

Vocal Fundamental Frequency and Sound Pressure Level in Charismatic Speech: A Cross-Gender and -Language Study

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Summary: Objectives/Hypotheses. Charismatic leaders use vocal behavior to persuade their audience, achieve goals, arouse emotional states, and convey personality traits and leadership status. This study investigates voice fundamental frequency (f0) and sound pressure level (SPL) in female and male French, Italian, Brazilian, and American politicians to determine which acoustic parameters are related to cross-gender and cross-cultural common vocal abilities, and which derive from culture-, gender-, and language-specific vocal strategies used to adapt vocal behavior to listeners' culture-related expectations.

Study Design. Speech corpora were collected for two formal communicative contexts (leaders address followers or other leaders) and one informal communicative context (dyadic interaction), based on the persuasive goals inherent in each context and on the relative status of the listeners and speakers. Leaders' acoustic voice profiles were created to show differences in f0 and SPL manipulation with respect to speakers' gender and language in each communicative context.

Results. Cross-gender and cross-language similarities in manipulation of average f0 and in f0 and SPL ranges occurred in all communicative contexts. Patterns of f0 manipulation were shared across genders and cultures, suggesting this dimension might be biologically based and is exploited by leaders to convey dominance. Ranges for f0 and SPL seemed to be affected by the communicative context, being wider or narrower depending on the persuasive goal. Results also showed language- and speaker-specific differences in the acoustic manipulation of f0 and SPL over time.

Conclusions. These findings are consistent with the idea that specific charismatic leaders' vocal behaviors depend on a fine combination of vocal abilities that are shared across cultures and genders, combined with culturally- and linguistically-filtered vocal strategies.

Key Words: Charisma—Voice quality—f0—SPL—Cross-cultural.

INTRODUCTION

Charisma is the set of characteristics, including political vision, emotions, and dominance, that leaders use to share beliefs and achieve goals. Charismatic characteristics are displayed through “charisma of the mind”—verbal behaviors that convey the strength of the leaders' ideas and visions, expressed through spoken words and written texts—and/or through “charisma of the body,” the nonverbal behaviors (voice, facial expression, gesture, posture, etc.) that leaders use to shape ideas and visions and to express personality and emotions. In particular, voice characteristics are fundamental in conveying speakers' personality traits and internal affective states,^{1–3} and in identifying speakers and distinguishing them from one another.^{4–10} Speakers directly manipulate the acoustical patterns of their speech to convey different traits across communicative contexts (environmental acoustics, audience's social status, gender, and age¹¹).

The link between these extrinsic and intrinsic speaker characteristics and the specific acoustic characteristics of speech also depends in part on social context,^{12,13} and several studies show how speech acoustics affects speakers' credibility and social attractiveness differently in different languages and cultures. For example, a regional or foreign accent negatively affects speakers' credibility among American English listeners,^{14,15} but does not affect speakers' social attractiveness among Italian listeners.¹⁶

This study investigates voice acoustics in political speech from a cross-gender, cross-language sample of speakers. Our goal is to distinguish vocal manipulations related to gender, which could reflect political leaders' inherent strengths^{17,18} and dominance,¹⁹ from those resulting from strategies depending on the language spoken, presumably reflecting learned strategies for conveying strength and dominance. To this end, we measured female and male political leaders' vocal fundamental frequency (f0) and sound pressure level (SPL) across a variety of communicative contexts. Across species, genders, and cultures, f0 depends in part on learned factors, including the phonetic and phonologic structure of the language being spoken²⁰ and on the extralinguistic uses of voice quality shared by a given group of speakers.²¹ F0 also depends on the speaker's anatomy^{22–26} and physiology,^{27,28} and thus can reliably signal physical size^{18,29} along with a speaker's emotional state,^{30,31} personality,⁷ sex,³² age,²¹ attractiveness,^{33,34} and threat potential,¹⁹ in addition to leadership status.^{17,35,36} Pitch, the perceptual

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correlate of f_0 , has been shown to influence listeners' choice of a leader,^{37–40} and is exploited by listeners according to a “frequency code.”¹⁹ This code associates (1) high frequencies with a primary meaning of small and harmless vocalizers, and a secondary meaning of a subordinate attitude and submissive behavior, and (2) low frequencies with a primary meaning of a big and potentially dangerous vocalizer and a secondary meaning of a superior attitude and dominant behavior. Note that most studies particularly focusing on f_0 range are based on read speech,⁴¹ singing voice,⁴² voice disorders,²⁷ or acted speech,⁴¹ and not on naturally-occurring utterances, which are difficult to gather under controlled circumstances.

SPL is the primary acoustic correlate of perceived loudness, and has been associated with listeners' perceptions of pragmatic²¹ and idiomatic meaning,⁴³ as well as emotional state.^{1,44} SPL physically depends on the interaction between subglottal pressure, resistance at the vocal folds, and the status of the upstream vocal tract (see²¹ for review). As a consequence, it is phonetically related to prosodic features, such as pauses in utterances, articulatory changes, and word stress.²⁸ SPL measurement also depends on the distance between the speaker and the listener or recording device, thus complicating comparison of measurements across occasions or contexts. Finally, environmental factors (eg, background noise^{45,46} and communicative contexts⁴⁷) influence SPL variation, so that experimentally controlled recordings are nearly impossible to gather. For these reasons, absolute measures of SPL from noncontrolled settings are poor independent indices of speakers' identity, sex, or age.²¹ However, it is possible to examine normalized ranges of SPL variation (*relative SPL*, or SPL_{rel}), which can be compared across utterances, speakers, and contexts. This is the approach taken in the present study.

To investigate how biological and social factors affect the speech of political leaders, we studied recorded orations by female and male charismatic speakers and compared the manner in which they varied f_0 and SPL across contexts. Three communicative contexts were examined: a monologue addressed to followers in a formal campaign context (the monologue context, MON), a monologue addressed to other politicians at a formal conference in an institutional conference room (the conference context, CON), and an informal face-to-face interview, during which no political topics were addressed (a control condition, INT). Biologically-based uses of voice predict that leadership is conveyed innately, which would lead to similarities between languages and genders across contexts. Use of learned vocal strategies to enhance persuasion suggests that we should expect differences across communicative contexts as speakers tune orations to specific audiences. Specifically, because of the frequency code described above, we hypothesized that all speakers, regardless of gender and language spoken, would use lower mean f_0 (compared to the monologue addressed to followers in the campaign context) to convey dominant charisma when addressing an audience of their peers. Speeches addressed to peers should also be characterized by

narrower ranges of f_0 and SPL, again reflecting efforts to convey dominance. In contrast, we further hypothesized that speakers would use higher f_0 , with wider f_0 and SPL ranges, when addressing listeners of lower status and differing backgrounds and expectations (the monologue context), in order to enhance persuasion by conveying such nondominant “charisma types” as competence and activeness, combined with activated emotional states (fear, happiness, etc.). These manipulations contrast with the dyadic interview, in which speakers should use the narrowest f_0 and SPL ranges because the absence of specific persuasive goals would imply that no special prosodic adjustments to speech are required.

Patterns of f_0 and SPL manipulation over time and context reflect not only the speaker's charismatic voice, but also a vocal strategy similar to the *climax* figure of speech, in which words, sentences, and arguments are delivered in order of increasing duration or importance, with the peak of importance at the end of a discourse.⁴⁸ Reflecting the differences in persuasive goals inherent in different communicative contexts, we hypothesized that f_0 and SPL will correlate in formal discourse in which speakers address political topics with the goal of persuading the audience. In informal discourse, we do not expect consistent time-related adjustment of vocal f_0 and/or SPL, because speakers do not deal with political topics or pursue a specific persuasive goal. Instead, we expect the leaders studied here to differ from one another in how they organize their vocal behavior over time, with these differences reflecting gender and the language spoken.

MATERIALS AND METHODS

Corpus

A multigender, multilingual corpus of political speech was collected from recordings of politicians in four countries with distinct cultures: the United States of America, Italy, France, and Brazil (Supplementary Table S1). Speakers were selected through surveys described in several previous studies.^{11,49,50} Briefly, 170 participants (American-English native speakers; 120 females, 50 males; average age 21.96 year old) generated lists of adjectives they felt described a charismatic leader, from which the 68 most-frequently occurring responses were selected. Adjectives corresponded to five dimensions of charisma: empathy, competence, benevolence, dominance, and ability to induce emotions. The scales were validated by asking 96 additional listeners (French native speakers: 51 females, 13 males; average age 24.5 year old; Italian native speakers: 25 females, seven males; average age 31 year old) to rate a set of speakers and then performing factor analysis on the results (see¹¹ page 15). This resulted in three factors: proactive-seductive (eg, vigorous, active, dynamic, charming, and sexy), benevolent-competent (eg, wise, prudent, fair, sincere, and intelligent), and authoritarian-threatening (eg, self-confident, resolute, threatening, and egocentric). Speakers were selected based on their scores on these factors. The final set included two female American English speakers (Hillary Clinton, aged between 62 and 67 years old at the time of the recording; and

Carly Fiorina, 60 years old), three male American English speakers (Barack Obama, 51–53 years old; Bernie Sanders, 74 years old; and Donald Trump, 68–69 years old), two male Italian speakers (Luigi de Magistris, 44–45 years old; and Walter Veltroni, 57–57 years old), two male French speakers (François Hollande, 57–60 years old; and Nicolas Sarkozy, 56–57 years old), and two male Brazilian Portuguese speakers (Luiz Inácio Lula da Silva, 63–65 years old; and José Serra, 67–70 years old).

Speech data produced in three different communicative contexts were collected for each speaker. The first was a monologue addressed to followers in a formal campaign context (an arena or other large venue) during which political topics were addressed. In this context, speakers were higher in leadership than their listeners, and attempted to persuade followers to adopt the speakers' goals (providing resources to help the politician win the next election). The second context was a monologue addressed to other politicians at a formal conference in an institutional conference room, during which political topics were addressed. Speakers and listeners were equal in leadership and social status in this context. During these interactions, the politicians also attempted to persuade colleagues to provide resources to help them maintain leadership status. The final context was an informal face-to-face interview, during which no political topics were addressed. In this type of informal interaction, the politician does not forward a precise persuasive goal related to politics. This third context served as a control condition to verify the validity of the hypotheses above, and also to determine if dominance was displayed in vocal behavior in informal dyadic interaction (see also⁵¹).

f0 and SPL measurements

f0 and SPL values were measured from [a] vowels extracted from each speech sample. [a] was chosen for analysis because its high first formant reduced the likelihood that the frequency tracker would confuse f0 with first formant F1.⁵² Mean f0 ($f0_m$) was measured in Hertz (Hz) using Praat software.⁵³ f0 range ($f0_{rng}$) values expressed in semitones (ST) were obtained through the equation: $f0_{rng} = 12 * \log_2 \left(\frac{f0_{max}}{f0_{min}} \right)$, where the maximum ($f0_{max}$) and minimum ($f0_{min}$) frequencies were measured in Hz with Praat.

SPL measurements were made from audio recordings created without control of microphone-to-mouth distance or recording environment. To allow comparisons across contexts, speakers, genders, and languages, relative SPL (SPL_{rel}) was measured as the difference in dB between minimum and maximum SPL. This subtraction amounts to generating the ratio of minimum to maximum values, thereby normalizing the measure so that values can be compared within and across recordings.

To compare vocal behavior across communicative contexts and speakers,^{41,52} we plotted f0 against SPL to create normalized Voice Range Profiles (VRPs; Figures 1–11) representing the entire vocal output of the charismatic leaders. Correlations among measures within each context were calculated using mean $f0_m$ and mean absolute SPL (SPL_{abs}); VRPs across contexts were plotted using $f0_{rng}$ and SPL_{rel} range values. In the VRPs the f0 range scale (X axis) ranged from 0 to 30 ST and the scale for relative SPL (Y axis) ranged from 1 to 40 dB. Finally, the Kruskal-Wallis test by ranks⁵⁴ with post hoc focused comparisons (⁵⁵, p. 213–214) was used to compare speakers and/or contexts (see also⁵⁶). The calculations performed for the Kruskal-Wallis tests

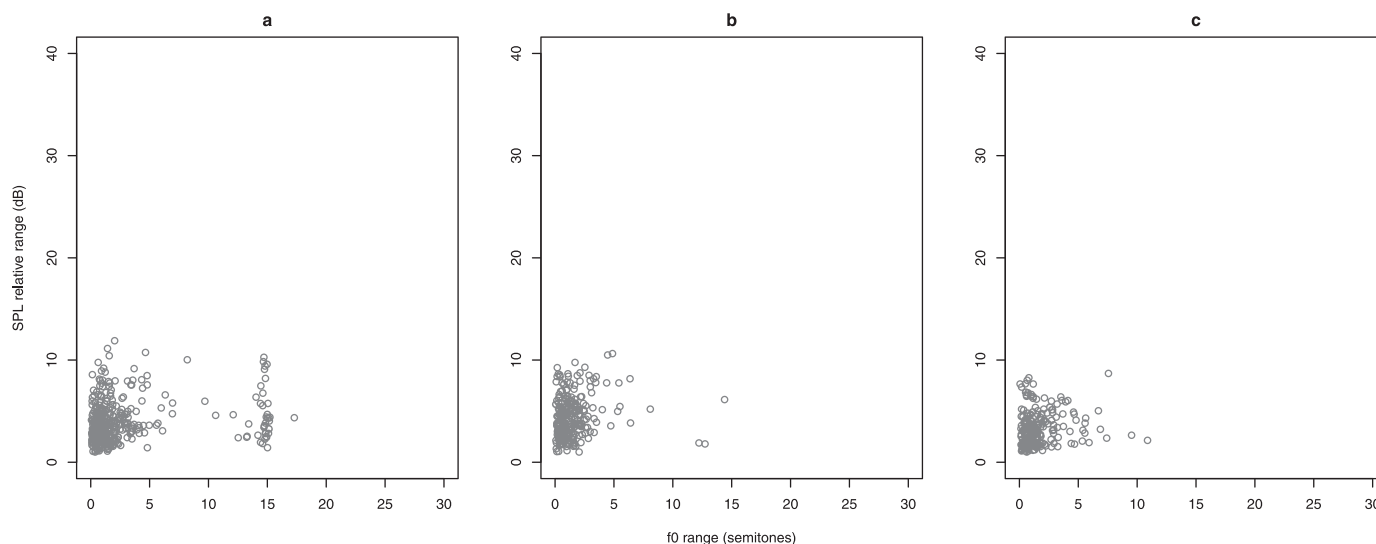


FIGURE 1. Voice range profile for American English speaker Hillary Clinton. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication: (a) monologue addressed to followers (MON); (b) monologue addressed to other politicians (CON); (c) informal interview addressed to one listener (INT). Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.36$, a; conference: $r = 0.17$, b; interview: $r = 0.24$, c).

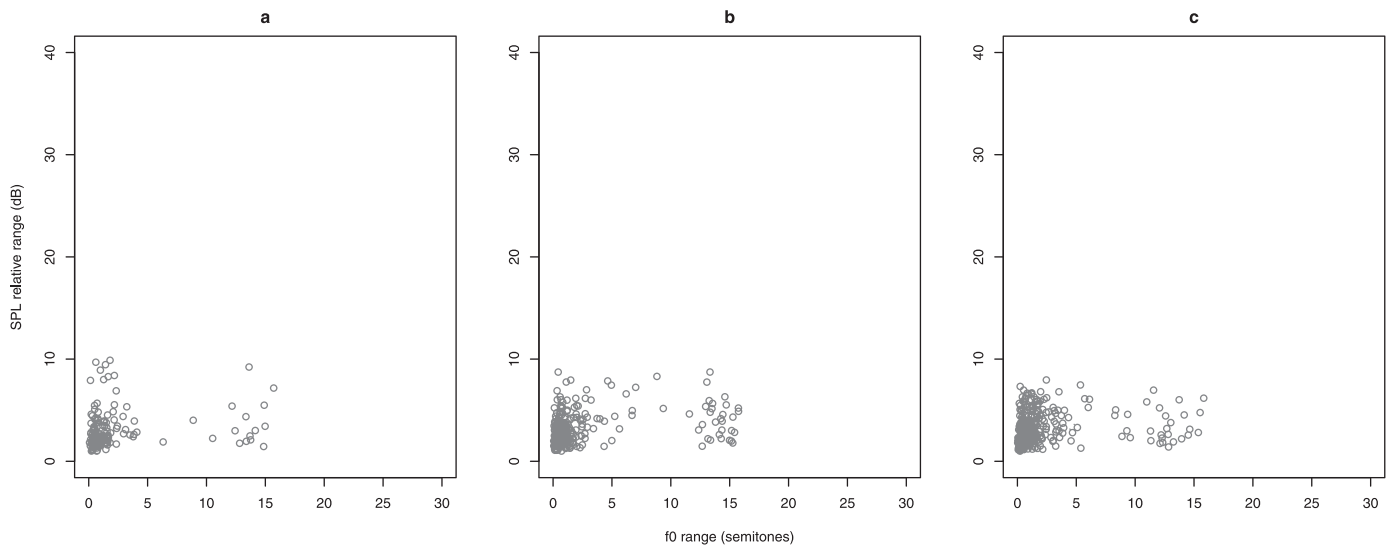


FIGURE 2. Voice range profile for American English speaker Carly Fiorina. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.39$, a; conference: $r = 0.41$, b; interview: $r = 0.34$, c).

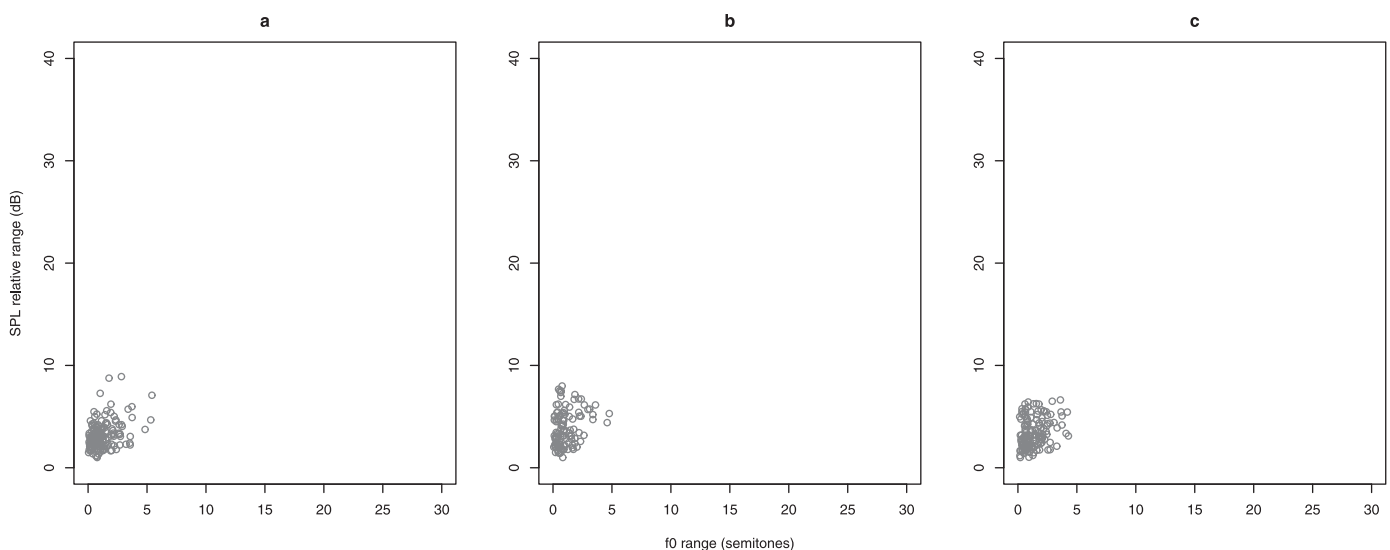


FIGURE 3. Voice range profile for American English speaker Barack Obama. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot corresponds to acoustic parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.45$, Fig. 3a; conference: $r = 0.44$, b; interview: $r = 0.36$, c).

were conducted using ranked lists of measures including the following number of [a] vowels collected for each speaker and each communication context (Table S1 for the sources of the audio data): Clinton (MON: 445, CON: 269, INT: 225); Fiorina (MON: 150, CON: 306, INT: 392); Obama (MON: 151, CON: 123, INT: 163); Sanders (MON: 116, CON: 88, INT: 32); Trump (MON: 955, CON: 160, INT: 175); de Magistris (MON: 868, CON: 373, INT: 207); Veltroni (MON: 776, CON: 612, INT: 463); Hollande (MON: 125, CON: 293, INT: 364); Sarkozy (MON: 831, CON: 401, INT: 141); Silva (MON: 796, CON: 1117, INT: 214); Serra (MON: 2133, CON: 1025, INT: 109).

A simple regression analysis was used to study dynamic manipulations of fundamental frequency and SPL over time in political speech. We compared changes in $f0$ and SPL for different stages of each speech. The predictor variable was time (i.e., the sequence of [a] vowels from the beginning to the end of speech utterances); the dependent variables were $f0_m$ and SPL_{abs} .

RESULTS

P values were adjusted for multiple comparisons as appropriate for all analyses described below.

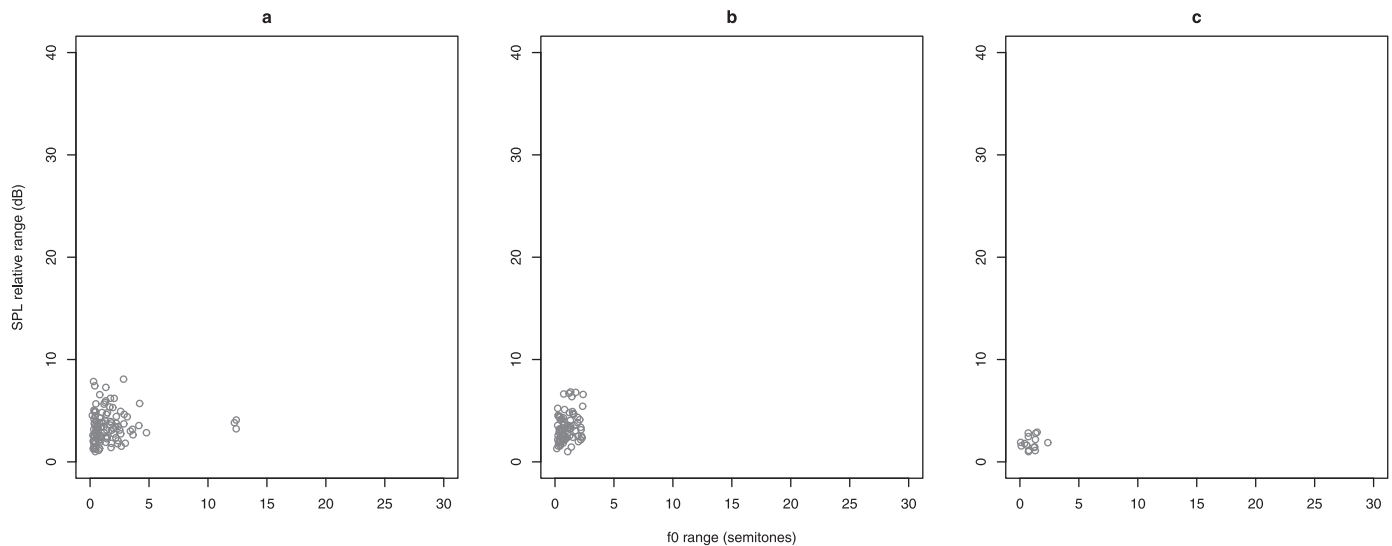


FIGURE 4. Voice range profile for American English speaker Bernie Sanders. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot corresponds to acoustic parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated for monologue ($r = 0.26$; a) and interview ($r = 0.82$; c), but not for conference ($P > 0.05$, b).

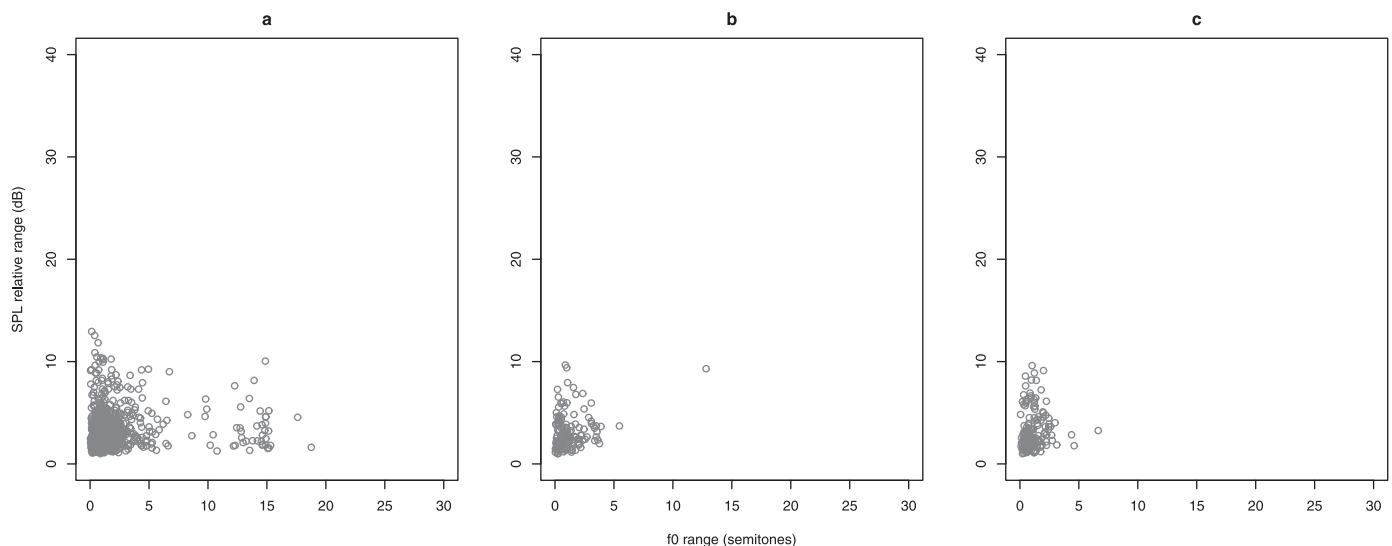


FIGURE 5. Voice range profile for American English speaker Donald Trump. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot corresponds to acoustic parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.47$, a; conference: $r = 0.37$, b; interview: $r = 0.53$, c).

Average fundamental frequency

Table 1 shows speakers' average voice fundamental frequencies in the three communicative contexts (monologue, conference, and interview). As hypothesized, speakers used the highest mean $f0$ s in the monologues, during which they addressed an audience with lower leadership and social status (mean $f0$ across speakers = 193 Hz; SD = 18 Hz). Mean $f0$ was intermediate (161 Hz; SD = 26 Hz) in the conference context, during which speakers addressed an audience with similar leadership and social status, and lowest (126 Hz; SD = 23) in the context of a dyadic interview (the control

condition). Results of Kruskal-Wallis tests (Table 1) confirmed that the three contexts differed significantly ($P < 0.05$). Post hoc comparisons of mean $f0$ ranks within communicative contexts showed that this pattern was significant for all speakers except American English speaker Sanders, whose mean $f0$ did not vary significantly with context ($P > 0.05$) and Brazilian Portuguese speaker Serra, whose mean $f0$ in the conference and interview contexts did not differ significantly ($P > 0.05$) (Supplementary Table S2).

Not surprisingly, female speakers used higher mean $f0$ s overall than did male speakers, particularly in the interview

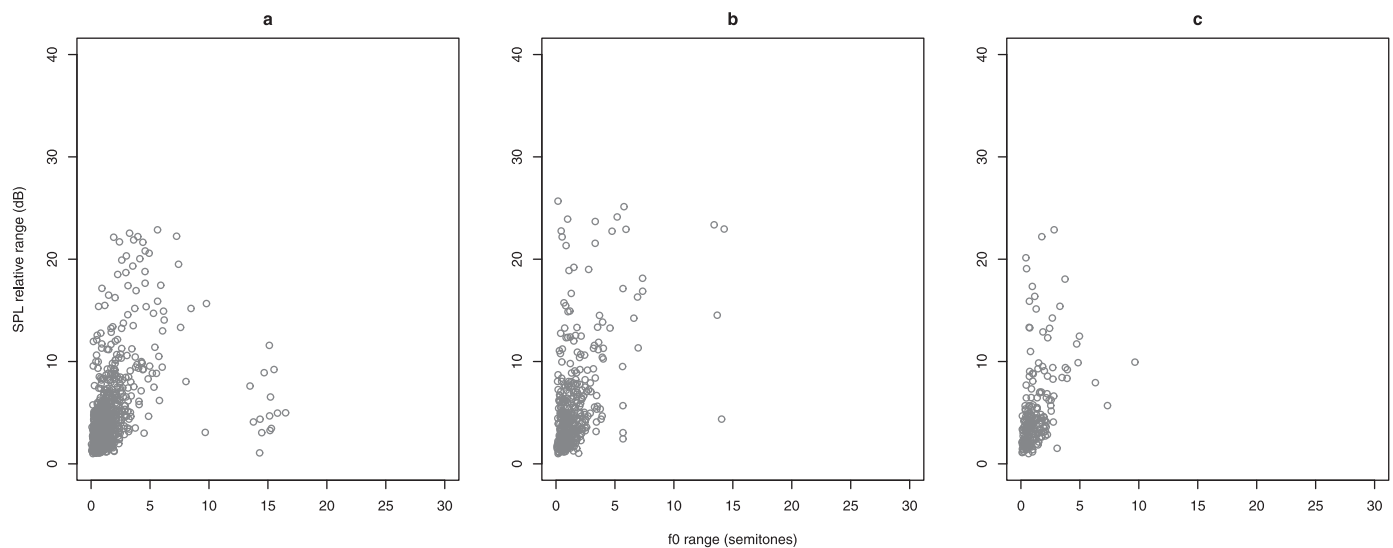


FIGURE 6. Voice range profile for Italian speaker Luigi de Magistris. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.57$, a; conference: $r = 0.68$, b; interview: $r = 0.45$, c).

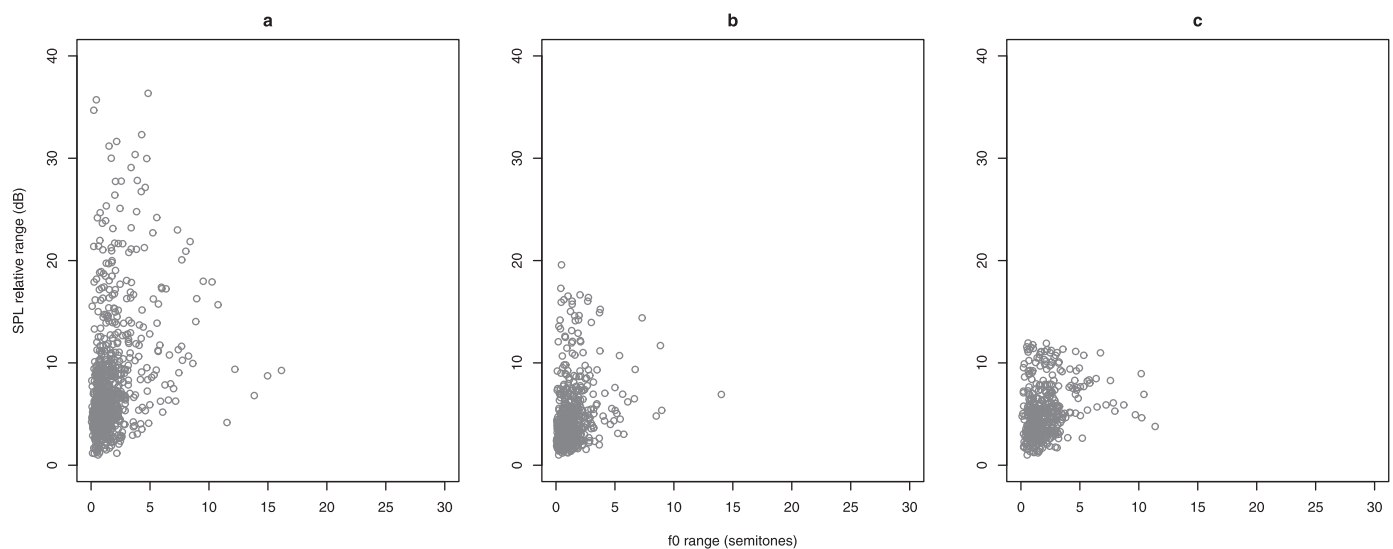


FIGURE 7. Voice range profile for Italian speaker Walter Veltroni. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in monologue ($r = 0.51$; a) and conference ($r = 0.60$; c), but not interview ($P > 0.05$; b).

context (Table 1). Cross-language comparisons showed that Brazilian Portuguese speakers had the lowest mean $f0$ during the monologue and conference contexts. American English speakers' voices were characterized overall by the highest mean $f0$ in all three communicative contexts. Only speaker Trump presents a lower mean $f0$ in monologue, compared to the other American English speakers (Table 1).

Fundamental frequency range

Both female and male speakers varied their frequency ranges ($f0_{rng}$) across communicative contexts (Table 2).

Monologues were characterized by the widest frequency ranges, conference presentations by intermediate ranges, and interviews by the narrowest $f0$ range. Kruskal-Wallis tests (Table 2) statistically confirmed these findings for five of the 11 individual leaders (Obama, Trump, Veltroni, Sarkozy, and da Silva). Post hoc comparisons of $f0_{rng}$ mean ranks within communicative contexts (Supplementary Table S3) also confirmed these results, with the exception of American English speaker Obama whose $f0_{rng}$ did not differ significantly ($P > 0.05$) in monologue versus conference or in monologue versus interview, American English speaker Trump whose $f0_{rng}$ in the monologue and conference

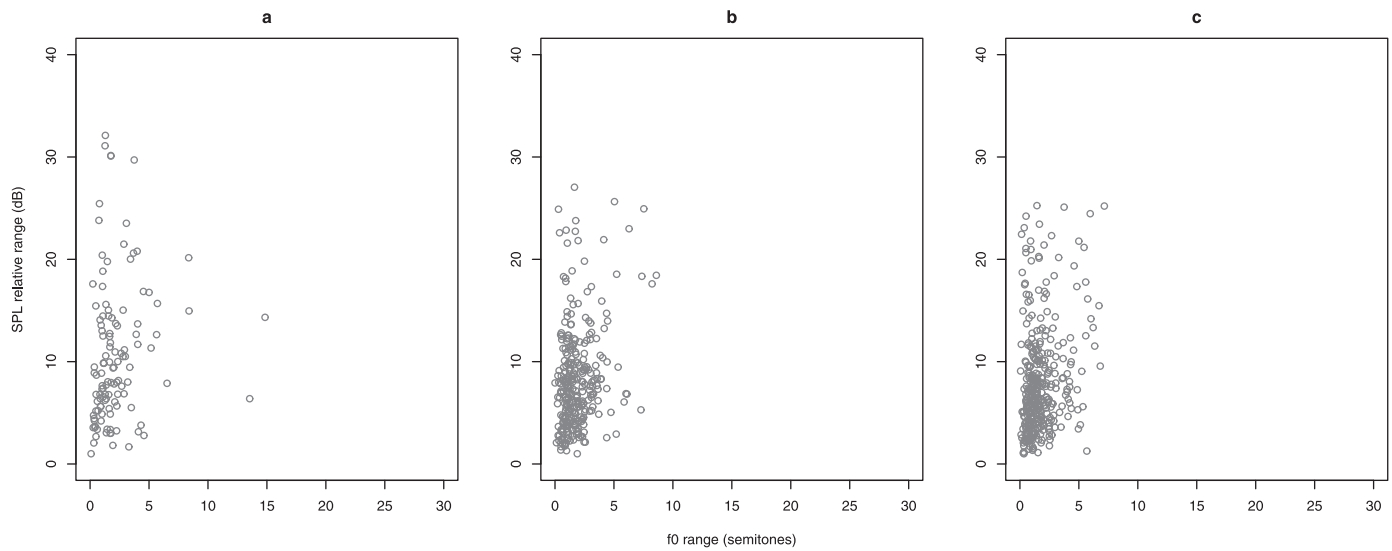


FIGURE 8. Voice range profile for French speaker François Hollande. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.44$, a; conference: $r = 0.57$, b; interview: $r = 0.51$, c).

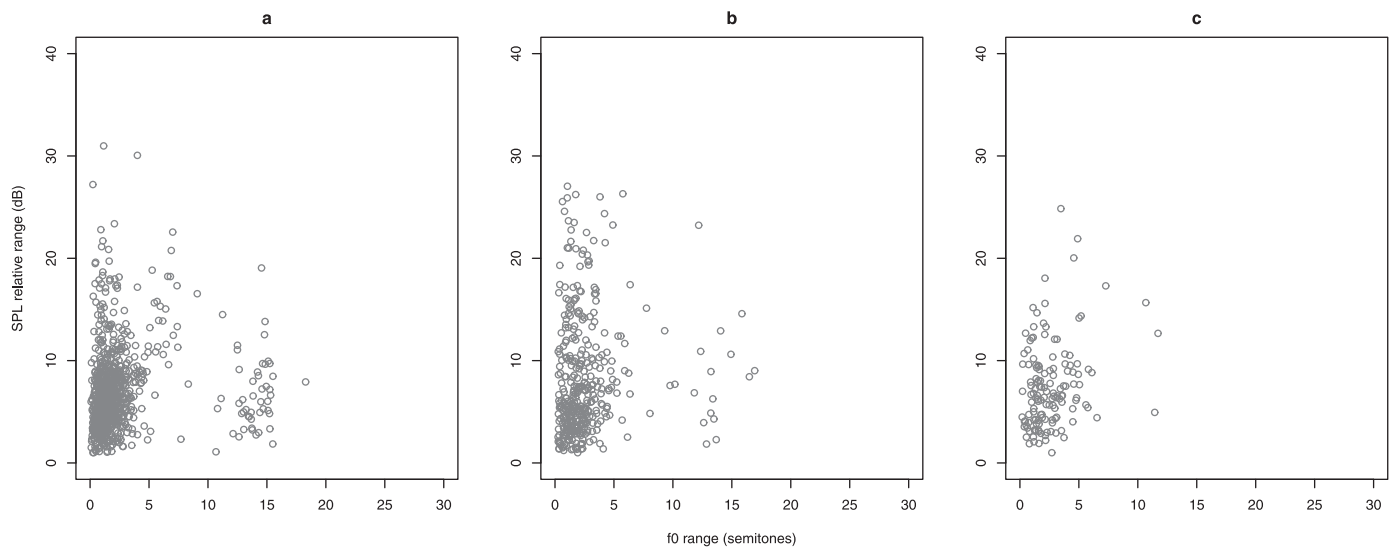


FIGURE 9. Voice range profile for French speaker Nicolas Sarkozy. X axis: fundamental frequency range ($f0_{rng}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.20$, a; conference: $r = 0.51$, b; interview: $r = 0.55$, c).

communicative contexts did not differ significantly ($P > 0.05$), French speaker Sarkozy whose $f0_{rng}$ did not differ significantly ($P > 0.05$) for conference versus interview, and Brazilian Portuguese speaker da Silva whose $f0_{rng}$ in monologue did not differ significantly from interview ($P > 0.05$).

Finally, native language had a significant effect on $f0_{rng}$, with American English speakers characterized by wider $f0_{rng}$ in the monologue communicative context (Table 2). Cross-gender differences were highlighted by significantly higher $f0_{rng}$ in American English female speakers in comparison to male American English speakers, as expected.

This difference was the greatest in conference and interview contexts (Table 2).

SPL range

Relative SPL (SPL_{rel}) also varied significantly across the three communicative contexts (Table 3). Monologues were characterized by the widest SPL range; conference orations were characterized by an intermediate range, and interviews by the narrowest SPL_{rel} range. Post hoc Kruskal-Wallis tests (Supplementary Table S4) indicated that this pattern

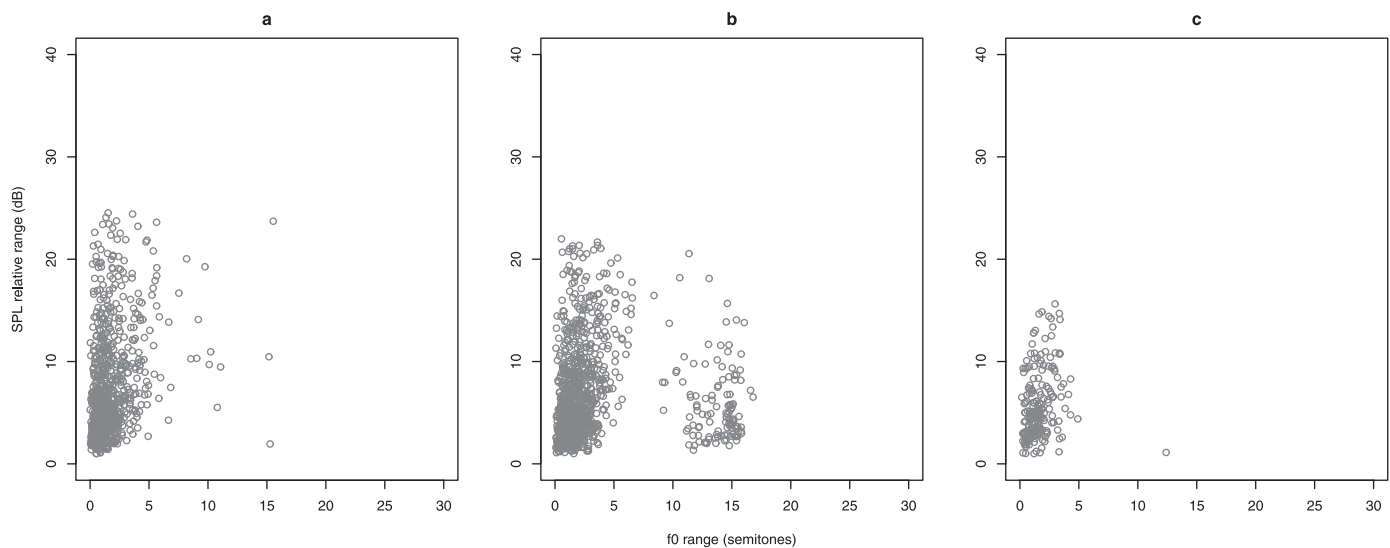


FIGURE 10. Voice range profile for Brazilian speaker Luiz Inácio Lula da Silva. X axis: fundamental frequency range ($f0_{\text{rng}}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.63$, a; conference: $r = 0.40$, b; interview: $r = 0.46$, c).

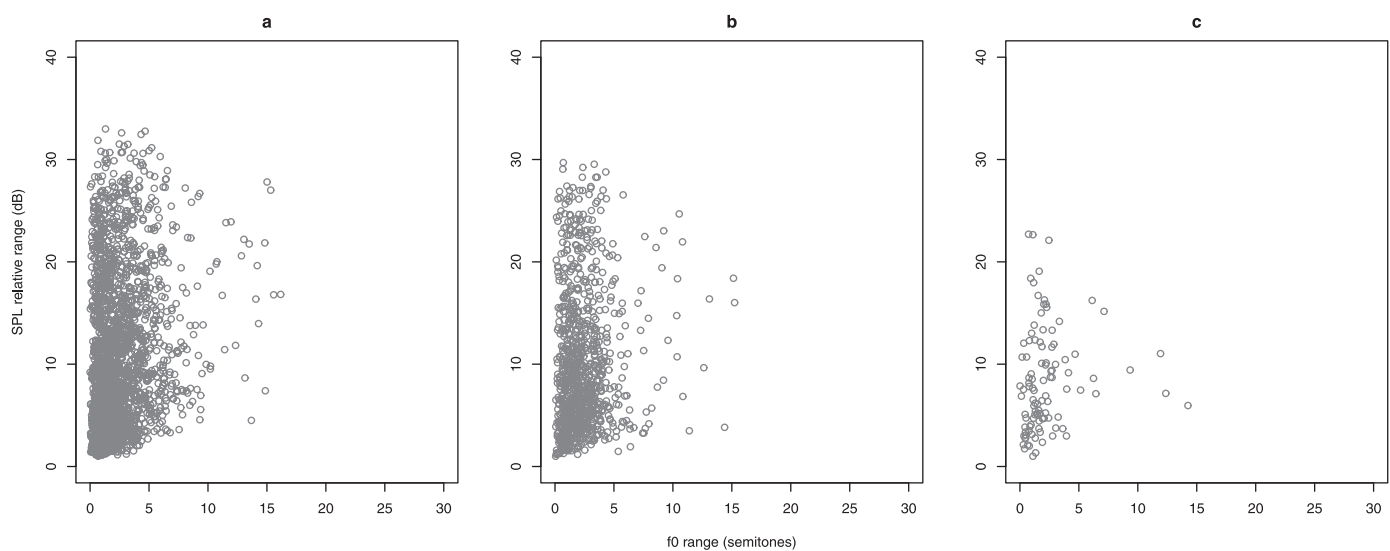


FIGURE 11. Voice range profile for Brazilian speaker José Serra. X axis: fundamental frequency range ($f0_{\text{rng}}$) in semitones. Y axis: sound pressure level relative range (SPL_{rel}) in decibels. Each point in the scatterplot represents parameters measured in one [a] vowel. Contexts of communication as in Fig. 1. Mean $f0$ and SPL_{abs} were positively correlated in all contexts (monologue: $r = 0.33$, a; conference: $r = 0.22$, b; interview: $r = .27$, c).

was significant for seven of the 11 individual speakers: Clinton, Obama, de Magistris, Veltroni, Hollande, da Silva, and Serra. Additional post hoc focused comparisons (Supplementary Table S3) showed that SPL was not significantly different in conference versus interview contexts for American English speaker Clinton and Italian speaker de Magistris, and that only the monologue and conference contexts differed significantly for Brazilian Portuguese speaker Serra.

Cross-gender comparisons, in this study limited to speakers of American English, showed that female and male

speakers did not differ very much in SPL_{rel} , (Table 3). Cross-language comparisons showed that male American English speakers' voices were characterized by the narrowest overall SPL_{rel} range (Table 3). Within the American English speakers, only Clinton and Obama showed significant differences between communicative contexts. Italian, French, and Brazilian Portuguese speakers showed wide SPL_{rel} ranges, which differed significantly for all three communicative contexts: a wider range in monologues, a slightly narrower range in the conference context, and the narrowest range in interviews (Table 3).

TABLE 1.
Mean Fundamental Frequency Values for Individual Female and Male Charismatic Voices for the Three Communicative Contexts. MON: Monologue Addressed to the Followers; CON: Monologue Addressed to Other Politicians; INT: Interview Addressed to an Interviewer. The Kruskal-Wallis Test Were Performed by Ranks of Absolute Mean of f0

| Speaker | Gender | Language | Mean f0 (Hertz) | | | Kruskal-Wallis |
|--------------|--------|----------------------|-----------------|-----|-----|----------------------------|
| | | | MON | CON | INT | |
| Clinton | F | American English | 218 | 188 | 175 | $H(2) = 196.69, P < 0.001$ |
| Fiorina | F | | 206 | 186 | 148 | $H(2) = 169.23, P < 0.001$ |
| Obama | M | | 217 | 182 | 112 | $H(2) = 317.88, P < 0.001$ |
| Sanders | M | | 201 | 181 | 138 | <i>ns</i> |
| Trump | M | | 195 | 183 | 136 | $H(2) = 288.18, P < 0.001$ |
| de Magistris | M | Italian | 182 | 147 | 130 | $H(2) = 531.81, P < 0.001$ |
| Veltroni | M | | 199 | 166 | 110 | $H(2) = 855.29, P < 0.001$ |
| Hollande | M | French | 183 | 142 | 111 | $H(2) = 373.54, P < 0.001$ |
| Sarkozy | M | | 190 | 184 | 125 | $H(2) = 229.47, P < 0.001$ |
| da Silva | M | Brazilian Portuguese | 176 | 141 | 100 | $H(2) = 700.26, P < 0.001$ |
| Serra | M | | 165 | 114 | 122 | $H(2) = 1053, P < 0.001$ |

TABLE 2.
Fundamental Frequency Ranges for the Charismatic Voices in the Different Communicative Contexts. MON: Monologue Addressed to the Followers; CON: Monologue Addressed to Other Politicians; INT: Interview Addressed to an Interviewer. In All Cases the Critical Difference ($\alpha = .05$) was Corrected for the Number of Tests and for Each Focused Comparison. The Kruskal-Wallis Test Were Performed by Ranks of f0 Range Calculated in Semitones

| Speaker | Gender | Language | f0 range (semitones) | | | Kruskal-Wallis |
|--------------|--------|----------------------|----------------------|-------|-------|----------------------------|
| | | | MON | CON | INT | |
| Clinton | F | American English | 18.93 | 14.57 | 11.21 | <i>ns</i> |
| Fiorina | F | | 20.6 | 18.59 | 16.01 | <i>ns</i> |
| Obama | M | | 14.62 | 7.02 | 4.35 | $H(2) = 11.22, P = 0.003$ |
| Sanders | M | | 13.48 | 3.12 | 2.59 | <i>ns</i> |
| Trump | M | | 20.44 | 13.92 | 7.85 | $H(2) = 16.45, P < 0.001$ |
| de Magistris | M | Italian | 16.76 | 15.81 | 14.32 | <i>ns</i> |
| Veltroni | M | | 19.92 | 14.92 | 12.4 | $H(2) = 107.8, P < 0.0001$ |
| Hollande | M | French | 15.11 | 10.57 | 8.19 | <i>ns</i> |
| Sarkozy | M | | 18.97 | 17.58 | 15.51 | $H(2) = 31.4, P < 0.001$ |
| da Silva | M | Brazilian Portuguese | 16.99 | 16.82 | 12.48 | $H(2) = 85.82, P < 0.0001$ |
| Serra | M | | 17.13 | 15.99 | 14.66 | <i>ns</i> |

Interactions between fundamental frequency and SPL

Figures 1–11 show VRPs for each speaker, demonstrating how f_0 and SPL_{rel} covary across the three communicative contexts. Across speakers, genders, and languages, these two parameters were positively correlated in all three communicative contexts (Supplementary Table S5). This is consistent with the physiologically-based relationship between f_0 and SPL: an increase in SPL often results in an increase in f_0 . However, with few exceptions, correlations were small to moderate in size. This fact, along with examination of the figures, suggests that speakers used rather different approaches to manipulating f_0 and SPL, presumably related to prosodic control. For speakers Obama,

Sanders, Hollande, and Serra, patterns of covariation between f_0 and SPL did not differ substantially across communicative contexts, indicating a consistent manner of self-presentation regardless of the audience or persuasive goal. The pattern of f_0 variation was bimodal for a number of speakers, primarily for the monologue context (speakers Clinton, Trump, de Magistris, and Sarkozy), but also in conference presentations (da Silva), and in one case in all contexts (Fiorina). This pattern suggests an oratory style in which pitch, rather than rate or loudness, is used emphatically to engage and arouse the audience. Finally, speakers differed in their patterns of SPL variation, with some (Trump, de Magistris, and Veltroni) using greatest SPL variation in the monologue context, others (Sarkozy,

TABLE 3.
Sound Pressure Level Ranges for Charismatic Voices in Different Communicative Contexts. MON: Monologue Addressed to the Followers; CON: Monologue Addressed to Other Politicians; INT: Interview Addressed to an Interviewer. In All Cases the Critical Difference ($\alpha = .05$) was Corrected for the Number of Tests and for Each Focused Comparison

| Speaker | Gender | Language | SPL _{rel} (dB) | | | Kruskal-Wallis |
|--------------|--------|----------------------|-------------------------|-----|-----|-----------------------------|
| | | | MON | CON | INT | |
| Clinton | F | American English | 13 | 11 | 9 | $H(2) = 30.27, P < 0.0001$ |
| Fiorina | F | | 11 | 9 | 8 | <i>ns</i> |
| Obama | M | | 9 | 8 | 7 | $H(2) = 20.15, P < 0.0001$ |
| Sanders | M | | 9 | 7 | 3 | <i>ns</i> |
| Trump | M | | 13 | 11 | 10 | <i>ns</i> |
| de Magistris | M | Italian | 38 | 24 | 23 | $H(2) = 15.35, P = 0004$ |
| Veltroni | M | | 38 | 21 | 12 | $H(2) = 274.59, P < 0.0001$ |
| Hollande | M | French | 33 | 28 | 27 | $H(2) = 15.47, P = 0004$ |
| Sarkozy | M | | 31 | 28 | 25 | <i>ns</i> |
| da Silva | M | Brazilian Portuguese | 25 | 22 | 16 | $H(2) = 16.48, P < 0.0002$ |
| Serra | M | | 33 | 30 | 24 | $H(2) = 8.04, P = 0.017$ |

da Silva) using more SPL variation in the conference context, and the rest keeping patterns of SPL relatively constant across contexts.

Manipulation of fundamental frequency and SPL over time

Across speakers, similar strategies emerged for adjusting mean f_0 over time in the monologue context, but not in other contexts (Supplementary Table S6). Overall patterns of temporal variability in SPL were consistent across all contexts. These patterns held for all individual speakers except Obama, Sanders, and Serra, for whom f_0 did not vary over time. In the monologue context speakers both decreased f_0 over time (Clinton, Fiorina, Hollande, and Sarkozy) and increased it (Trump, de Magistris, Veltroni, and da Silva), while most speakers increased f_0 over time in conference utterances.

Language-based strategies mostly affected formal speech contexts (monologue and conference). The French, Italian, and Brazilian speakers increased mean f_0 over time in every communicative context; the Italians and Brazilians significantly decreased SPL during monologues, and the French significantly decreased SPL in the conference context.

DISCUSSION

In this study we investigated the acoustics of charismatic political leaders' speech by examining within- and cross-language similarities and differences in politicians' vocal behavior in three different communicative contexts and over time. Analyses focused on speakers' manipulations of mean fundamental frequency (f_{0m}), fundamental frequency range (f_{0rng}), relative SPL (SPL_{rel}), absolute SPL (SPL_{abs}), and the interaction between f_{0m} and SPL_{abs}. Results showed both shared and idiosyncratic patterns of voice manipulation whose ultimate purpose is to persuade listeners.^{11,57–59}

All leaders studied here addressed followers of mixed social status (the monologue context, Figures 1–11, panel a) using high mean f_0 (female speakers average $f_0 = 212$ Hz; male average $f_0 = 189$ Hz), wide f_{0rng} (female speakers = 17.5 ST; male speakers = 17 ST), and wide SPL_{rel} ranges (female speakers = SPL_{rel} 12 dB; male speakers = SPL_{rel} 25 dB). Mean f_0 was lower in the conference or interview contexts (Table 1). SPL_{rel} ranges were also narrower overall in conferences (Figures 1–11, panel b) and interviews (Figures 1–11, panel c). Previous experiments^{40,49,60} demonstrated that increasing f_0 and f_0 variability arouses listeners' emotions while conveying charisma types in a way that matches the diverse expectations of a large group of listeners regarding what a charismatic leader should sound like, what emotional states a charismatic leader should arouse, and what personality traits a charismatic leader should display. Higher f_0 and larger f_0 variations appear to emphasize the speakers' social status as represented by at least three charisma types (proactive-seductive, benevolent-competent, and authoritarian-threatening) that make leaders socially attractive to a group with larger diversity in terms of gender, age, social status, ethnicity, and educational background.

In the conference communicative context in which the speakers' goal was to persuade a medium-sized audience of their peers, the leaders studied here generally used a less-varying vocal pattern, with mean f_0 , f_{0rng} , and SPL_{rel} ranges that were significantly lower and narrower than in the monologue context. With the exception of SPL_{rel} ranges for the American English speakers, this vocal profile was shared across cultures, suggesting that it could be (at least partly) biologically based (Figures 1–11, panel b). This result is consistent with,²⁹ who found that male speakers adjust f_0 according to the listener's perceived social status: male speakers who consider themselves more physically and socially dominant than their listeners tend to use lower f_0 . The present study shows that female charismatic speakers

also lower mean f_0 when addressing their peers, further consistent with views that this strategy has an underlying biological basis.

In the control interview context, in which speakers did not address political topics or pursue specific persuasive goals and addressed a single interlocutor, they all used the least varying voice profiles (narrow mean f_0 ; Figures 1–11, panel c), along with very low mean f_0 . However, SPL_{rel} ranges were significantly narrower than those for monologue and conference for only three individual speakers (the French speaker Sarkozy and both Brazilian Portuguese speakers da Silva and Serra). Values were significantly higher than monologue for the American English speakers; and they were higher than conference for the French speaker Hollande and for both Italian speakers. This pattern reflects two possible vocal strategies: (1) a shared pattern in which speakers lower f_0 and SPL average frequencies and narrow ranges because they consider the listener to be physically and socially submissive, consistent with²⁹; or (2) less variable vocalization because the goal of the speech is not persuasion, so it is not necessary to generate emotional arousal in the listener.

Analyses of acoustic variability over time in charismatic speech showed few commonalities across speakers, but instead a set of individual-specific manipulations of mean f_0 and SPL_{abs} . All speakers significantly increased SPL_{abs} over time in the interview context, and most adjusted mean f_0 over time in the monologue context, but in different ways (Supplementary Table S6). Female American English speakers and male French speakers decreased mean f_0 over time, while male Italian speakers and one Brazilian Portuguese speaker increased it in all three contexts. The Italian speakers also significantly increased SPL_{abs} over time in all three contexts. These varying strategies for voice adjustment over time, termed *Vocis Climax* (see¹¹), are related to the way in which leaders culturally learn how to lead their audiences. Charismatic speakers use average acoustic values and ranges of mean f_0 and SPL_{rel} that differ significantly from the beginning to the end of the speech to amplify the emotional connection with the audience, with the aim of arousing emotional states to enhance persuasion. This acoustic strategy appears most strongly in the monologue communicative context, where leadership must be clearly demonstrated to a large and varied crowd. Finally, variation over time in fundamental frequency and SPL suggests that the changes in overall f_0 and SPL described above are in fact due to speakers' adaptation to the particular audience and are not solely a result of bias related to room acoustics or audience size. Speakers' individual variations of voice parameters (f_0 , SPL) over time demonstrate the speakers' adaptation to the particular audience in a voluntary manner (Supplementary Table S6).

CONCLUSIONS

In conclusion, the present results show the subtle integration between cross-language abilities and culture-/language-

specific strategies that charismatic leaders use to persuade listeners. The study addresses the voice production domain using acoustic analyses and statistical modeling to determine the overall physiological vocal range of charismatic leaders-speakers and its adaptation to contexts of communication and time. We found evidence of a corresponding exploitation of voice in terms of vocal fundamental frequency and loudness range by leaders from different languages and cultures involved in the same context of communication, consistent with a biological commonality in the use of these vocal characteristics. Yet we also found evidence of a cultural distinction in the use of these vocal characteristics in terms of modulation over time. Although speakers in high leadership positions share some common vocal behaviors, the acoustics of charismatic speech depend more on the communicative context than on the language spoken. Leaders speaking in formal political contexts, requiring high psychological involvement to arouse a large range of emotions and convey specific personality traits, use higher overall voice fundamental frequency and wider fundamental frequency and SPL ranges. Conversely, leaders speaking in informal political communicative contexts, requiring lower levels of psychological involvement with less need to arouse emotions or display a specific personality, display voice acoustics with lower overall fundamental frequency and narrow fundamental frequency and SPL ranges, and display more idiosyncrasies that mark their individual verbal style.

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DECLARATIONS OF INTEREST

None

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online a <https://doi.org/10.1016/j.jvoice.2019.04.007>.

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