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Evolution of human pitch: Preliminary analyses in the French population using INA audiovisual archives of Vox Pops

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Introduction

Beyond its linguistic content, the human voice is a formidable tool to convey a wide range of emotions and affective states. Moreover, it also reflects various biological and social information about the emitter such as sex, age, some personality traits and, importantly, his or her socio-cultural background.

Indeed, vocal characteristics are also subjected to the cultural and social expectations of the society the individual belongs to. For instance, van Bezooijen [1] showed that the significant difference in voice pitch observed between Japanese and Dutch women (~230 Hz vs. ~190 Hz respectively) are explained by the fact that they comply to social expectations linked to their gender, which vary considerably between the two cultures. In Japan, traits traditionally associated with femininity include “modesty”, “innocence” and “psychological dependence”. In order to conform to the preferences of men sharing the same cultural representations, Japanese women vocally express these traits by using a higher pitch, which is known to be perceptually associated with impressions of “docility” and “weakness” [2]. Conversely, in a culture where the social roles attributed to men and women are relatively more egalitarian like the Netherlands, Dutch men tend to value traits related to female “independence” and “hard-working”, which result in a preference for women with lower-pitched voices, which are known to be perceptually associated with “self-confidence” and “leadership” [3]. Thus, Japanese and Dutch men show preferences towards culturally congruent voices related to the values attributed to femininity. More generally, it illustrates the idea that voice pitch reflects how a given culture considers men and women social roles.

Interestingly, some evidence suggests that these gender representations have significantly evolved over time, at least for women from Western’s societies. Indeed, several studies have shown that women are increasingly moving away from feminine stereotypes by adopting traits that are generally associated with masculinity, such as competitiveness, independence, leadership, as well as declaring themselves as being more orientated towards higher professional careers [4,5]. In turn, such changes would shift the use of their voices towards a lower-frequency pitch in order to project those impressions, to which men seem to be more attracted nowadays [6]. However, there is currently a strong lack of information on whether voice pitch has evolved or not across a larger span of time to confirm such results.

In this context, audiovisual archives offer a unique opportunity to tackle this issue and the present project aims at exploring the evolution of both men and women voice pitch in the French population as a first study case. For this purpose, we focused on Vox Pops recorded for television news that are most representative of how individuals vocally behave within a

given society at a given time. Therefore, the relevance of this work is twofold: (1) offer an original systematic analysis of how the human vocal pitch has evolved over time and (2) highlight how audiovisual archives can shed light on the evolution of human social behaviors such as speech.

Methods

Voice samples

Voice samples were selected from French speakers interviewed during TV news Vox Pops between 1940 and 2019. These recordings generally took place in public areas, and involved anonymous passers-by who were asked to give their opinion on a particular subject. recordings were provided by the INA (Institut National de l'Audiovisuel, France) as online video clips from which we selected suitable ones for our purpose. The reason for choosing this kind of material is that these individuals' spontaneous speech were felt to be more representative of the general population than, for instance, interviewers, TV presenters, comedians or singers who have generally a better control of their vocal apparatus.

Clips with high background noise or chaotic vocalizations (e.g. screaming, shouting, laughing, crying...) were excluded. Eventually, 96 video clips were selected. Then, we extracted the audio signals associated from each selected video and saved them as .WAV files for further analyses.

Voice analysis

Speech segmentation and acoustic analyses of audio signals were conducted using Praat v. 6.0.43 [7]. Segmentation consisted in isolating speech samples (i.e. speakers talking) by removing fragments of external noises (i.e. surrounding noises), multi-voicing (i.e. voice overlaps) and non-linguistic vocalizations (e.g. laughter, crying...). For some speakers, multiple speech samples were selected since they could appear several times in the same interview. Then, we used a batch-processing script to measure four parameters of fundamental frequency ($F0$, Hz): mean ($F0_{\text{mean}}$), range ($F0_{\text{min}}$ and $F0_{\text{max}}$) and $F0$ contour with its standard variation ($F0_{\text{sd}}$). Then, we measured the coefficient of variation $F0_{\text{CV}}$, which corresponds to $F0_{\text{sd}} / F0_{\text{mean}}$. This measure represents the logarithmic perception of voice pitch (i.e. controlling for the effect of magnitude on variability, [6,8]). All $F0$ parameters were measured using Praat's autocorrelation algorithm with a search range of 100–500 Hz for women speakers and 75–300 Hz for men speakers. We also measured the duration (s) of each voiced segments. For speakers with multiple voice samples, we averaged all five $F0$ parameters.

Perceptually, $F0_{\text{mean}}$, $F0_{\text{min}}$ and $F0_{\text{max}}$ refer to voice pitch while $F0_{\text{sd}}$ and $F0_{\text{CV}}$ refer to global intonation. As such, voices with relatively lower $F0_{\text{mean}}$, $F0_{\text{min}}$ and $F0_{\text{max}}$ will sound lower-pitched or “deeper” whereas voices exhibiting relatively higher $F0_{\text{mean}}$, $F0_{\text{min}}$ and $F0_{\text{max}}$ will sound higher-pitched. Voices with relatively lower $F0_{\text{sd}}$ and $F0_{\text{CV}}$ will sound more monotonous whereas voices exhibiting relatively higher $F0_{\text{sd}}$ and $F0_{\text{CV}}$ will sound more dynamic and expressive.

Note that differences are perceptually noticeable between the two sexes. Women’s voices are significantly higher in pitch than men (approximately twice as much) as well as more expressive. These characteristics are consistent across languages. For instance, mean pitch ($F0_{\text{mean}}$) of French speaking women vary between 140 and 240 Hz and between 100 and 150 Hz in men [9], while pitch variation $F0_{\text{sd}}$ is around 30 Hz in women and 13 Hz in men [10].

Analyses and results

Except for the period 1940 – 1959, women and men’s voices were analyzed separately by decade, from 1960 – 1969, 1970 – 1979, etc. to 2010 – 2019 (see Table 1 for details concerning the number of speakers analyzed for each decade). In total, we analyzed 340 women and 432 men unique speakers across 7 decades. Speech samples averaged a duration of 4.7 seconds (± 4.6).

Table 1. Number of analyzed speakers per sex and decade

	Women	Men
1940 – 1959	27	48
1960 – 1969	49	37
1970 – 1979	50	80
1980 – 1989	62	83
1990 – 1999	42	62
2000 – 2009	49	56
2010 – 2019	62	72

ANOVAs (Analyses of Variance) were used to examine the evolution of all $F0$ parameters over time (i.e. per decade) for each sex. Tukey post-hoc comparisons with Bonferroni’s correction were then performed to look for specific differences between each decade. Results were considered significant at the $\alpha = .05$ level.

All results are summarized in Figure 1. Mean pitch ($F0_{\text{mean}}$) was significantly higher in women after 1940 – 1959 (all $p < .05$) but remained constant after that specific period. In men, no significant increase or decrease was observed between each decade and thus mean pitch remained constant over almost ~80 years (all $p > .05$). Pitch variation ($F0_{\text{sd}}$) did not significantly vary in both women and men across time (all $p > .05$). Although there was considerable variation, a look at the evolution of CV ($F0$ coefficient of variation), which corrects for the logarithmic perception of voice pitch [11], shows that it was only significantly lower between 1940 – 1959 and 2000 – 2009 ($p < .05$). Women’s $F0_{\text{CV}}$ also overlapped the values observed for men between 1970 – 1979 and 1990 – 1999. In other terms, it appears that women’s voices became relatively more monotonous over time. Values of $F0_{\text{CV}}$ for men did not significantly change over time (all $p > .05$). Maximum pitch ($F0_{\text{max}}$) was significantly higher in women after 1940 – 1959, with another important increase in 2010 – 2019 (all $p < .05$), while in men it only started to be significantly higher between 2000 – 2009 and 2010 –

2019 compared to 1940 – 1959 (all $p < .05$). Minimum pitch ($F0_{\min}$) significantly increased after 1940 – 1959 in 1970 – 1979 and 1980 – 1989, but significantly decreased after those decades between 1980 – 1989 and 2010 – 2019 (all $p < .05$). In men, a similar pattern was observed (all $p < .05$). In summary, these results reveal that women's voices have evolved higher pitched voices after 1940 – 1959 but remained constant after that. We also observed an increase in vocal range (i.e. simultaneous increase in $F0_{\max}$ and decrease in $F0_{\min}$) and a more monotonous voice after 1970 – 1979. For men, voice pitch has not significantly changed over time but vocal range also increased after the same period.

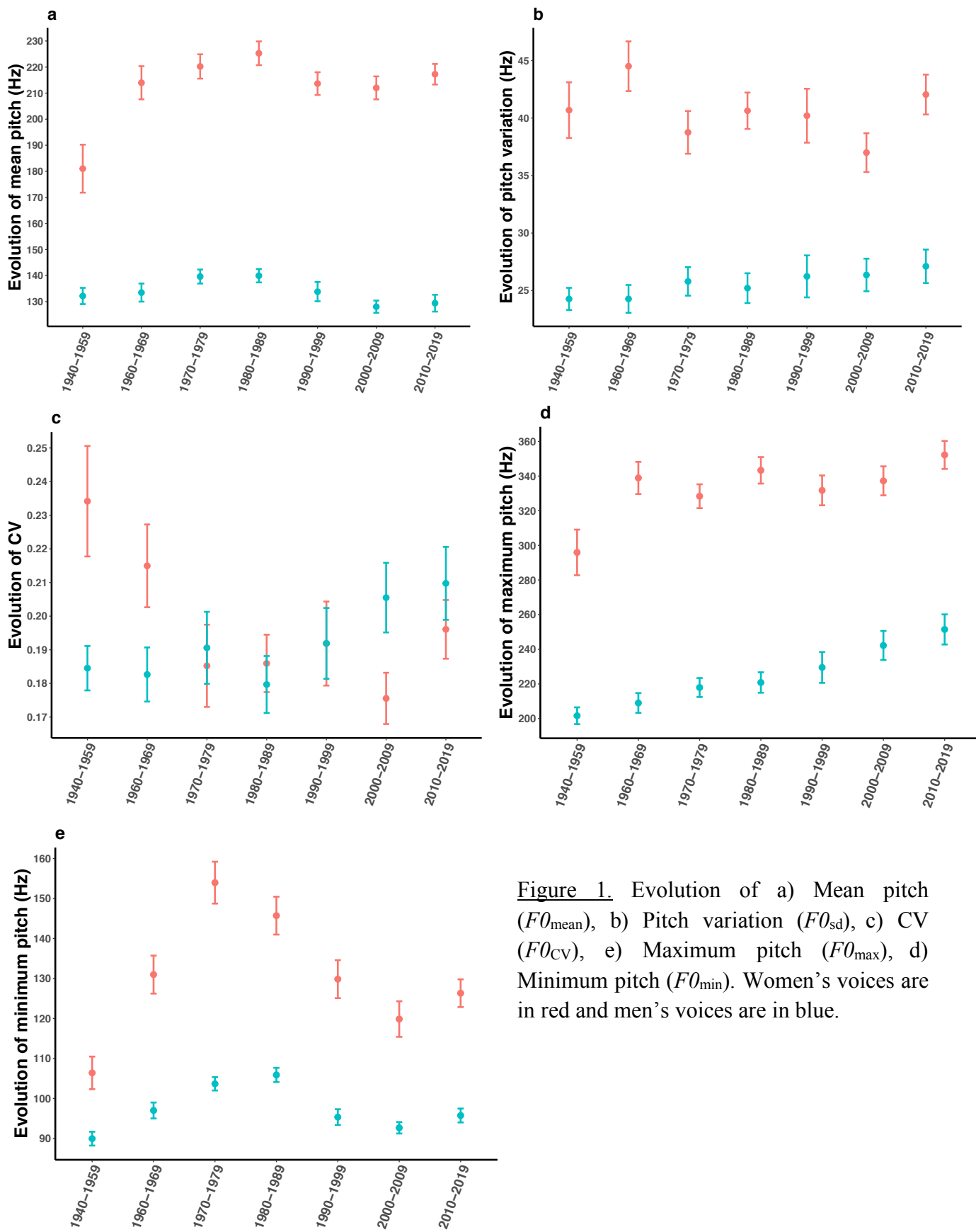


Figure 1. Evolution of a) Mean pitch ($F0_{\text{mean}}$), b) Pitch variation ($F0_{\text{sd}}$), c) CV ($F0_{\text{CV}}$), e) Maximum pitch ($F0_{\text{max}}$), d) Minimum pitch ($F0_{\text{min}}$). Women's voices are in red and men's voices are in blue.

Discussion and future perspectives

Our study shows that voice pitch ($F0_{\text{mean}}$) in both men and women has little evolved over time (Figure 1a). Those results seem to contradict the hypothesis of a female vocal masculinization, as initially suggested. In this context, we suggest two possible explanations. First, $F0_{\text{mean}}$ may not be the most reliable acoustic parameter to study the evolution of voice over time as it captures relatively little information on how an individual vocally behaves (i.e. static cue). Second, lack of significant changes could also be explained by an important factor we did not control for: individuals could use their voice pitch differently depending on their social positions such as a lower and a higher voice pitch in high- and low-ranking individuals, respectively [3,11,12]. Indeed, some studies showed the existence of a link between vocal characteristics and social class [13–15]. Here, the relevance of INA archives (and any other audiovisual archives for that matter) should be underlined since a detailed analysis of available visual data could be particularly useful to verify the validity of this hypothesis. For instance, a fine-grained analysis of clothes could allow us to infer the interviewed individual's social background and account for an original method to further investigate this topic.

Nonetheless, considering more dynamic acoustic criteria (i.e. $F0_{\text{sd}}$, $F0_{\text{cv}}$, $F0_{\text{min}}$, $F0_{\text{max}}$) revealed interesting patterns. Figure 1d and 1e (i.e. $F0_{\text{min}}$ and $F0_{\text{max}}$) show that both men and women's vocal range increased (simultaneous increase of $F0_{\text{max}}$ and decrease of $F0_{\text{min}}$) from the 1970's to nowadays. Considering that $F0_{\text{mean}}$ and $F0_{\text{sd}}$ did not change significantly, we could interpret these results by suggesting that there are two "vocal profiles" coexisting within both sexes of the French population. All things being equal, this would mean that a part of the population progressively spoke over time in a more lower pitch register and another in a higher pitch register. Again, one possible explanation we suggest is that different social classes are using different ways to express themselves, which became more marked over time. Otherwise, this could also partially confirm that, at least in some parts of the population, there has been a "female vocal masculinization" and, unexpectedly, a "male vocal feminization". Along with results of a respective decrease and increase in $F0_{\text{cv}}$ in women and to a lesser extent men (which are considered to be respectively a masculine and feminine vocal trait [16]), such results occurring from the 1970's could be interpreted by the fact that some men and women started to depart themselves vocally from the social expectations attributed to their sex and gender at the very beginning of the 1960's because of the relaxation of social taboos and norms [17]. Indeed, the culture of decades prior to the 1960's was described as being unable to contain the demands for greater individual freedom, which saw people breaking free of the social constraints through extreme deviation from the norm. This major socio-historical phenomenon has been studied in the context of several domains, but our study could be, to our knowledge, the first one to investigate its effect on the human voice. Therefore, our work allows us to hypothesize that the evolution of vocal characteristics may be considered as a reliable sign of cultural evolution.

Although results are few, the current study offers a more systematic analysis on the evolution of voice pitch in both men and women. Cross-sectional studies are particularly important because they answer questions regarding the evolution of human behavior. As such, the use of audiovisual archives for that purpose is useful and extremely precious. In this context, we suggest two avenues for further research. Firstly, other acoustic parameters

should be given attention as the human voice cannot be defined solely on the basis of voice pitch and modulation but also on timbre (vocal resonances), quality (roughness, breathiness...) and rhythm (speech tempo). Furthermore, as all languages can significantly differ across all these aspects, comparing the evolution of voices from different cultures is a particularly interesting aspect. Indeed, this could give us important cues on how gender and social roles have evolved over time across each culture.

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Access to data

Data can be requested by sending an email to Alexandre Suire: alexandresuire@hotmail.fr

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