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GENDER AND FUNDAMENTAL FREQUENCY IN ENGLISH/FRENCH BILINGUAL SPEAKERS

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The present study deals with the productions of English/French bilingual speakers in a reading task and in semi-spontaneous speech. Average fundamental frequency (F0), F0 range and F0 standard deviation were measured in both languages. Results show a significant effect of gender and language on all these parameters. Overall, average F0 was higher in French while F0 modulation was stronger in English. Regardless of language, female speakers exhibited higher F0 than males. Moreover, the increase of average F0 in French was larger in female speakers. On the other hand, the decrease of F0 modulation in French was stronger for male speakers. These data support the idea of language- and gender-specific vocal norms, to which bilingual speakers seem to adapt.

Key words: fundamental frequency, intonation, bilingualism, voice and gender, cross-language variation

Introduction

Over the last decades, many studies have been conducted on acoustic differences between female and male speech. Most of them focussed on fundamental frequency (F0) and resonant frequencies. These parameters are indeed considered as the two main cross-gender differences. Some authors investigated cross-gender F0 differences in several languages (e.g. Traunmüller & Eriksson, 1995), but very few were interested in intra-individual variations that occur when bilingual speakers switch from one language to another. We suggest that the study of these variations can help us reconsider the traditional approach of F0, in which it is presented as mostly dependent on the speaker's anatomy. On the contrary, we support a more dynamic approach, taking into account culture-related gender differences.

Acoustically, F0 is usually lower in male voices (Boë et al., 1975). This acoustic difference between males and females is partly due to developmental differences in the vocal apparatus that emerge during puberty. Vocal folds are

then becoming longer and thicker in males (Kahane, 1978; Abitbol et al., 1999). This is one of the reasons why vocal folds are usually vibrating more slowly in male speakers. Additionally to hormones, other factors such as age (Honjo, Isshiki, 1980) and cigarette consumption (Matar, 2016) have an effect on the vocal folds, causing a modification of the average F0.

However, in the study of voice and speech, anatomical and social factors are inextricable. For instance, voice and speech are involved in the social construction of gender identities (Arnold, 2015; Pépiot, 2014a). Each speaker has a unique vocal apparatus with a given shape (influencing F0 and resonant frequencies) and uses it to index a specific gender identity. Therefore, a voice is never the sole reflection of anatomy, but also the result of a gendered performance. Typically, women use certain articulatory practices to produce relatively clear and high-pitched voices, while men use other practices to achieve relatively dark and low-pitched voices (Arnold, 2016).

Other acoustic parameters such as F0 range or more generally, F0 modulation, could also exhibit cross-gender differences: female speakers would tend to use greater F0 modulation and range than males (Austin, 1965; Lakoff, 1975, p.56). However, these results are still debated. On the one hand, when using the semitone scale (more representative of human perception than the Hertz scale), Henton (1989; 1995) found no significant female / male differences in F0 modulations in American English speakers. On the other hand, Pépiot (2014b) used the same method and found significant cross-gender differences in French speakers: female speakers were actually modulating more than males. Such findings suggest that cross-gender differences on F0 range / modulation could be language-related.

What about bilingual speakers, then? Do they adapt to gender-related norms in different languages? These questions have not sparked much interest and have, until now, not been thoroughly investigated. A few studies conducted on bilingual speakers showed that their average F0 depended on the language they used (Altenberg, Ferrand, 2006; Lee, Van Lanker Sidtis, 2017). Similar results were found for F0 range (Mennen et al., 2012). In their 2006 study, Altenberg and Ferrand showed that Russian L1 / English L2 bilingual female speakers tended to exhibit a lower F0 in English. However, this analysis was only conducted on the production of female speakers: it is then impossible to know whether the variation was an adaptation to gender norms, or simply to language norms (regardless of gender).

In the present study, we decided to investigate the productions of English L1 / French L2 bilingual speakers, by measuring their F0 in different conditions (reading and spontaneous speech). Our hypothesis is

that *bilingual speakers will adapt their vocal practices accordingly to gender norms of the language they are using*.

1. Material and method

1.1 Linguistic material

This study is based on the analysis of French and English material. This material was collected through two different tasks.

The first one was a reading task. Each speaker had to read 12 sentences in English (such as *"When the weather is cold and rainy, I'd rather stay at home."; "My sister told me she'd come by tomorrow."; "If you do that again, I'll call the police!";* etc.) and 12 similar sentences in French *("Quand il fait froid et qu'il pleut, je préfère rester chez moi"*; *"Ma soeur m'a dit qu'elle allait passer demain."*; *"Si tu refais ça, j'appelle la police !"*; etc.).

During the second task the speakers had to produce semi-spontaneous speech. Speakers were invited to talk about their last vacation. The narration was initiated with the following sentences: *"Tell me about your last vacation"* (in English) and "*Parlez-moi de vos dernières vacances"* (in French).

1.2 Speakers

Twelve English L1 / French L2 bilingual speakers (6 women, 6 men) were recorded for this study. They were North-Eastern American speakers who had been living in Paris for several years. All of them used French on a daily basis and their self-reported fluency level in this language was superior or equal to 3, on a scale going from 0 to 5 (questionnaire inspired by Grosjean, 2013).

These participants were 29 to 54 years old (SD = 7.6 years) when the recording took place. The average age was 40 for male speakers and 41.8 for female speakers. They were all non-smokers, and reported no speech disorder. Each of them received a USB stick for their participation in the study.

1.3 Recording procedure

Recordings took place in a quiet room, using a digital recorder *Edirol R09-HR* by Roland. Each participant was asked to perform the tasks described above (see 1.1): the reading of sentences (two readings per item) and the narration about their last vacation. The participants performed these tasks in both French and English. Half of the speakers started with French, the other half with English, in order to neutralise possible biases caused by the order of usage of the different languages (see Altenberg & Ferrand, 2006).

1.4 Data analysis

The acoustic analysis was conducted in *Praat* (Boersma, 2017). We analysed the following parameters on read sentences and spontaneous speech:

• Average F0

• F0 range, which corresponds to the difference between the highest and the lowest F0 within a given linguistic unit.

• Standard deviation of F0 (SD), a parameter that shows the modulation of F0 (mean difference between each point of the F0 curve and average F0).

These data were obtained by creating a "pitch file" for each sentence / discourse and then collecting the values in the "pitch info" window. F0 range and SD were measured in Hertz but also in semitones. This scale is indeed particularly appropriate because it takes into account the variations of pitch as they are perceived by human listeners (Henton, 1995).

Data were then statistically tested with ANOVAs, in order to investigate the influence of the factors "*spoken language*" and "*gender*".

2. Results

2.1 Read sentences

Average F0 for female and male speakers in read sentences are presented in Table 1, below.

	Average F0 – Reading task (Hz)		
Speakers	**English**	**French**	**% diff. FR/EN**
F1	195	211	**+8.28**
F2	224	234	**+4.29**
F3	176	192	**+8.68**
F4	201	218	**+8.37**
F5	186	205	**+10.20**
F6	187	206	**+10.01**
F average	**195**	**211**	**+8.17**
M1	113	112	**–1.29**
M2	81	83	**+2.63**
M3	120	121	**+1.11**
M4	106	103	**–3.49**
M5	129	129	**–0.10**
M6	108	119	**+9.77**
M average	**110**	**111**	**+1.33**

Table 1: *Average F0 in Hertz (Hz) for female (F) and male (M) speakers in read sentences (12 x 2 occurrences) as a function of the spoken language (English or French). The variation (in %) between English and French languages for each individual speaker is indicated in the right column*

All female speakers exhibit higher F0s in French than in English. All female speakers taken together, the average increase is 8.17%. On the other hand, no clear tendency was found in male speakers: 3 of them increased their average F0 in French, while the 3 others increased it in English.

A two-factor ANOVA ("*spoken language*" and "*gender*") confirmed the significant influence of the spoken language ($F(1,572) = 25.566$ with $p < 0.0001$) and of the speaker's gender ($F(1,572) = 2897.3$; $p < 0.0001$) on average F0. Moreover, this test shows a significant interaction between the two factors ($F(1,572) = 17.712$; $p < 0.0001$). It means that female and male speakers did not adapt their average F0 the same way when they switched from one language to the other, suggesting that there is a cross-gender variation in the use of this acoustic parameter as a function of the spoken language.

F0 range (in Hertz and semitones) as well as its average standard deviation (in Hertz and semitones) on read sentences are shown in Table 2.

	Read sentences – EN				**Read sentences – FR**				
Speaker	**F0 ran. (Hz)**	**F0 ran. (st)**	**SD (Hz)**	**SD (st)**	**F0 ran. (Hz)**	**F0 ran. (dt)**	**SD (Hz)**	**SD (st)**	**% diff. FR/EN SD (st)**
F1	218.28	20.37	50.56	4.85	219.36	19.06	40.53	3.60	**–25.76**
F2	233.25	20.21	46.37	3.79	203.33	15.92	39.46	2.97	**–21.76**
F3	166.34	16.71	32.56	3.22	165.56	14.95	25.24	2.29	**–28.90**
F4	201.91	17.93	38.39	3.23	224.59	19.56	41.46	3.54	**+9.60**
F5	182.75	16.61	38.00	3.45	162.96	14.00	33.85	2.88	**–16.54**
F6	173.64	16.88	28.12	2.68	213.91	18.91	33.74	2.92	**+8.88**
F aver.	**196.03**	**18.12**	**39.00**	**3.54**	**198.28**	**17.07**	**35.71**	**3.03**	**–14.26**
M1	101.92	15.30	23.61	3.51	88.56	13.96	19.00	3.00	**–14.59**
M2	54.12	10.68	9.78	2.01	53.50	10.47	10.53	2.14	**+6.27**
M3	91.55	13.82	22.03	3.24	82.75	11.49	19.19	2.62	**–19.05**
M4	79.84	12.50	20.13	3.16	72.43	11.86	16.91	2.79	**–11.55**
M5	94.08	11.95	24.41	3.13	78.71	10.32	18.48	2.41	**–23.25**
M6	76.66	12.98	16.85	2.73	69.23	9.94	14.87	2.06	**–24.84**
M aver.	**83.03**	**12.87**	**19.47**	**2.96**	**74.20**	**11.34**	**16.50**	**2.50**	**–15.61**

Table 2: *Average values of F0 range in Hertz (Hz) and semitones (st), standard deviation (SD) of F0 in Hertz and semitones, for both female (F) and male (M) speakers on read sentences (12 x 2 occurrences) as a function of the spoken language (English or French). The variation of SD in semitones (expressed in %) between English and French languages for each individual speaker is indicated in the right column*

These data show that F0 range tends to be reduced when the bilingual speakers used French language. The average reduction is 11.89% (in st) for male speakers and 14.36% (in st) for female speakers.

Speakers also tend to exhibit smaller SD in French. The scope of this phenomenon is greater in male speakers, for whom the SD (in st) decreased by 15.61%, compared to 14.26% for female speakers.

A two-factor ANOVA ("*spoken language*" and "*gender*") was conducted on F0 range values (in st). The analysis confirms a significant influence of the spoken language ($F(1,572) = 18.823$; $p < 0.0001$) and of the speaker's gender ($F(1,572) = 340.109$ with $p < 0.0001$). The same holds for the SD (in st), with a significant influence of *language* ($F(1,572) = 44.087$; $p < 0,0001$) and *gender* ($F(1,572) = 57.530$; $p < 0.0001$).

2.2 Semi-spontaneous speech

As explained in section 1.1, our speakers also had to produce semi-spontaneous speech. Average F0 values for these speech sequences (1 to 2 minutes long) are presented in Table 3.

	Average F0 – Semi-spontaneous (Hz)		
Speakers	**English**	**French**	**% diff. FR/EN**
F1	179	189	**+5.47**
F2	190	195	**+2.95**
F3	167	175	**+4.73**
F4	193	197	**+2.13**
F5	173	177	**+2.25**
F6	184	182	**–0.98**
F average	**181**	**186**	**+2.76**
M1	104	105	**+0.86**
M2	74	73	**–1.62**
M3	103	105	**+2.43**
M4	99	99	**+0.20**
M5	121	121	**+0.50**
M6	99	100	**+1.52**
M average	**100**	**101**	**+0.65**

Table 3: *Average F0 of female and male speakers on semi-spontaneous speech, as a function of the spoken language. The variation (in %) between English and French languages for each individual speaker is indicated in the right column*

The results are consistent with what was found on read sentences. Indeed, 5 female speakers out of 6 used a higher F0 when they spoke French. The sixth produced very similar values in both languages (–0.98%

in French). All female speakers taken together, there is a 2.76% increase of average F0 in French, compared to English. In male speakers, there is a relative stability of average F0 in both languages (+0.65% in French).

A two-factor ANOVA ("*spoken language*" and "*gender*") shows that the difference between the values obtained in French and those obtained in English is significant ($F(1,476) = 7.059$; $p < 0.01$). The difference between female and male speakers is also significant ($F(1,476) = 6062,193$; $p < 0.0001$). Similarly to what was found on read sentences, there is an interaction between the two factors. However, it does not reach the significance threshold ($F(1,476) = 3.816$; $p = 0,0513$).

F0 range (in Hz and st) and F0 standard deviation (in Hz and st) in semi-spontaneous speech are shown in Table 4.

	Semi-spontaneous speech – EN				**Semi-spontaneous speech – FR**				
Speaker	**F0 ran. (Hz)**	**F0 ran. (st)**	**SD (Hz)**	**SD (st)**	**F0 ran. (Hz)**	**F0 ran. (dt)**	**SD (Hz)**	**SD (st)**	**% diff. FR/EN S (dt)**
F1	300.32	25.41	42.62	3.94	297.94	25.30	41.65	3.54	**–10.15**
F2	309.61	25.82	34.26	3.24	305.69	25.64	36.92	3.34	**+3.09**
F3	211.16	20.89	22.51	2.23	253.20	23.05	23.44	2.18	**–2.24**
F4	289.14	23.41	28.16	2.52	276.55	23.57	28.38	2.46	**–2.38**
F5	300.88	25.42	40.94	3.64	306.62	25.61	42.90	3.52	**–3.30**
F6	244.63	22.63	30.98	2.75	286.52	24.78	29.70	2.60	**–5.45**
F aver.	**275.96**	**23.93**	**33.25**	**3.05**	**287.75**	**24.66**	**33.83**	**2.94**	**–3.41**
M1	224.44	28.21	34.33	4.21	177.13	28.42	26.78	3.56	**–15.44**
M2	67.52	16.27	7.13	1.58	53.24	12.52	6.87	1.54	**–2.53**
M3	124.70	24.24	21.91	4.36	151.39	21.68	13.37	2.09	**–52.06**
M4	155.71	24.44	20.11	3.18	151.03	24.08	7.53	2.95	**–7.23**
M5	179.88	21.87	25.44	3.21	176.18	21.78	20.98	2.67	**–16.82**
M6	127.53	19.71	11.87	1.94	107.71	17.79	11.75	1.92	**–1.03**
M aver.	**146.63**	**22.46**	**20.13**	**3.08**	**136.11**	**21.05**	**14.55**	**2.46**	**–15.85**

Table 4: *Average values of F0 range in Hertz (Hz) and semitones (st), standard deviation (SD) of F0 in Hertz and semitones, for both female (F) and male (M) speakers on semi-spontaneous speech as a function of the spoken language (English or French). The variation of SD in semitones (expressed in %) between English and French languages for each individual speaker is indicated in the right column*

When one observes the SD differences between the two languages expressed in semitones (last column in Table 4), one can see that all participants, except one female speaker, modulated less in French than in English. But this tendency is more salient in male speakers than in female speakers – the SD decrease from English to French is 15.85% in male speakers' speech, whereas it is only 3.41% in female speakers'. This result is consistent with what was found in read speech.

A two-factor ANOVA ("*spoken language*" and "*gender*") on the SD parameter showed that language played a significant role, with $F(1,476) = 29.353$ and $p < 0.0001$. The same was true for gender, with $F(1,476) = 11.371$ and $p < 0.001$. Moreover, one can observe a significant interaction between the two factors ($F(1,476) = 14.097$; $p < 0.001$), which indicates that female and male speakers did not change their modulations in the same manner when switching from one language to the other. Hence, female and male modulations where similar in the English sequences: 3.05 semitones in speech produced by female speakers, and 3.08 semitones in speech produced by male speakers. However, in the sequences produced in French, female speakers modulated more than male speakers – their SD was 2.94 semitones, whereas the male speakers' was only 2.46.

3. Conclusion – Discussion

As mentioned in the previous section, we found a significant interaction between the factors "*spoken language*" and "*gender*" on average F0 in read speech and on SD in spontaneous speech. We could also observe a similar tendency on average F0 in spontaneous speech, even if the interaction between the two factors did not prove to be statistically significant. This indicates that in these contexts, language determines average F0 and F0 modulations, but determines them differently for women and men.

Our analysis showed that average F0 is globally higher in French than in English, whether the speakers are female or male. Nevertheless, when one compares female and male speakers as groups, one can note a difference: in French, average F0 rises in all female speakers' read speech and in 5 out of 6 female speakers' spontaneous speech; while in male speakers' speech, average F0 is fairly similar in both languages in spontaneous speech, and only half of them rose their F0 during the read sequences in French. These results can be interpreted as the effect of an ethnolinguistic gender difference in average F0 use.

When it comes to modulations, SD expressed in semitones shows that all participants, except one single female speaker, modulated less in

French than in English. Modulation decrease is more pronounced in male speakers' speech – 15.61% in read speech and 15.85% in spontaneous speech – than in female speakers' speech – 14.36% in read speech and only 3.41% in spontaneous speech. Moreover, we noticed that during the semi-spontaneous sequences produced in English, male speakers modulated as much as the female speakers. This result is consistent with Henton's (1995), who found no significant differences between female and male American speakers when F0 modulations where expressed in semitones. However, we discovered that the male speakers who participated in the experiment modulated clearly less than the female speakers when they spoke in French. This result confirms what Pépiot (2014b) suggested: that in French, F0 modulations are gender-dependent – a practice that participates in the production of differences between the groups of women and men, and that reduces the differences within these groups.

The analysis of these two acoustic parameters along with the cross-sectional study of *language* and *gender* in bilingual speakers' speech have brought to light new facts that previous studies, such as Altenberg and Ferrand (2006), Lee and Van Lanker Sidtis (2017) or Mennen et al. (2012), did not investigate. Indeed, the present study clearly shows that the production of a female or a male voice involves different vocal practices, and that these practices vary from one language to another. It also confirms that F0 isn't an *essential* characteristic of speakers that would only depend on the shape of their vocal apparatus. This acoustic parameter also depends on the way speakers *use* their vocal apparatus. Such practices are learned during the socialisation process in which individuals become members of one specific gender group. This constitutes a further argument to abandon simplistic understandings of the relationship between voice and anatomy, where voice is understood as solely determined by the shape of the vocal apparatus, and a further argument to give social factors, such as gender dynamics, more consideration in phonetic studies.

The main limitation of this study is the relatively small number of participants. To confirm our results, the present study could be replicated with a larger amount of speakers. Furthermore, we only analysed speech produced by bilinguals who were native English speakers and whose second language was French. It would be interesting to test if the results are similar with native French speakers whose second language is English. As a matter of fact, the increase in F0 in French we observed could be due, in a certain way, to the stress induced by speaking a second language – since stress can induce an F0 increase (Scherer 1986). Comparing speech produced by native French

bilinguals to speech produced by native English bilinguals could indicate if speaking in one's second language has actually an effect on F0.

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