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Fundamental frequency of speech – Reference values for speech therapy

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Summary: In this article, we provide a literature review about the value of the fundamental frequency (fo) of voice and speech. Reference values for men, women and children are proposed, based on more than two hundred case studies. We also analyze our own corpora of children, men, and women to extract the evolution of fo according to age on two specific modalities: sustained vowels and repetition of short sentences. A summary of the main trends and a model of fo evolution is proposed. We describe the implementation of these reference values in the voice therapy software VOCALAB and speech therapy software DIADOLAB.

Keywords: speech therapy, voice, speech, objective analysis, average usual fundamental, fo, modeling, sentence repetition, vocal pathologies, speech pathologies, vowels, male voice, female voice, children's voice, ERU 15, ERU 46, VOCALAB, DIADOLAB.

Introduction

It is commonly accepted that the fundamental frequency of the voice (fo)¹ gradually decreases from childhood (around 300 Hz) to puberty, then is around 100 Hz for men and 200 Hz for women, i.e. a difference of an octave. Numerous studies highlight a trend towards a decrease in fo in women, and an increase in men starting 50 years old. However, to our knowledge, there is no consensus on these values, which are notably dependent on the language studied, the recording protocol, the instructions, the software and the operating mode used to analyze the patient's speech.

On the protocol aspects, notable differences are measured depending on whether the patient is asked to make sustained vowels, count, introduce themselves, read a text or describe a particular situation. Many studies focus on the English language, a significant part of which concerns young adults, such as university students, which may differ from situations of clinical speech therapy practice, particularly in relation to young children, as well as elderly patients.

Many voice and speech pathologies affect the value of fo, as described in the classification of voice pathologies published by [Verdolini 2006]. The value of fo is considered an important parameter of voice alteration, and is part of the formulation of the Dysphonia Severity Index (DSI), which aims to establish an objective metric correlated to the severity of the patient's vocal disorders [Wuyts 2000]. On the other hand, other indicators such as the AVQI [Jayakumar 2022], considered less sensitive than the DSI by [BenBarsties 2018] do not directly include the value of fo in the input data.

¹ We use the notation “fo” to designate the fundamental frequency of the voice in accordance with [Titze 2015]. Other names exist such as SFF (Speaking Fundamental Frequency), SFO (Speaking F0).

The observation is the same for the Cepstral Spectral Index of Dysphonia (CSID) which does not include consideration of gender or reference value of fo, risking underestimating the severity of certain pathologies, but also only giving a partial evaluation of the progress made thanks to speech therapy treatment [Peterson 2013].

As part of the development of the VOCALAB [Sicard 2023] and DIADOLAB [Sicard 2023b] software, we give a relatively modest place to the values of fo. Values that are very different from the expected reference values, however, generate alerts and penalize the vocal flexibility (VOCALAB) and intelligibility (DIADOLAB) scores. Concerning the voice, we have rather concentrated our efforts on the alteration of the sustained vowel /a:/, concerning the instability in pitch, in amplitude and the noise/signal ratio, all metrics which we find in a manner comparable in the DSI. We also calculate harmonic poverty which is directly correlated to the cepstral peak prominence (CPP) used in the AVQI and CSID indicators.

We have proposed tools linked to the objective analysis of prosody [Sicard 2021]: variation of fo on conversational voice, vocal range in VOCALAB, variation of fo on short sentences in DIADOLAB. There is also an indicator regarding the evolution of fo with therapy [Menin-Sicard 2021] but this plays a relatively minor role in the evaluation of the macro-skill “Vocal flexibility” in VOCALAB. In DIADOLAB, fo is considered in the “Intelligibility” macro-skill. The evaluation of fo, however, remains relevant and provides valuable information [Verdolini 2006].

In this study, we analyze the average fo values for men, women and children, by compiling data accessible through open archives, particularly from scholar.google.com and hal.science. We also address the influence of the recording protocol and the effect of age and gender on the variation of fo. To identify trends with statistical relevance, we carried out a bibliographic synthesis of open data linked to the fundamentals of the voice of men, women and children, from which we extracted trends with age (Section II). Thanks to a large corpus of sustained vowels and standard sentences in the French language as close as possible to the clinical speech therapy, we conducted statistical analyzes from which we extracted reference values (Section III). We finally explain how we implement the fo model in the VOCALAB and DIADOLAB software (Section IV). This report is an English translation of the on-line publication at hal.science in French [Sicard 2023c].

Bibliographic studies

We searched for publications in open archives relating to the study of the usual fundamental of speech (FUM), in English Speaking Fundamental Frequency (SFF), Speaking FO (SFO) for men, women and children, without pathology, according to various speech modalities: sustained vowel, reading of text, spontaneous speech. In the remainder of this article, we will note this parameter fo, according to the recommendations of [Titze 2015]. We do not use the FO notation which is confusing compared to the usual formant notation (F1..Fn), the “f” meaning frequency and “o” meaning oscillation.

We relied in particular on open data published in [Berger 2019], [De Pinto 1982], [Deliyski 2011], [Eichhorn 2018] [Fougeron 2021] [Fukuda 2023] [Fitch 1970], [Gilmore 1992], [Goy 2013], [Graddol 1983], [Lee 1999], [Leung 2020], [Murry 1995], [Nishio 2008], [Pemberton 1998], [Poulain 2020], [Remacle 2020], [Russel 1995], [Sebastian 2012], [Sicard 2019], [Spazzapan 2020], [Tavares 2010], [Trollinger 2003], [Troughear 1979] [Weirich 2013] and [Zraick 2006]. We also had access to the summary of [Baken 2000] on the subject. Various data compiled in the literature review by [Spazzapan 2019] are also reported. The data used in this article are reported in Appendix A (men) and Appendix B (women).

The publications we used are based on calculations based mainly on PRAAT [Boersma 2017], as well as other tools such as MDVP, Dr. Speech, CSL and DIADOLAB. The evaluation of the differences between the values of fo according to the programs was studied by [Batalla 2014] between PRAAT and Dr. Speech showing an acceptable correlation (0.7) but much lower than the noise/signal ratio (0.9), or by [Amir 2009] between PRAAT and MDVP with a correlation of only 0.5 on sustained /a:/, which means that many differences can be observed depending on the software used. For our part, we compared PRAAT and VOCALAB on children's voices [Sicard 2019] with a correlation of 0.88 on sustained vowels, with some divergences, particularly for altered voices. The comparative study by [Vaz-Freitas 2018] between MDVP, VoiceStudio, Dr. Speech & PRAAT shows an excellent correlation for the detection of fo on the stable portion of an /a:/ (>0.9) but strong differences on the standard deviation of fo (correlation <0.5). In general, comparisons between software are made taking little risk: sustained vowel, short portion after one to two seconds of phonation, which limits transient portions of signals.

The recording of sustained /a:/ is very common in phonation assessment protocols in France [Ghio 2012] [Henrich-Bernardoni 2014] [Menin-Sicard 2016] and speech [Fougeron 2016] [Sicard 2020b]. However, the analysis of spontaneous speech is at least as important, and we must anticipate significant variations in fo values depending on the software and configurations used.

Fo women's voice

We used 117 results from studies covering a total of more than 8,200 women, mainly in English. The trend curve, including standard deviation data when available, shows a decrease towards 220 Hz at 20 years, then a tendency towards a decrease in fo with a move to around 190 Hz at 40 years and 180 Hz at 60 years, which can be approximated by a loss of 5 Hz per decade between 20 and 60 years. The standard deviation for all studies combined is 25 Hz. We can draw a first curve at fo- σ (195 Hz at 20 years, 165 Hz at 40 years, 155 Hz at 60 years), and a 2nd at fo-2 σ as shown in Figure 1. Statistically, the curve at fo- σ (or z-score -1.0, or 16% percentile) covers 84% of the female population, if we consider a normal distribution. The one at fo-2 σ (z-score -2.0 or 2.3 percentile) covers 98% of the population.

There is no clear trend towards a reduction in fo beyond the age of 60, despite a significant number of studies covering various corpora. This result is quite surprising because it contradicts old trend curves such as [Baken 2000], which at the time focused on a smaller number of studies, particularly on old age. Fo values change relatively little with age, either because natural physiological aging has limited effects or because individuals compensate for age-related changes, particularly after menopause [Eichhorn 2018]. Conversely, we can formulate the hypothesis that if sudden changes in fo value are observed in an individual, they may be a sign of an underlying pathology, which also justifies the interest in carrying out this measurement in clinical practice.

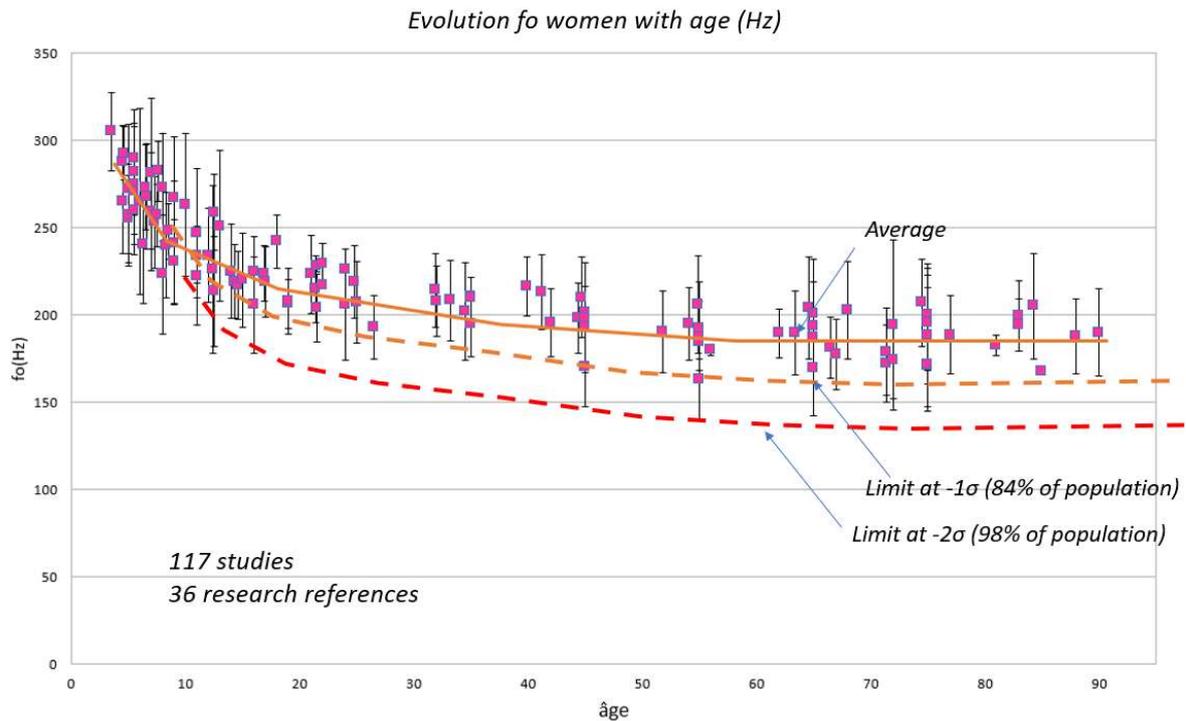


Figure 1 : compilation of 117 studies on fo analysis for women

For each age group, several studies can give quite different results. This could be explained by the variety of protocols: conversational voice, sustained voice, sustained /a:/, enumeration, reading of text or spontaneous speech. Most studies, however, focus on a sustained /a:/ [Spazzapan 2019], as that vowel is universal, simple to record, practical to analyze and is the subject of a plethora of comparative studies. It is also difficult to observe a discontinuity in the 50-60 age group as a result of menopause, which is more characterized by a reduction in vocal intensity and range [Abitbol 1999].

Fo men's voice

The trend curve, based on 107 different groups of men, totaling 7500 individuals, shows a phase of decline like that of girls from 3 to 12 years old, then a rapid descent to adolescence, followed by a long plateau at 120 Hz from 15 to 60 years old, before a slight upward trend from 60 years old, which could be of the order of 5 to 10 Hz/decade. Considering an average standard deviation σ of 25 Hz, all studies combined, we can consider a curve at $fo + 1\sigma$ and another at $fo + 2\sigma$, as illustrated in figure 2.

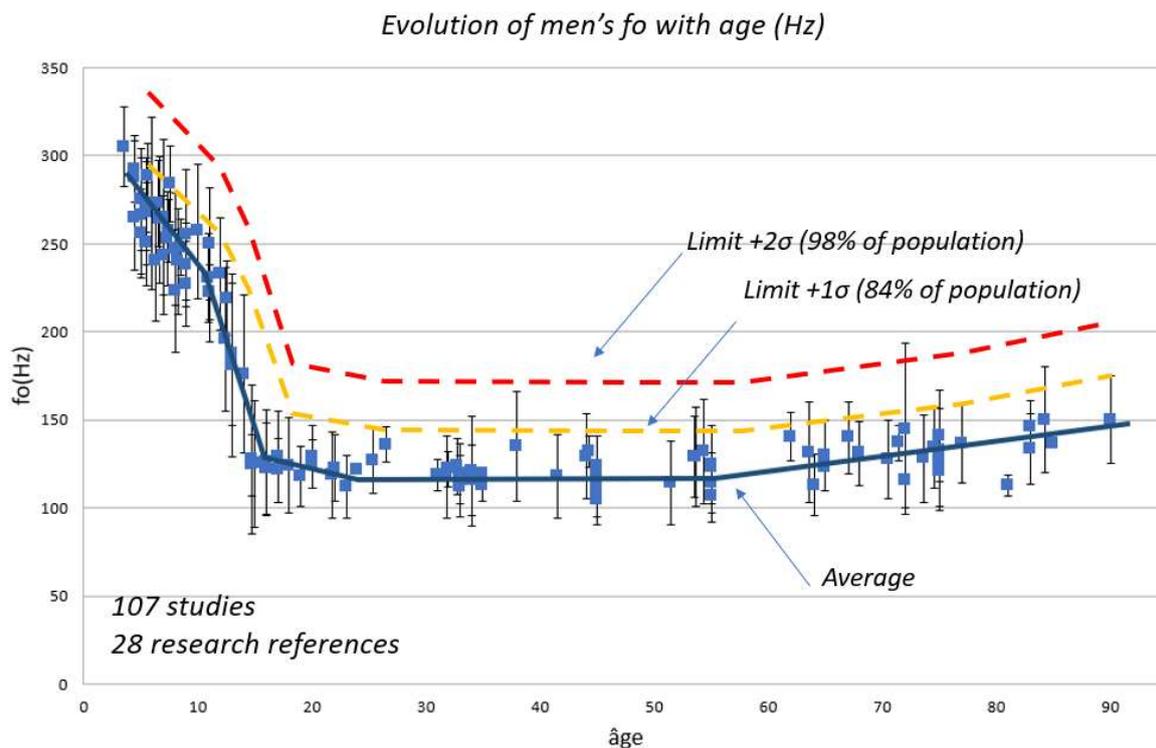


Figure 2 : compilation of 107 published data on fo analysis for men

Reference values

Thanks to the average trends extracted from Figures 1 and 2, we can give some reference values of fo according to a selection of age groups as indicated in Table 1. According to the results of bibliographic studies, the limit/man woman is around 160 Hz from 15 to 30 years old, then drops to 150 Hz from 30 to 60 years old, before rising slightly beyond 60 years old. The maximum M/F difference is in the 15-20 year old range, which can be considered as a maximum gender contrast.

AGE RANGE	WOMEN	MEN	LIMIT M/W
2-4	300	295	
5-9	270	265	
10-14	240	230	
15-19	225	125	175
20-29	205	120	160
30-39	195	120	160
40-49	190	120	155
50-59	185	120	150
60-69	185	130	155
70-79	185	140	160
80-89	185	150	165
>90	185	160	170

Table 1: Average fo values by age group for men and women, according to all available bibliographic studies

Corpus analysis

Method

We analyze a corpus of 150 recordings of sustained vowels produced by healthy control (HC) females, aged 15 to 97, and a corpus of 90 recordings of sustained vowels produced by HC males, aged 16 to 96 years. All participants are native French speakers. The recordings were made as part of the research of [Lefol 2015], [Barbera Frenay 2016] and [Papazian 2019]. Various recordings were also provided by speech therapists who are members of the research teams [ERU 15] and [ERU 46] from the LURCO/UNADREO laboratory. Concerning children, we use the corpora of [Bardelang 2020] and [Grenier 2020], as well as the corpus of 5-year-old child voices from [Remacle 2020], as well as recordings of HC children made by members of ERU 46.

We also have more than 80 samples of standard sentences [Sicard 2020] from HC female of different ages. Concerning men, we use around forty recordings of standard sentences. All people are free from voice and speech pathologies. Social origins and regions of registration are quite varied.

We give here the results obtained with the statistical analysis tools of the DIADOLAB software [Sicard 2023b]. This software uses the same fo and intonation calculation algorithm as VOCALAB [Sicard 2023], which gives results close to PRAAT [Sicard 2019] particularly on normal speech, which is the case for the corpora studied here.

Analysis of vowels

Our goal is to position the value of fo based on the analysis of our own French language corpora, constructed as close as possible to the clinical speech therapy, in relation to the data from the scientific literature presented in the previous section. We wish to deduce the reference values of fo for the sustained /a:/ recording, as well as for the standard sentence repetition test. These values are intended to be implemented in the voice analysis software VOCALAB [Sicard 2023c] and speech DIADOLAB [Sicard 2023].

Vowels pronounced by 5 years-old children

We have a corpus of isolated vowels pronounced by 50 5-year-old children [Remacle 2019] for which we can evaluate the average fo. We do not have a similar corpus for younger or older children. The recordings studied here include the extreme vowels of the vowel triangle /a,i,ou/ [Sicard 2020c]. As we can see in Figure 3, the average fo over the entire corpus is around 263 Hz, with a standard deviation of 13 Hz, i.e. a variability half as much as that usually observed (25 Hz).

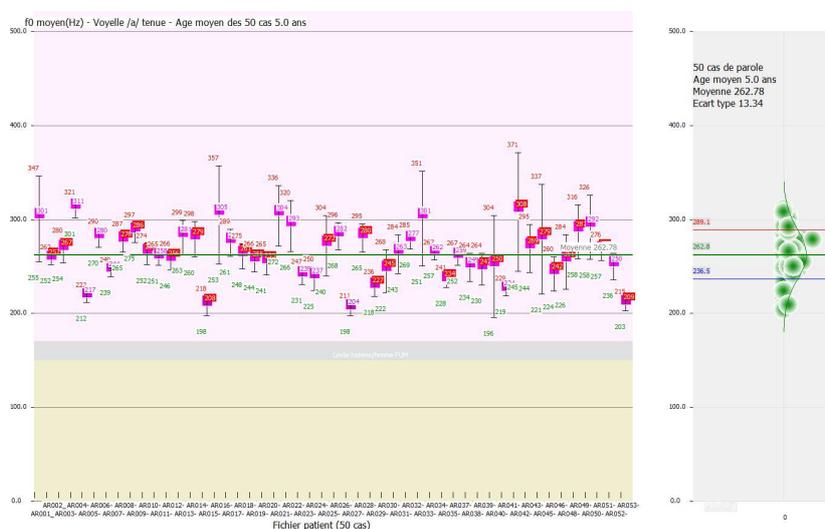


Figure 3 : fo extract of held vowels for fifty 5-year-old children [Remacle 2019]

Women’s vowels

The values obtained on sustained vowels (mainly /a:/), reported in Figure 4, are consistent with the trends noted for women in Figure 1 from 20 to 35 years old, but appear overall higher than the expected fo (Hz). It is possible that the protocol which consists in asking the patient to produce the bowel “the best you can” encouraged the patient to use a loud voice, or even for some patients the singing voice, shifting the value of fo towards the highest frequencies. Two cases (less than 2% of the corpus) are located below 150 Hz, and 6 cases (4%) are in the 150-170 Hz zone. The frequency gap between the female’s trend from the meta-analysis and the average fo compute from the corpus is 20 to 30 Hz depending on the decade (Figure 4 top).

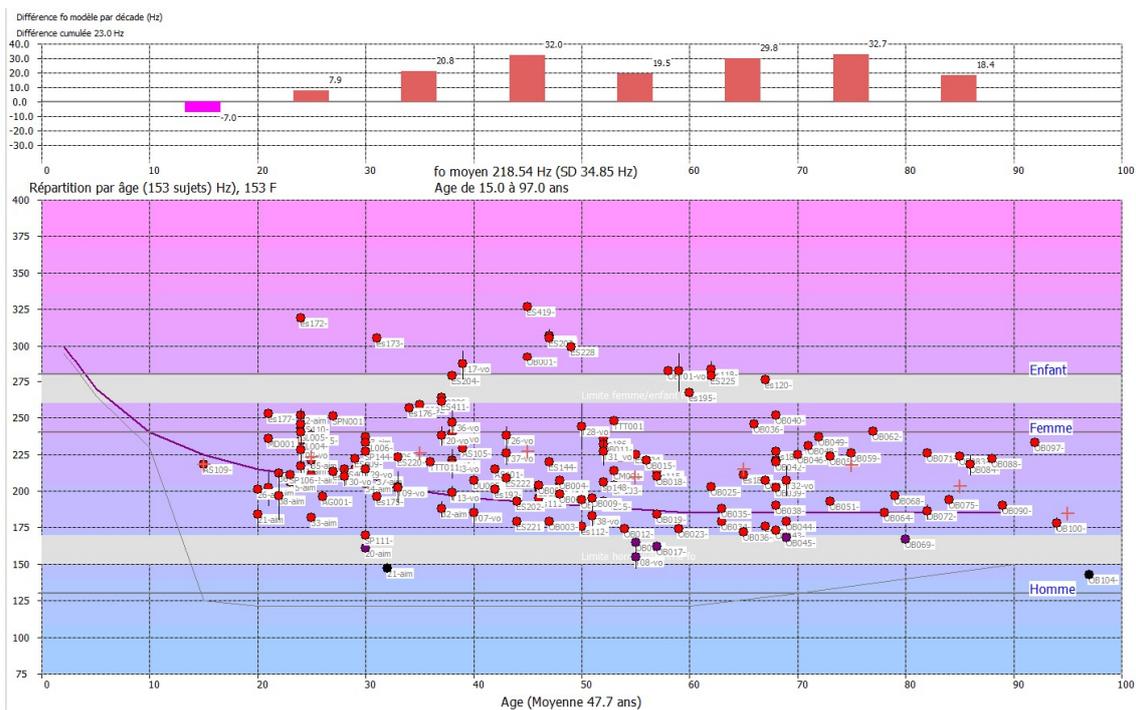


Figure 4 : fo extracted from sustained vowels pronounced by 150 female healthy controls, and evaluation of the difference with the reference model

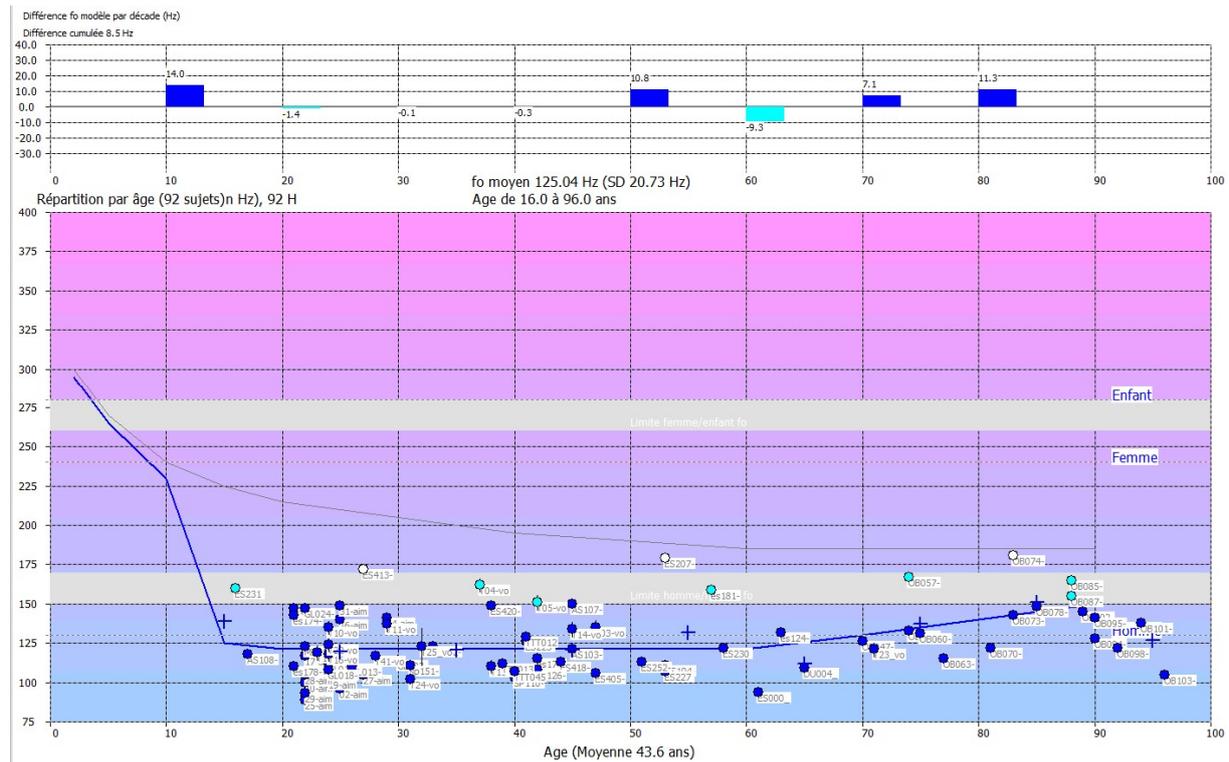


Figure 5 : fo extracted from sustained vowels pronounced by 100 healthy controls (mens)

Men's vowels

Concerning the male vowels (Figure 5), we note a good agreement between the average trajectory and the cloud of fo points as a function of age, with a cumulative error of 8 Hz, which is particularly low. About 3% of points are above 170 Hz, and 8% in the 150-170 Hz transition zone.

Analysis of standard sentences

Standard sentences - Children

The evolution of fo as a function of the age of children from 3 to 8 years old, based on a short sentence repetition task [Bardelang 2020] [Grenier 2020], is given in Figure 6. We note a regular decrease of fo with age, of the order of 8 Hz/year, and a significant reduction in the standard deviation, which is almost halved between 3 and 8 years. The average values correspond well to the bibliographic study, as shown in Figure 7.

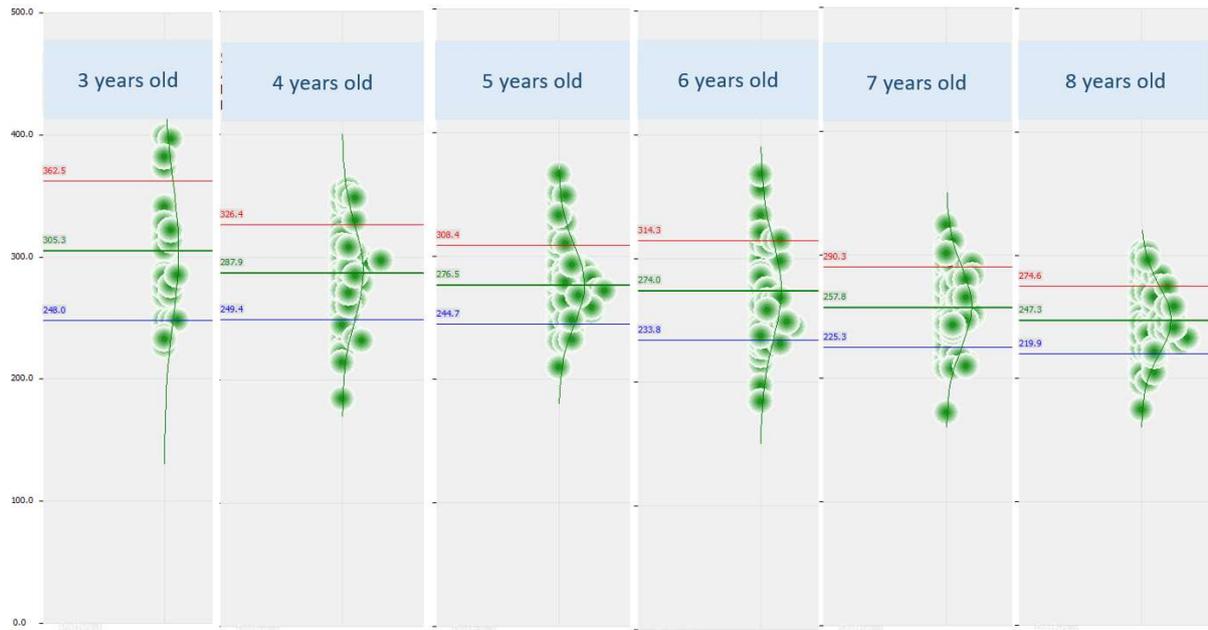


Figure 6 : fo extracted from standard sentences for children aged 3 to 8 years old

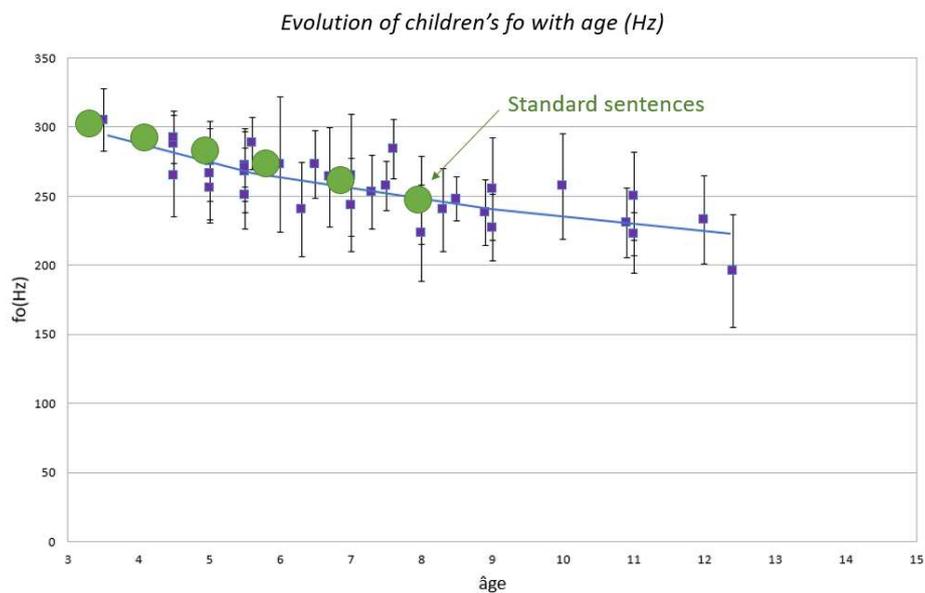


Figure 7 : Superposition of the global trend of fo vs age for young children (boys and girls combined) for standard sentences pronounced by children aged 3 to 8 years old

AGE	N	FO (HZ)	STD DEV (HZ)
3-3,9	25	305	32,5
4-4,9	55	288	20,5
5-5,9	60	277	16,0
6-6,9	49	274	22,5
7-7,9	60	258	18,0
8-8,9	75	247	16,0

Table 2 : evolution of fo for young children (boys and girls combined) from 3 to 9 years old, based on the repetition of short sentences

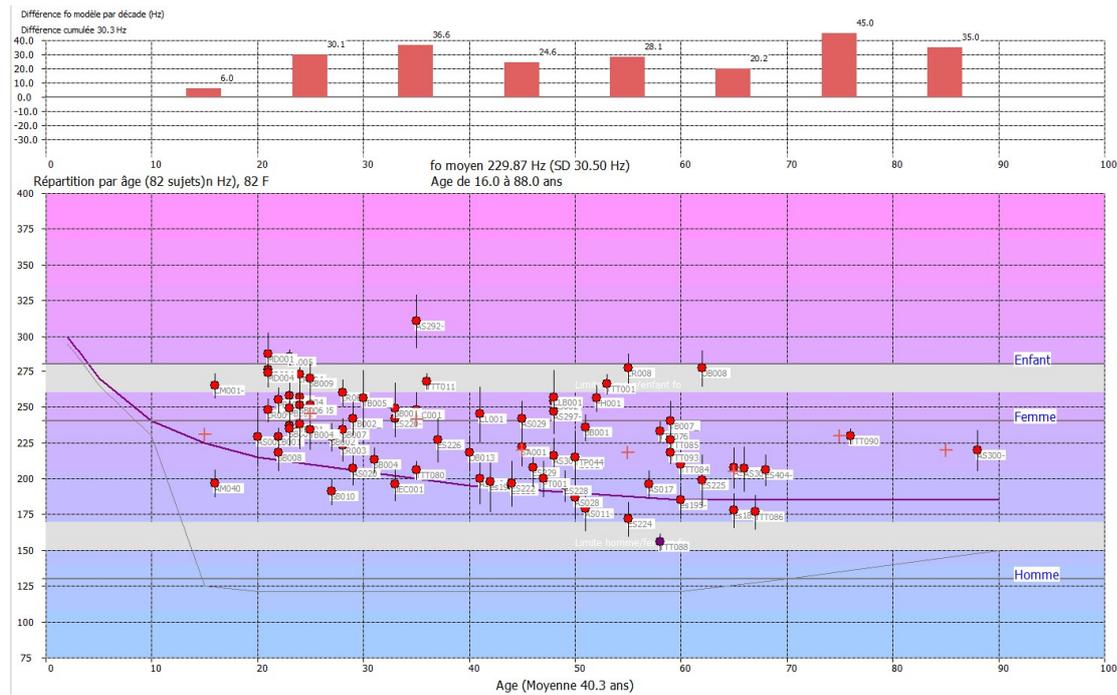


Figure 8 : fo extract of standard sentences or conversational voice for 82 female HC

Standard sentence - Women

For each sentence, we plot the average fo (red circle), the associated vertical line symbolizing +/- a standard deviation of intonation (Figure 8), as a function of age, for 82 samples of HC women. We observe a regular decrease in values, of the order of 5 Hz/decade up to 70 years, which is consistent with the trend observed in the meta-analyses. Beyond 70 years, we do not have enough points to confirm any trend.

On the other hand, evaluating the differences between averages and reference values (top of Figure 8) allows us to observe a significant shift towards high frequencies, from 20 to 30 Hz in the central decades. This shift can find its origin in the enriched prosody of the sentences analyzed, unlike a sustained /a:/. A single data point is in the 150-170 Hz zone. Compared to the averages obtained for sustained vowels, the values for standard sentences are higher, around 11.5 Hz.

Standard sentence - Men

We have a fairly small number of standard sentences pronounced by men (38 samples from 14 to 86 years old). We see in Figure 9 a cumulative error between the prediction curve of fo and the averages per decade of 13 Hz, i.e., much less than for women. About 8% are out of limit (fo>170 Hz) and 5% in the 150-170 Hz transition zone.

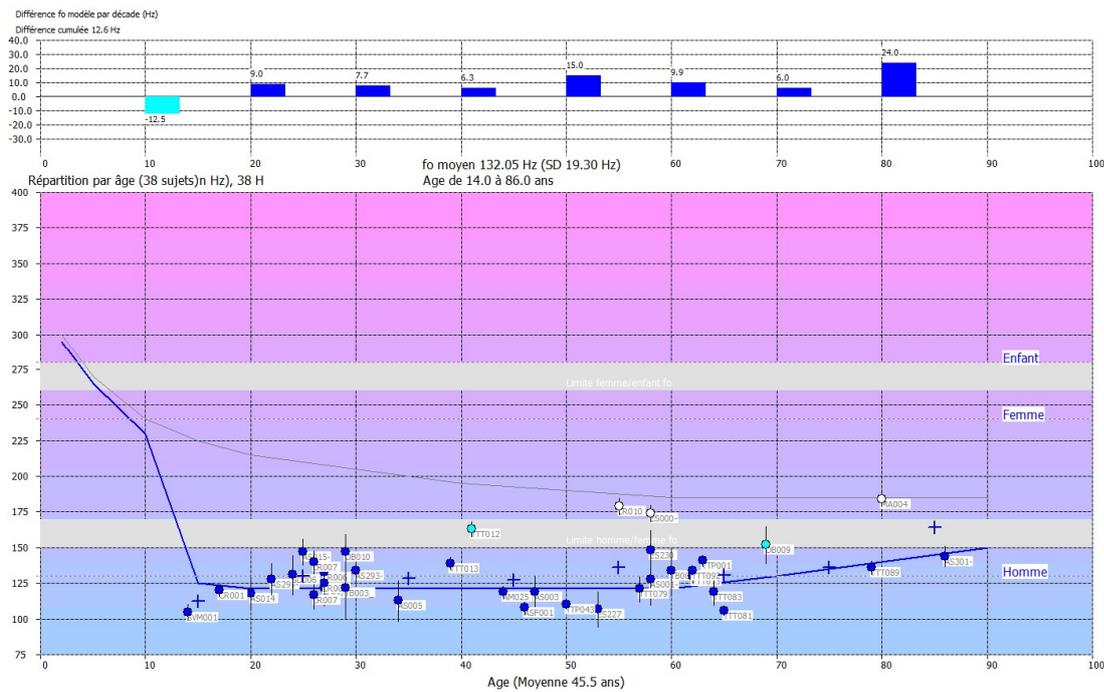


Figure 9 : fo extracted from typical sentences or conversational voice for 38 male HC.

Although the statistical strength is low, the frequency fo on typical sentences is approximately 7 Hz higher than for /a:/ held (132 Hz instead of 125 Hz).

Vocal feminization

Although the value of fo is far from being the only parameter which allows a speech segment to be perceived as masculine or feminine, the increase in fo towards the male/female transition zone, or even beyond is one of the important steps suggested by [Morsomme 2016] in the context of vocal feminization of a transgender patient. The example in Figure 10 from the “before/after” corpus of [Astrudillo 2023] shows a very clear rise in fo, initially at 160 Hz, which exceeds 220 Hz at the end of support. We also note a widening of intonation (variation of fo in the form of +/- 1 standard deviation), also identified as an important stage of vocal feminization. A summary of case studies highlighting the elevation of fo pre/post therapy is proposed in [Jaber 2021].

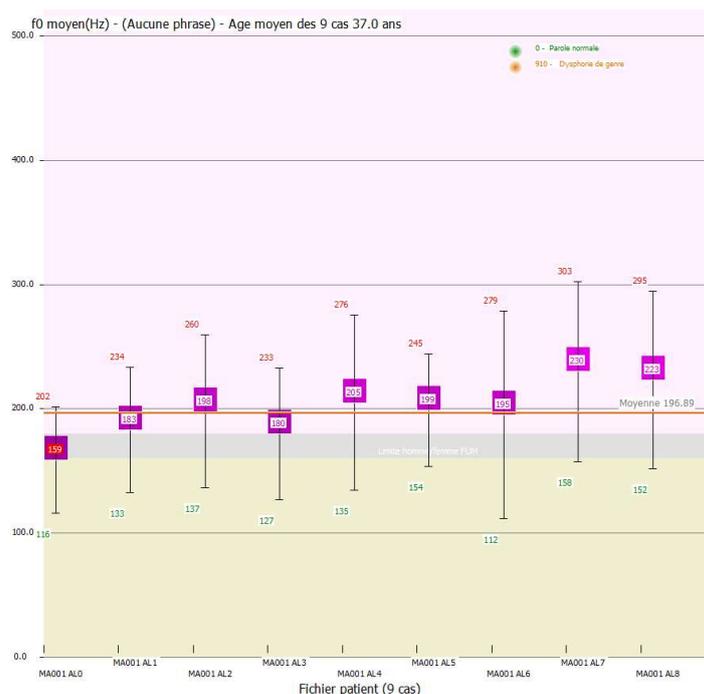


Figure 10: Evolution of fo during ten sessions of voice therapy [Astrudillo 2023]Synthèse

Reference values

If we consider spontaneous speech or text reading, we see an overall elevation of fo of the order of 12 Hz for 5-year-old children, 7 Hz for men and 11.5 Hz for women compared with sustained vowels. The reference values are reported in table 3. A transition zone of 160-180 Hz seems more appropriate than 150-170 Hz to separate the male and female corpora with this transfer method.

GENRE	LITTERATURE (HZ)	FO (HZ) SUST. VOWELS	FO (HZ) PHRASES	DIFFERENCE PHRASE/VOW. (HZ)
ENFANT 5 ANS	275	263	275	+12
HOMME 40 ANS	120	125	132	+7
FEMME 40 ANS	190	218,5	230	+11,5
ZONE DE TRANSITION	[150-170 Hz]	[150-170 Hz]	[160-180 Hz]	+10

Table 3: Evolution of fo according to gender and type of recording

Evolution with age

The rise of around 5 Hz/decade in men's fo seems to be confirmed from the age of 50-60. This result is quite close to [Fougeron 2021] which considers an increase of 5 Hz/decade from the age of 40, on a corpus of 500 cases, and the study by [Soltani 2013] which suggests an increase of 10 Hz/decade from 50 at 70 years old. A slightly lower value (2.5 Hz/decade from 60 years) is proposed by [Fukuda 2023]. Other studies cited in the literature review by [Eichhorn 2018] also note a tendency for fo to increase with age. However, there are studies such as [Spazappan 2020] which do not show a significant increase. We can, however, consider with some confidence trend towards an increase in fo from the age of 50, of the order of 5 Hz/decade.

Concerning women, a decrease in fo from 20 to 60 years old should be considered according to a slope of around 5 Hz/decade, followed by possible stabilization. These results are quite close to [Leung 2020] which estimates the reduction to -18 Hz between the ages of 20 and 60 for women and to [Fougeron 2021] which estimates the reduction of fo of around 20 Hz between the ages of 20 and 50, with little variation between 60 and 90 years. The trends are like those found by [Torre 2009], [Sebastian 2012],

or by other works cited in the literature review by [Eichhorn 2018] (table 3). However, certain different trends are reported, particularly beyond the age of 60. For example, [Fukuda 2023] estimates that the decrease in fo continues beyond the age of 60 for Japanese women at a rate of 5 Hz/decade, [Nishio 2008] even estimating it close to 10 Hz/decade.

Implementation in VOCALAB and DIADOLAB

Even if the average frequencies observed change little overall, over several decades of adult life (20-50 years for men, 60-90 years for women), the reference values for fo may serve as a normal/altere and altered threshold/pathological in clinical practice. A significant adjustment of fo should be made according to age, rather downwards for women aged 20 to 60 years and rather upwards for men over 50 years old.

Until recently, age-independent reference values were used in VOCALAB and DIADOLAB, setting an average value of fo around 220 Hz for women, 120 Hz for men and a transition zone of 140 to 160 Hz. These values were relatively consistent with publications on sustained /a:/ and clinical observations, and were used in the exploitation of the voice database [Sicard 2014] and in the case studies of voice pathologies described in [Menin-Sicard 2016], [Menin-Sicard 2016b] and [Menin-Sicard 2021].

The study on prosody conducted in [Sicard 2021] led us for the first time to question these reference values, noting a significant increase in fo calculated on standard sentences, compared to the protocol based on sustained /a:/.

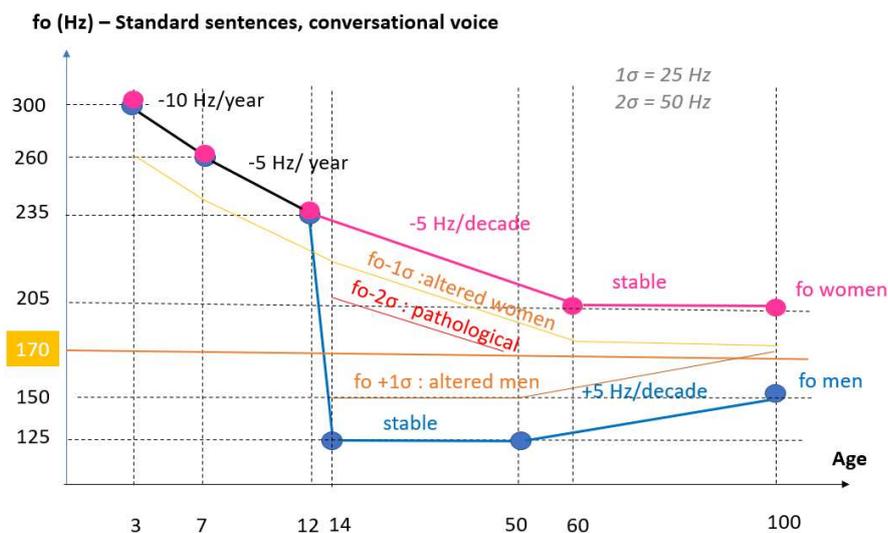


Figure 11 : Evolution of fo with age implemented in the VOCALAB and DIADOLAB tools for voice & speech therapy, valid for standard sentences or spontaneous speech.

We decided to implement the fo model as a function of age, which means that the value considered as the norm evolves in accordance with the slopes described in Figure 11. The standard deviation deduced from meta-analyses (25 Hz) is used to set the normal/altered limits at 1σ (-25Hz for women, +25 Hz for men), and the altered/pathological limits at 2σ (-50 Hz for women, +50 Hz for men). The reference values are accessible from the Media library > VOCALAB References and Resources > DIADOLAB reference menu.

VOCALAB

The VOCALAB protocol includes the recording of sustained /a:/ [Menin-Sicard 2021] and conversational voice. However, the evaluation of fo is performed mostly on conversational voice, in the “fo+vocal range” evaluation tool. Likewise, the “Evolution” tool is based on the calculation of fo on spontaneous speech and not on the sustained vowel. Only alteration indicators apply to the sustained /a:/ [Sicard 2013]. The histogram of fo is calculated on a presentation sentence.

We give in Figure 11 the histogram of the conversational voice of a woman (case study AS033 described in [Menin-Sicard 2021]) with a lowered fundamental frequency. The left part of the histogram is located below 160 Hz, significantly below the fo reference value for a woman at 63 years old (205 Hz), i.e. a shift towards low frequencies.

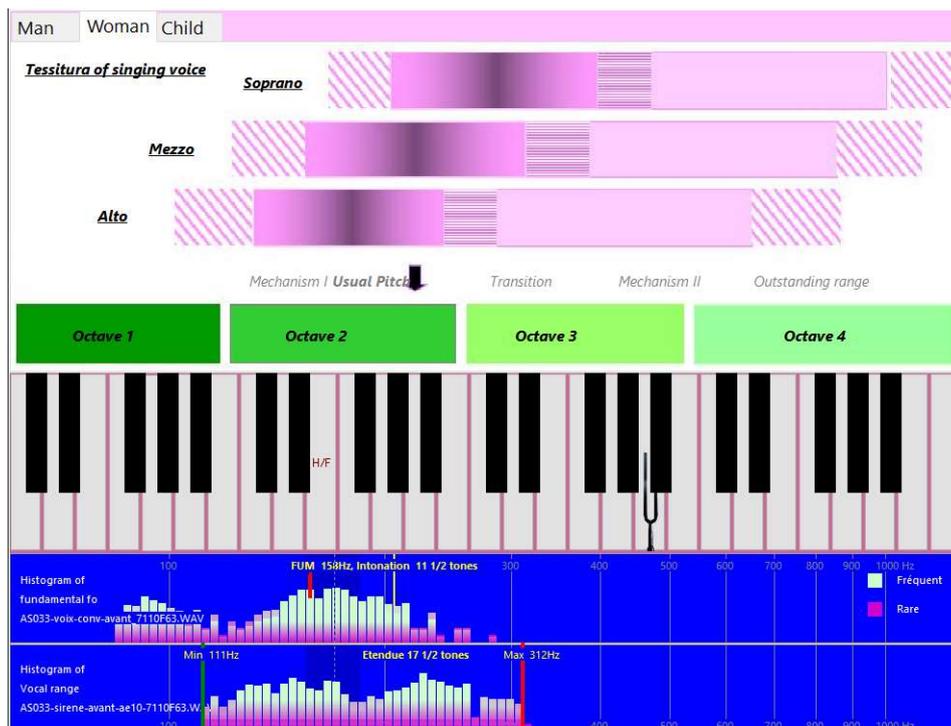


Figure 12 : Transition zone from 160 to 180 Hz defined in the VOCALAB voice therapy tool, illustration with the histogram of the conversational voice (top) and siren (bottom) [Sicard 2023]

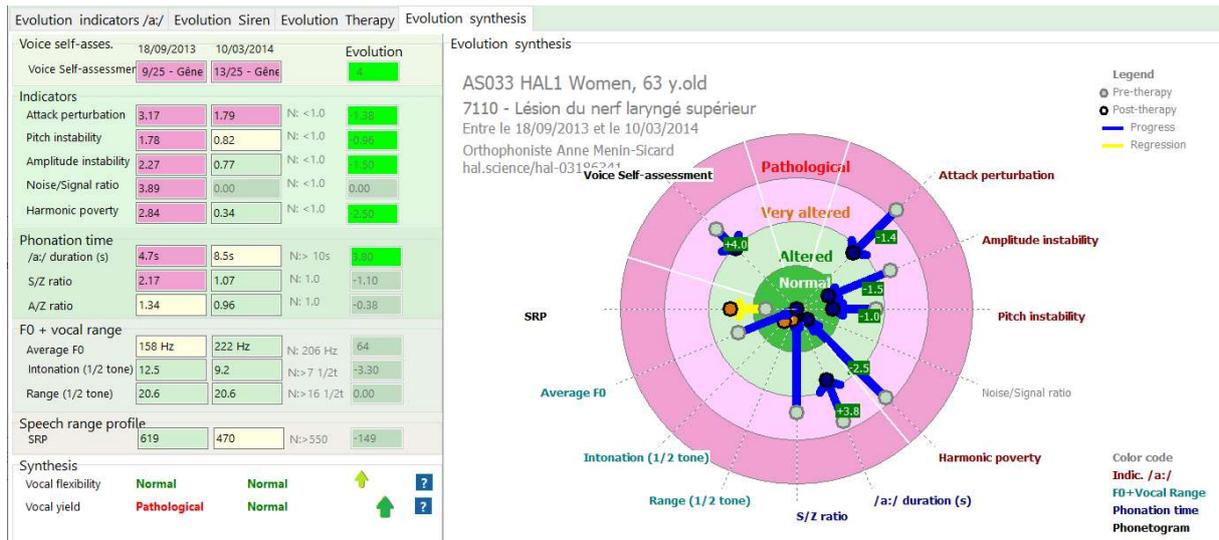


Figure 13 : Evolution of AS033 case study, before/after voice therapy using VOCALAB [Menin-Sicard 2021]

The VOCALAB evolution module also uses the fo benchmarks to alert on the non-compliance of fo as in the AS033 case before therapy (figure 13), which is evaluated at 158 Hz, while the average, according to the table 1, should be around 205 Hz according to the model presented in figure 11. After therapy, fo has reached 222 Hz, which is considered as normal.

DIADOLAB

In the tool *Assessment > Prosody*, we have implemented the fo thresholds according to age to alert the speech & language pathologist to a possible prosody anomaly. For the CS002 case study described in [Sicard 2021], the reference fo at 82 years old is around 140 Hz (15 Hz higher than at 50 years old). The patient crossed the normal/impaired limit of 165 Hz with an fo at 170 Hz (Figure 14).



Figure 14 : DIADOLAB Prosody module, case study CS002 [Menin-Sicard 2021]

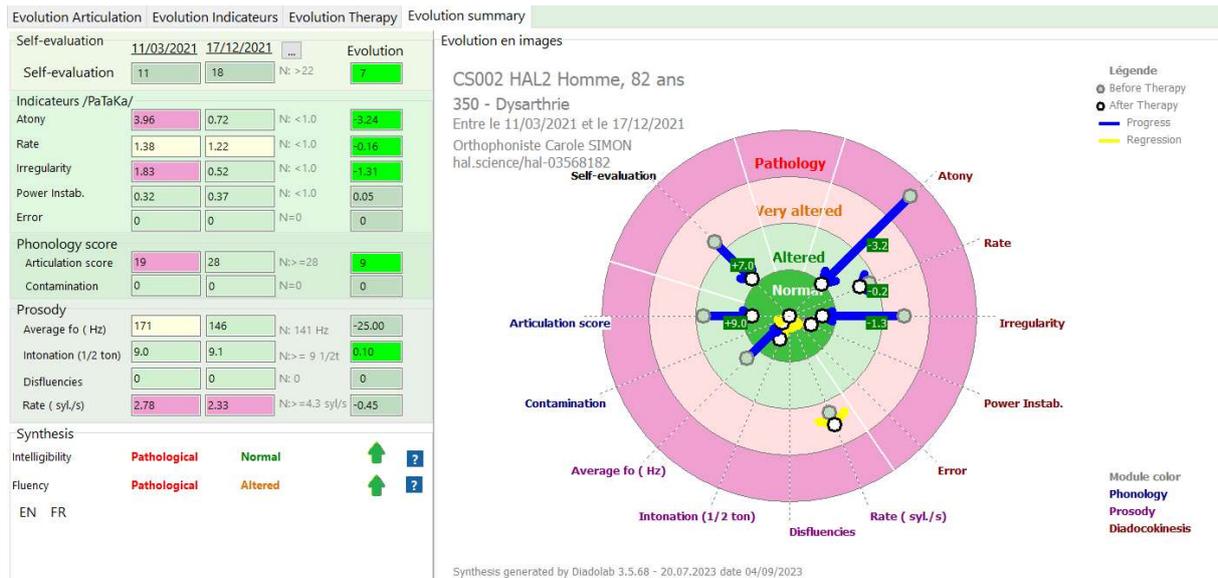


Figure 15 : DIADOLAB, evolution of case study CS002 [Menin-Sicard 2021]

In the *Evolution* module, the average fo at the initial assessment is 171 Hz, more than one standard deviation above the norm at 82 years (141 Hz), therefore considered “impaired”. After therapy, the average fo drops to 146 Hz, very close to the expected fo, therefore considered as normal (Figure 15).

Conclusion

We studied open data from recent scientific literature on the value of the fundamental frequency (fo) of voice and speech, depending on gender and age. We compiled around 200 groups of values in order to extract general trend over the whole lifespan. We separately studied the speech of children, women and men on two main modalities: sustained vowels and text reading. We observed significant differences between the two modalities. Reference values have been proposed, with a simplified model which takes up on the one hand the decrease of fo in young age, the decrease of fo for women up to 60 years of age and the increase of fo for men aged 50 and over. We have illustrated the implementation of the trends according to age in the VOCALAB tool for voice therapy, and DIADOLAB tool for speech therapy.

Acknowledgements

We would like to thank the speech therapists contributing to ERU 15 “pathological voice” and ERU 46 “pathological speech” from the LURCO laboratory, France, as well as the speech therapists who agreed to record healthy controls and patients, or to co-supervise research projects linked to voice, speech and their pathologies. We thank Cécile FOUGERON for giving us details in relation to the fo values from the *MonPaGe* protocol.

We would also like to thank all the speech therapists, students and researchers who have placed their trust in us by using our methodologies, approaches, and tools in the context of their clinical practice or their scientific research.

About the authors



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Annexe A – Fo values for men

<i>Average men age</i>	<i>fo (Hz)</i>	<i>Std dev (Hz)</i>	<i>Sources</i>
3,5	305,0	22,5	Sicard
4,5	265,0	29,9	Trollinger
4,5	288,0	20,5	Sicard
4,5	292,44	18,75	Soltani
5,0	256,0	25,0	Sicard
5,0	266,0	33,0	Lee
5	275,1	29,1	Tavares
5,5	250,5	24,1	Remacle
5,5	267,7	29,3	Remacle
5,5	272,5	26,3	Remacle
5,5	271,0	14,1	Sicard
5,6	288,33	19,02	Soltani
6,0	273,0	49,0	Lee
6,3	240,5	34,0	Gelfer
6,5	273,0	24,3	Sicard
6,7	263,7	35,8	Spazzapan
7,0	265,0	44,0	Lee
7	243,4	33,7	Tavares
7,3	253,0	26,6	Gelfer
7,5	257,0	17,8	Sicard
7,6	284,15	21,24	Soltani
8,0	223,3	34,8	Berger
8,0	247,0	32,0	Lee
8,3	240,0	30,0	Gelfer
8,5	248,0	15,8	Sicard
8,9	238,0	23,8	Spazzapan
9,0	255,0	37,0	Lee
9	227,3	23,8	Tavares
10,0	257,0	38,0	Lee
10,9	230,9	25,2	Spazzapan
11,0	222,3	28,2	Poulain
11,0	250,0	32,0	Lee
11	222,5	15,7	Tavares
12,0	233,0	32,0	Lee
12,4	195,8	40,7	Spazzapan
12,5	219,12	21,11	Soltani
13,0	187,3	40,7	Berger
13,0	181,0	52,0	Lee
14,0	176,0	45,0	Lee
14,7	127,6	42,0	
14,7	124,32	17,31	Soltani

15,0	125,0	36,0	Lee
16,0	122,3	25,8	Berger
16,0	126,0	30,0	Lee
17,0	129,0	26,0	Lee
17,0	121,3	18,4	Spazzapan
18,0	124,0	27,0	Lee
19,0	118,0	17,0	Goy
20,0	124,9	13,5	Gilmore
20,0	129,0	18,0	Hollien
21,8	118,53	24,64	Soltani
22,0	122,6	19,1	Spazzapan
23,0	112,0	18,0	Leung,Y.
24,0	121,7		Nishio
25,4	127,0	19,0	Fougeron
26,5	136,0	10,0	Murry
31,0	118,9	8,9	Sicard
31,8	117,65	23,35	Soltani
32,0	122,0	10,0	Graddol
32,8	123,6	16,0	Spazzapan
33,0	119,4	17,2	Ayoub
33,0	112,0	17,4	Troughear
34,0	121,0	31,0	Leung,Y.
34,0	116,0	20,0	Fougeron
35,0	119,3		Nishio
35	113	9,4	Dehqan
41,5	117,81	23,46	Soltani
44,1	129,3	24,1	Spazzapan
44,3	132,0	9,2	Sicard
45,0	119,3		Nishio
45,0	111,0	16,0	Leung,Y.
45,0	104,5	14,0	Berg
45,0	122,0	18,9	Berg
45,0	124,0	17,0	Fougeron
51,5	114,06	23,79	Soltani
53,5	128,9	23,1	Spazzapan
53,7	129,0	28,0	Fougeron
54,4	132,0	30,0	Fougeron
55,0	122,9		Nishio
55,0	114,0	17,0	Leung,Y.
55,0	106,5	14,9	Berg
55,0	124,7	22,2	Berg
62	140,4	13,9	Sebastian
63,6	131,5	28,8	Spazzapan
64,0	112,9	17,5	Berg
65,0	123,4		Nishio
65,0	130,0	20,0	Berg
67	140	20,4	Sebastian

68	130,9	18	Pessin
70,5	127,45	22,25	Soltani
71,4	137,0	10,0	Murry
72,0	116,0	16,0	Goy
72	144,8	48,7	Sebastian
74	128	25	Spazzapan
74,6	134,0	23,0	Fougeron
75,0	132,5		Nishio
75,0	127,6	29,2	Deliyski
75,0	120,6	19,8	Berg
75,0	141,0	26,1	Berg
77	136,3	22,4	Sebastian
81,0	112,5	6,0	Eichhorn
83	146	14,9	Dehqan
83	133,3	20	Pessin
84,3	150,0	30,0	Fougeron
85,0	136,5		Nishio
90,0	150,0	25,0	Fukada

Annexe B – Fo values for women

<i>Average age</i>	<i>fo (Hz)</i>	<i>Std Dev (Hz)</i>	<i>Sources</i>
3,5	305,0	22,5	Sicard
4,5	265,0	29,9	Trollinger
4,5	288,0	20,5	Sicard
4,6	292,53	15,37	Soltani
5,0	255,0	25,0	Sicard
5,0	272,0	37,0	Lee
5	257,1	29,1	Tavares
5,5	260,0	25,2	Remacle
5,5	275,0	34,5	Remacle
5,5	282,0	35,6	Remacle
5,5	271,0	14,1	Sicard
5,5	289,75	18,02	Soltani
6,0	265,0	53,0	Lee
6,3	240,5	34,0	Gelfer
6,5	273,0	24,3	Sicard
6,6	267,9	30,1	Spazzapan
7,0	281,0	43,0	Lee
7	258,9	33,7	Tavares
7,3	253,0	26,6	Gelfer
7,5	257,0	17,8	Sicard
7,6	282,4	17,12	Soltani
8,0	223,3	34,2	Berger

8,0	273,0	31,0	Lee
8,3	240,0	30,0	Gelfer
8,5	248,0	15,8	Sicard
9,0	267,0	35,0	Lee
9,0	241,2	35,2	Spazzapan
9	230,5	23,8	Tavares
10,0	263,0	41,0	Lee
10,6	238,2	28,0	Spazzapan
11,0	222,3	28,2	Poulain
11,0	247,0	37,0	Lee
11	234,1	15,7	Tavares
12,0	234,0	27,0	Lee
12,4	226,1	48,3	Spazzapan
12,5	213,5	31,3	Berger
12,5	258,65	21,63	Soltani
13,0	251,0	43,0	Lee
14,0	225,0	27,0	Lee
14,3	219,0	21,1	
14,6	217,2	19,49	Soltani
15,0	220,0	27,0	Lee
16,0	205,8	27,7	Berger
16,0	225,0	20,0	Lee
16,9	223,7	16,1	Spazzapan
17,0	219,0	20,0	Lee
18,0	242,0	15,0	Lee
19,0	206,3	14,3	Gilmore
19,0	208,0	19,0	Goy
21,0	223	22,3	Spazzapan
21,4	214,8	19,08	Soltani
21,5	228,0	3,4	De Pinto
21,5	204,0	19,3	Weirich
22,0	229,0	12,3	Pemberton
22,0	229,0	12,3	Russel
22,0	217,0		Fitch
24,0	226,1		Nishio
24,0	206,0	32,0	Leung,Y.
24,8	219,0	21,0	Fougeron
25,0	207,3	23,2	Zraick
26,5	193,0	18,0	Murry,
31,9	214,2	21,02	Soltani
32,0	208,0	20,0	Graddol
33	208,4	23,1	Spazzapan
34,5	202,0	28,0	Fougeron
35,0	210,2		Nishio
35,0	195,0	19,0	Leung,Y.
35	210	11,6	Dehqan
38,0	231,0	40,0	Lee

39,9	216,2	17,0	Sicard
41,2	213,07	21,3	Soltani
42,0	195,6	19,3	Troughear
44	198,2	20,1	Spazzapan
44,7	210,0	23,0	Fougeron
45,0	201,6		Nishio
45,0	193,0	23,0	Leung,Y.
45,0	170,5	23,2	Berg
45,0	198,4	31,3	Berg
51,8	190,27	23,57	Soltani
54	194,9	21,0	Spazzapan
54,9	206,0	28,0	Fougeron
55,0	190,1		Nishio
55,0	184,2	9,6	Russel
55,0	188,0	20,0	Leung,Y.
55,0	163,1	22,8	Berg
55,0	192,6	26,6	Berg
56,0	180,0	3,4	De Pinto
62	189,6	13,9	Sebastian
63	189,5	23,9	Spazzapan
64,6	204,0	29,0	Fougeron
65,0	187,1		Nishio
65,0	169,6	27,1	Berg
65,0	200,7	31,2	Berg
65	193,81	24,8	Cerceau
66,5	181,2	17,5	Russel
67	177,4	20,4	Sebastian
68	202,6	28	Pessin
71,4	172,0	22,0	Murry
71,4	178,96	25,03	Soltani
72,0	174,0	22,0	Goy
72	194,5	48,7	Sebastian
74,5	207,0	25,0	Fougeron
75,0	170,6		Nishio
75,0	187,0	42,2	Deliyski
75,0	171,3	23,8	Berg
75,0	200,0	26,9	Berg
75	188,1	27,6	Spazzapan
75	195,71	27,3	Cerceau
77	188,4	22,4	Sebastian
81,0	182,7	6,0	Eichhorn
83	194	15	Dehqan
83	199,4	20,1	Pessin
84,3	205,0	30,0	Fougeron
85,0	167,9		Nishio
88	187,6	21,6	Cerceau

90,0

190,0

25,0

Fukada