The loss of a generation: the accelerating decline of hearing acuity among healty adults

Catherine L. Lortie[1,2], Mylène Bilodeau-Mercure[1,2], Claudie Ouellet[2], Pascale Tremblay[1,2], Matthieu J. Guitton[1,2]

[1]Faculté de Médecine, Université Laval, [2]Centre de Recherche de l'Institut Universitaire en Santé Mentale de Québec (CRIUSMQ)

Introduction

According to the Canadian Association of Speech-Language Pathologists and Audiologists 20-40% of adults over 65 have a significant hearing problem. However, little is known about the manner in which hearing evolves throughout adulthood. Is hearing loss gradual or sudden? Does the rate of change accelerate after a certain age? This study aims to establish a detailed audiometric portrait of healthy adults. One hundred forty two healthy adults ranging in age from 19 to 93 years old participated in the study. Their pure tone hearing thresholds, speech reception threshold (SRT) and distortion product otoacoustic emissions (DPOAEs) were measured.

Table 1. Participants.

			Age	Education		MOCA		Handeness		GDS	
Age	**N**	**% women**	**mean ± SD**	**mean ± SD**	**range**	**mean ± SD**	**range**	**mean ± SD**	**range**	**mean ± SD**	**range**
19-29	27	70,4	23,56 ± 2,45	17,07 ± 2,2	13–21	29 ± 1,21	26–30	18,11 ± 2,65	9–20	2,41 ± 2,1	0–8
30-39	22	40,9	33,36 ± 2,84	18,14 ± 2,78	11–24	28,32 ± 1,09	26–30	19,32 ± 1,73	12–20	2,18 ± 2,15	0–6
40-49	10	50	44,6 ± 3,27	17 ± 4,37	11–24	28 ± 1,49	26–30	15,7 ± 12,89	-19–20	3,7 ± 4,67	0–11
50-59	23	60,9	54,7 ± 2,87	15,91 ± 4,33	10–29	28,04 ± 1,69	25–30	16,22 ± 11,15	-20–20	1,39 ± 1,9	0–8
60-69	29	65,5	64,62 ± 2,94	18,31 ± 4,26	11–33	27,48 ± 2,03	22–30	19,41 ± 1,35	15–20	1,97 ± 3,13	0–14
70-79	22	59,1	73,5 ± 2,43	16,05 ± 3,99	6–24	26,32 ± 1,99	22–29	19,27 ± 1,42	15–20	2,32 ± 2,55	0–9
80-93	9	88,9	83,11 ± 4,2	12,11 ± 3,98	6–18	26,78 ± 1,48	25–30	15,11 ± 11,02	-14–20	3,44 ± 4,19	0–12
Total	**142**	**61,3**	**51,5 ± 19,71**	**16,82 ± 3,93**	**6–33**	**27,8 ± 1,82**	**22–30**	**18 ± 6,38**	**-20–20**	**2,26 ± 2,78**	**0–14**

All participants had normal or corrected-to-normal vision and no self-reported history of speech, voice, language, hearing, psychological, neurological or neurodegenerative disorder. Participants were screened for depression using the Geriatric Depression Scale (GDS) and their cognitive functioning was evaluated using the Montreal Cognitive Assessment scale (MOCA). Handedness was assessed by the Edinburgh Handedness Inventory. Hearing assessments were included as part of the different projects for which the participants were recruited; all these projects were approved by the Institutional Ethical Committee of the "Institut Universitaire en Santé Mentale de Québec" (protocols 280-2011, 293-2012, and 294-2012). Informed written consent was obtained from all participants. Participants were compensated for their participation.

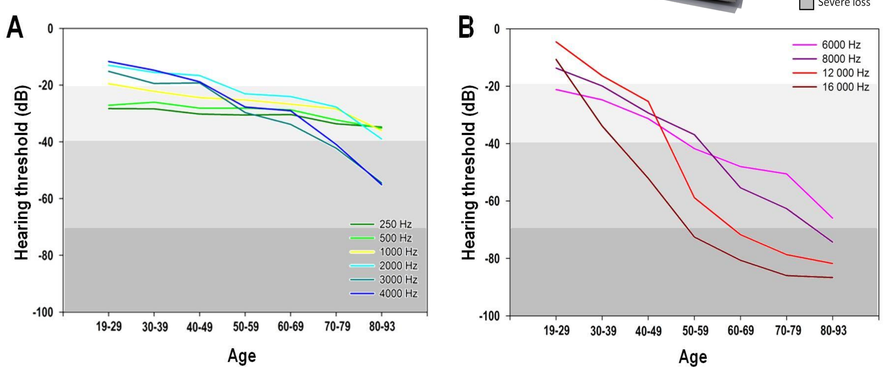
Analyses

Pure tone hearing thresholds (10 frequencies), speech reception threshold (SRT) and distortion product/noise floor ratios (DPOAEs; 9 frequencies) were used for statistical analyses. Associations between ears were calculated using Pearson correlation coefficients on PTA and DPOAEs. Because right and left PTA were highly correlated (r=0.86, p<0.0001), further analyses were conducted on the right ear only. ~~Same repeated~~ for right and left DPOAEs (r=0.36 to 0.77, p<0.0001), for which further analyses were conducted on the right ear only. When applicable, data were presented as mean ± SD. For all statistical procedures, α=0.05 was used to establish significance.

~~The~~ ANCOVA ~~on~~ repeated measures revealed that hearing thresholds were significantly affected by age when controlling for gender and educational level ($F_{(6,133)}$=53.54, p<0.001). As expected, hearing thresholds ~~were affected~~ by frequency ($F_{(4,564)}$=5.22, p<0.001). An interaction was observed between age group and frequency ($F_{(24,544)}$=25.51, p<0.001), meaning that the effect of age group on hearing thresholds depends on the frequency assessed. Also, educational level has an effect on hearing thresholds ($F_{(1,141)}$=5.08, p<0.05), but not gender ($F_{(1,141)}$=0.03, p>0.05). The repeated measures ANCOVA revealed that DPOAEs were significantly affected by age after controlling for gender and educational level ($F_{(6,133)}$=13.32, p<.001). An interaction was also observed between age group and frequency ($F_{(24,544)}$ = 2.62, p<.001), meaning that the effect of age on DPOAEs ~~depended~~ on the frequency. Neither gender or educational level have an effect on DPOAES amplitude ($F_{(1,141)}$ = 1.01 et 1.06, p>0.05).

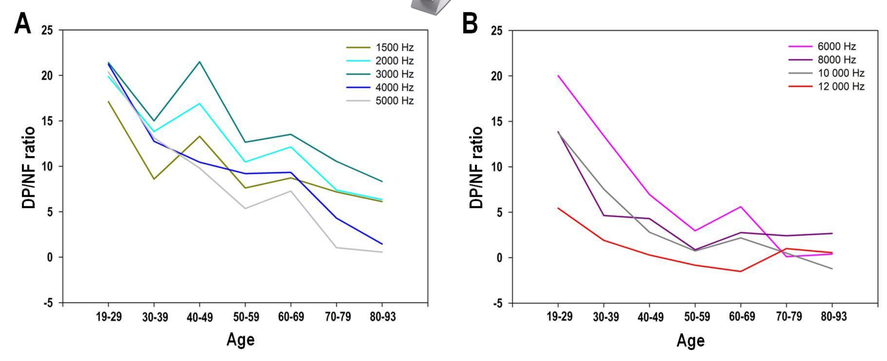
Results

Figure 1. Mean pure tone hearing thresholds by age group.



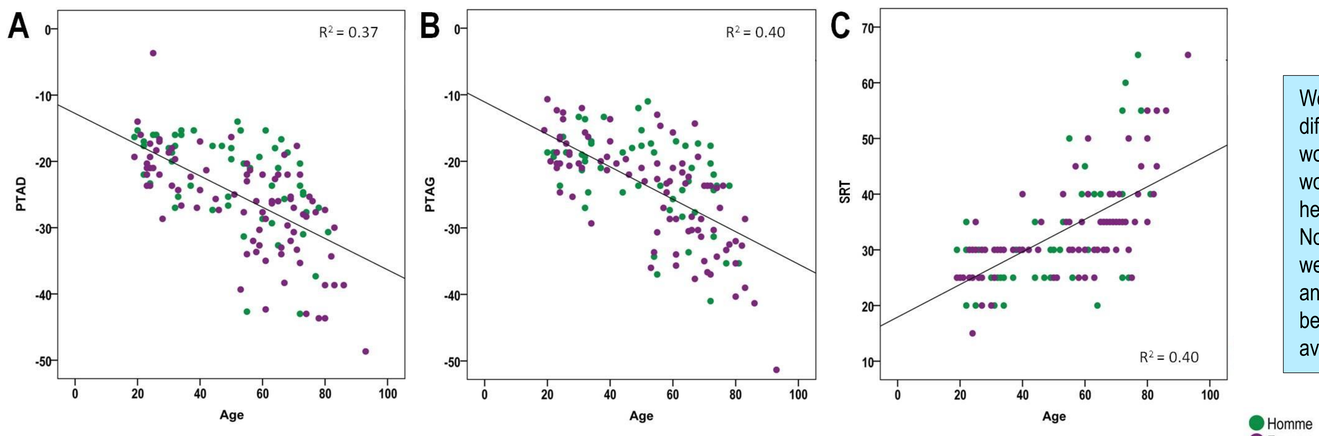
Legend: Mean hearing thresholds (right ear) for low (**A**) and high (**B**) frequencies were calculated within each age group.

Figure 2. Mean DPOAEs by age group.



Legend: Mean DPOAEs emitted by right ear cochlea at low (**A**) and high (**B**) frequencies were calculated within each age group.

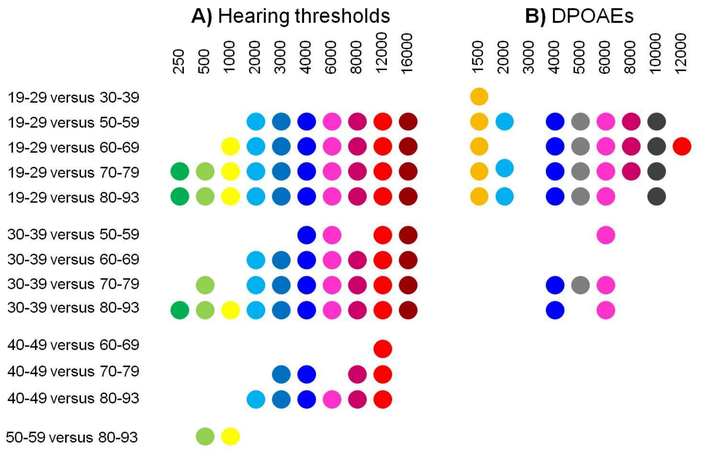
Figure 3. Age effect on pure tones PTA and SRT.



Legend: Linear regressions showed that right (**A**) (r=.61, $F_{(1,140)}$=94.07, p<0.001) and left PTAs (**B**) (r = 0.63, $F_{(1,140)}$=83.28, p<0.001) were significantly and positively related to chronological age, with threshold increasing with age. A linear regression also showed that SRT was positively correlated with age (**C**) (r=.63, $F_{(1,140)}$=93.71, p<0.001).

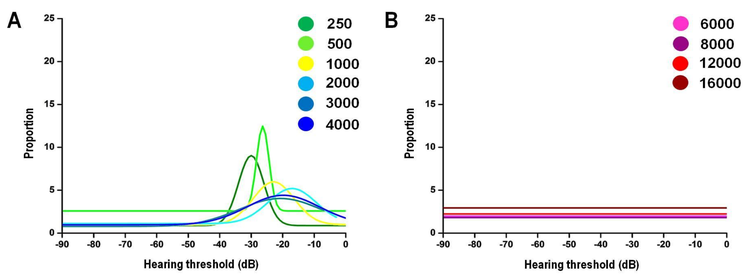
We observed a significant difference between men and women PTA (p<.0001), women having higher hearing threshold than men. No significant difference were found between men and women SRT (p=.15) nor between men and women average DPOAEs (p=.89).

Figure 4. Differences between age groups' hearing thresholds for pure-tone frequencies.



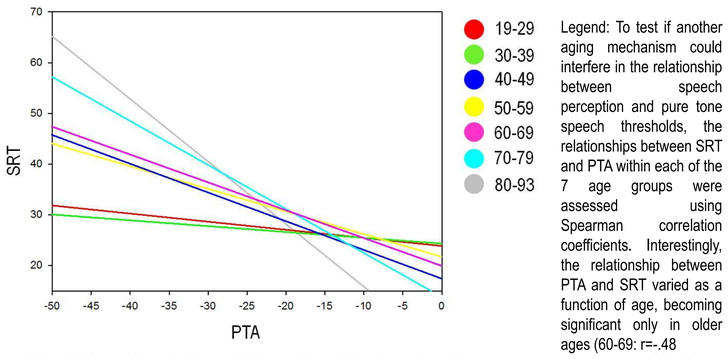
Legend: To determine if certain frequencies are more affected by age than others, the hearing thresholds (**A**) and the DPOAEs (**B**) of the seven age groups were compared to each other at each frequency using Kruskal-Wallis tests with Dunn pair wise multiple comparison correction (d.f.=6; right ear). Colored dots indicate a significant difference, alpha level at p<0.05. ***- Hearings thresholds (A).*** Unsurprisingly, the younger group (19-29 years old) differed from the older groups (80-93 and 70-79) on all frequencies, and from the 60 to 69 years group on almost all frequencies with the exception of 250 and 500 Hz. Differences between contiguous groups (30-39 vs. 50-59, 30-39 vs. 60-69, 40-49 vs. 60-69) were situated mostly at medium and high frequencies (4 kHz and higher). ***- DPOAEs (B).*** Results showed that the younger group (19-29) was significantly different than groups of 50 years old and more at almost all frequencies. The 30 to 39 years old group also differed from older groups of 50 years old and more to a lesser extent at frequencies situated mostly within the conversational range. Contrary to the pure tone results, there was little difference between younger and older groups at the highest DPOAEs frequency assessed (12 kHz) as all groups had low DPOAEs (means ranged from -1.51 to 5.44).

Figure 5. Distributions of hearing thresholds proportions at each pure tone frequency.



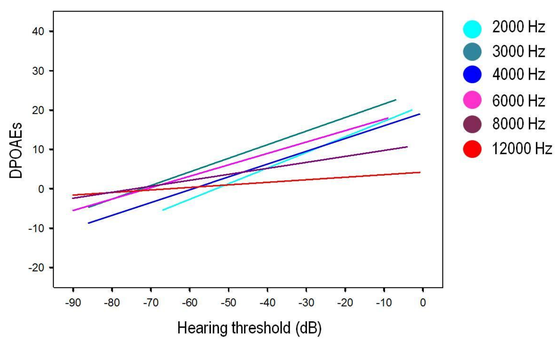
Legend: The distributions of hearing thresholds proportions across participants for each frequency were fitted using a Gaussian amplitude fit to test for a normal distribution, which revealed that low frequencies (**A**) were normally distributed (250-4000 Hz), but high frequencies (**B**) did not follow a Gaussian distribution (6000-16000 Hz).

Figure 6. Relationship between PTA and SRT.



Legend: To test if another aging mechanism could interfere in the relationship between speech perception and pure tone speech thresholds, the relationships between SRT and PTA within each of the 7 age groups were assessed using Spearman correlation coefficients. Interestingly, the relationship between PTA and SRT varied as a function of age, becoming significant only in older ages (60-69: r=-.48 p=.0084, 70-79: r=-.50 p=.0162 and 80-93: r=-.83 p=.0019; Figure P). SRT was also related to average DPOAEs (r=-0.45, p<0.0001), to pure tone thresholds for every frequency (r ranged from .39 to .79, p<.001) and to PTA (r=-.69 p<0.0001).

Figure 7. Relationships between pure tones and DPOAEs.



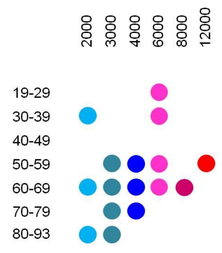
Legend: Linear regressions between pure tones hearing thresholds and DPOAEs for mutual frequencies are shown. To determine if results in different hearing assessments are related, Pearson correlation coefficients were calculated between hearing thresholds and DPOAEs on shared frequencies (i.e., 2K, 3K, 4K, 6K, 8K and 12 kHz). Results showed that hearing thresholds and DPOAEs were moderately correlated at mutual frequencies (i.e., 2, 3, 4, 6, 8 and 12 kHz; r ranged from .40 to .58, p<.001). PTA and average DPOAEs were also moderately correlated (r=.53, p<0.0001).

Table 2. Comparison between 1949 and today's mean hearing losses across frequencies according to age groups.

Age	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	Mean difference (dB) 1949-2013
19-29	28 (0)	24 (0)	19 (0)	13 (0)	12 (3)	14 (5)	**17**
30-39	28 (5)	26 (5)	22 (5)	15 (6)	15 (14)	20 (16)	**12.5**
40-49	30 (7)	28 (7)	24 (8)	17 (8)	19 (21)	30 (25)	**12**
50-59	31 (10)	28 (12)	25 (12)	23 (13)	28 (29)	37 (32)	**10.6**
60-69	30 (14)	29 (15)	27 (19)	24 (24)	29 (40)	55 (48)	**5.6**
70-79	34 (19)	32 (23)	28 (24)	28 (31)	41 (47)	63 (59)	**3.8**
80-93	35 (23)	35 (27)	36 (33)	39 (39)	55 (56)	74 (66)	**5**

Legend: Pure tone hearing thresholds at .25, .5, 1, 2, 4 and 8 kHz were superposed to the normative values for similar age groups published in 1949 (in parenthesis; Leisti, 1949). Negative discrepancies of minus 5 dB and more are indicated in yellow and minus 10 dB and more in red. Positive differences of 5 dB and more are indicated in light green and 10 dB and more in dark green. This analysis revealed a major increase in hearing thresholds for the youngest group (19-29: 17 dB worse). Indeed, an increase in hearing threshold ranging from 5 to 10 dB was found in all frequencies. Surprisingly, older adults' hearing thresholds (60 to 93 years old individuals) exhibited only a 5 dB decline compared to the 1949 data, with some frequencies (4 KHz) better heard by 60 to 79 years olds individuals than their compatriots 65 years ago. Since the effect sizes were not provided, this analysis was only qualitative; thus results must be interpreted with most caution.

Figure 8. Relationships between pure tones and DPOAEs within age groups.



Legend: Relationships between hearing thresholds and DPOAEs within age groups are shown. Colored dots indicate significant relationships. The results showed that this relationship varied as a function of age. In younger groups, there was very little or no relationship between those measures. However, the relationship between hearing thresholds and DPOAEs became significant at age 50 for almost all frequencies tested.

Conclusions

- Hearing loss begins around 50 to 59 years old and worsens with age.
- While higher frequencies are affected first, lower frequencies (including the conversational range) progressively weaken.
- Results suggest that normal age-related hearing decline has changed over the past fifty years occurring earlier and being more extensive.
- Data suggest a difference in tool sensibility across ages to identify and measured ~~-~~hearing loss.

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