of observations for any speaker. We remove five speakers with particularly few observations in German, leaving us with 4,440 phrases for 20 speakers, ten men and ten women. Though we report results on this subsampled dataset, they are consistent with what we find without subsampling.

4.2. Results

Model outputs are given in Table 3.

For both the F0 mean and variance models all main effects were significant, as was the gender and group interaction effect.

Overall in this dataset, longer phrases and those spoken by men had a lower F0 mean but higher F0 variance. Interestingly, however, there was a main effect for group, such that phrases spoken by German-Italian bilinguals had a higher F0 mean and variance.

Furthermore, both models had significant interaction effects, visualized in Figure 3. For F0 mean, the interaction effect shows that German-Italian men are more different from German-French men than German-Italian women are from German-French women. For F0 variance, the effect shows that German-Italian women are using much more F0 variation than German-French women, while for men the trend is reversed, and German-Italian men are using less F0 variation than German-French men.

These interaction effects also suggest that perhaps more crucially than raw frequency differences, the distance between men and women is the more central element. In this case, German-French men and women are more distant from one another in F0 mean, while German-Italian men and women are closer to one another.

Table 3: Between-speaker results comparing German-French and German-Italian bilinguals while speaking German. Reference categories are a female and a second language of French.

	Dependent variable:	
	F0 mean	F0 variance
Phrase Duration	-11.678^{***}	5.297^{***}
Gender (Male)	-80.102^{***}	18.413^{***}
Second Language (Italian)	24.182^{*}	24.405^{***}
Gender * Second Language	24.182^{***}	-21.782^{***}
Constant	249.481^{***}	68.825^{***}
Observations	4,440	

$^{\bullet}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$, $^{***}p<0.001$

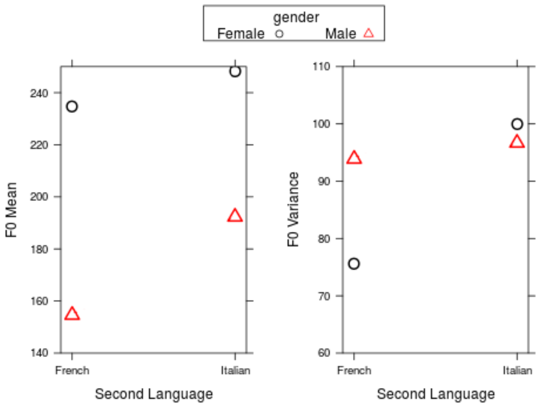

Figure 3: Between-speaker group differences for German-French and German-Italian bilinguals when speaking German, blocked by gender.

5. Discussion

This study confirms and extends existing findings about social and cultural influences on the use of F0. We found first that indeed, bilingual speakers in our dataset use F0 differently in each of their languages (Section 3). This result adds to existing evidence that SF0 is dependent not only on physical, structural, and contextual factors, but that culture can play an important role, and represents the first such finding for bilinguals speaking languages other than English.

We also showed that these two groups of bilinguals are separable in terms of F0 variance even when they are speaking their second native language, a phenomenon not previously reported in the literature on bilinguals (Section 4). This suggests that in spite of observed differences from cultural factors, bilinguals do not necessarily transfer wholesale from one linguistic-cultural context to another when they switch languages. Cultural background from other contexts and other available languages within a speaker may also influence positioning with regards to SF0.

This study is the first to find conclusive differences with regards to gender; men and women of both groups used F0 differently by language. We found that for German-French bilinguals, the distance in F0 mean between men and women increases when they speak French as opposed to German; conversely, this distance shrinks for German-Italian bilinguals when they speak Italian as opposed to German.

Furthermore, observed differences in German as an overlap language between our two groups of bilingual speakers help contextualize our findings with regards to gender. Even when speaking German, German-French men and women already displayed a greater distance between their SF0 than German-Italian men and women, and indeed these differences were intensified when not speaking German. This finding builds on existing work in speaker normalization showing male-female distance in vowel spaces varies across cultures and languages, in ways that cannot be explained by physical parameters alone [37, 38].

Our findings show that gender absolutely cannot be ignored in studies of SF0. Indeed, the divergent behavior of men and women in our data is such that had we not addressed it systematically, in both cases we would have found erroneous within-speaker effects. In the German-French case, not controlling for gender yields a negative main effect of language; controlling for gender we see this is because for these speakers men's F0 declines more than women's F0 increases when speaking French as compared to German. In the German-Italian case, we would have found an erroneous null effect. Since the German-Italian men and women vary in such directly opposite ways, a model not accounting for gender finds no difference across languages based on which language is being spoken; in fact, we observe substantial differences.

These findings suggest an important role for social factors in general in SF0. What feels "natural" or what it means to be male or female may differ with language or socio-cultural context, and this may have effects not only for speakers when using the language in question, but throughout their idiolectical linguistic system.

Existing work on language choice has shown that bilingual speakers are perceived more favorably the more they accommodate listeners [39], and furthermore listeners have been shown to mediate the role of F0 in vowel normalization by perceived speaker identity [40]; one possible explanation of our results is that a sensitivity to these culturally-specific perceptual cues influences speakers to try to better "fit" in the context of the current speaking situation.

Other linguistic and social constraints may also be involved. In the English-Japanese case [29], the authors note a difference in SF0 may be attributable in part to differences in prosodic phonology between the two languages: English has a wide range of available pitch accents while Japanese has only one. Our findings differ in that we find opposite trends across two languages from the same language family (French and Italian), suggesting a reduced importance of this factor. In the English-Welsh context, [30] mention the potential significance of prestige language effects as well as which parent spoke which language. This seems less of a factor in our findings, since we have a larger group of speakers living in all three countries in question, with a mix of which parents speak which language.

Our findings may have implications for engineering applications as well. Given that speech recognition systems may rely on assumptions of a stable SF0 per speaker, when within-speaker SF0 variation occurs along axes of socio-cultural context, this assumption may have to be relaxed.

Other linguistic and prosodic features beyond F0 are implicated in social meaning, and social variables beyond gender are implicated in the construction of identity; future work may consider how features such as intensity, speech rate, or rhythm and social variables such as class, race, and education level might influence these dynamics both within and between speakers.

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