Judit Bóna: JASA Express Letters [http://dx.doi.org/10.1121/1.4885482] Published Online 11 July 2014

# Temporal characteristics of speech: The effect of age and speech style

**Judit Bóna**
*Department of Phonetics, Eötvös Loránd University, H-1088 Budapest, Múzeum krt 4/A, Hungary*
*bona.judit@btk.elte.hu*

**Abstract:** Aging affects temporal characteristics of speech. It is still a question how these changes occur in different speech styles which require various cognitive skills. In this paper speech rate, articulation rate, and pauses of 20 young and 20 old speakers are analyzed in four speech styles: spontaneous narrative, narrative recalls, a three-participant conversation, and reading aloud. Results show that age has a significant effect only on speech rate, articulation rate, and frequency of pauses. Speech style has a higher effect on temporal parameters than speakers' age.


**PACS numbers:** 43.70.Fq, 43.70.Bk [AL]
**Date Received:** January 30, 2014 **Date Accepted:** June 13, 2014

## 1. Introduction

With increasing age, a number of changes occur in speech production, from which the slowing-down of speech rate is confirmed by most researchers (for example, Hartman and Danhauer, 1976; Ramig, 1983; Duchin and Mysak, 1987; Jacewicz *et al.*, 2010). The differences in speech rate of speakers of different ages are attributable to several reasons: hormonal, psychological, and cognitive changes (Rodríguez-Aranda and Jakobsen, 2011); the aging of the speech organs (Xue and Hao, 2003); and the deterioration of hearing (Hnath-Chisolm *et al.*, 2003).

In relation to temporal changes in aging, mainly speech rate and articulation rate have been analyzed (Hartman and Danhauer, 1976; Ramig, 1983), although there are some other factors in speech planning which influence the temporal characteristics: for example, difficulties in lexical access can lead to many pauses and disfluencies in speech (Schmitter-Edgecombe *et al.*, 2000). However, there are contradictory findings about whether these difficulties of speech planning really occur in more frequent and longer pauses or in more disfluencies. Martins and Andrade (2011) found that speakers of 80+ age produced pauses more often than speakers between 60 and 79 (they did not analyze the speech of young speakers). On the other hand, Bortfeld *et al.* (2001) found that old speakers produced more filler words than young speakers did, which is an alternative strategy instead of pausing.

The frequency of pausing due to difficulties in lexical access is influenced by speech styles too. For example, in a picture description task, the speakers have to activate a given vocabulary. If they have difficulty in activating these words, they tend to produce more pauses and disfluencies, while in a different speech task they could avoid these difficulties by choosing another word or paraphrasing it.

The joint impact of age and speech style on temporal characteristics has been analyzed only in a few papers (Ramig, 1983; Duchin and Mysak, 1987; Jacewicz *et al.*, 2010), and these works analyzed only the speech rate without the characteristics of pausing. Among the different speech styles, some authors found that reading aloud was faster than spontaneous speech (Ramig, 1983; Duchin and Mysak, 1987), but there were contradictory results too (Jacewicz *et al.*, 2010).

In this paper, the influence of age and speech style on temporal characteristics (rate and pausing) is analyzed. The novelty of this research compared to earlier studies

 

is that more speech parameters (beyond speech and articulation rate and the characteristics of silent and filled pauses) are analyzed in more speech styles (which need different speech planning processes: spontaneous narrative, narrative recall, conversation, and reading aloud) of young and old speakers.

The hypotheses of the research are (1) there will be slower speech rate and articulation rate in old speakers' speech than in all speech styles of younger speakers, (2) the characteristics of pausing is significantly influenced by aging (old speakers produce more pauses in all speech styles than young speakers), and (3) there will be significant differences between speech styles in both age groups.

## 2. Method

### *2.1 Subjects*

Forty subjects' recordings from BEA, the Hungarian Spoken Language Database (Gósy, 2012) were selected for the research. Twenty subjects were between 66 and 90 years of age (M = 75.4 years), and 20 between 21 and 32 (M = 24.9 years). In both groups there were ten males and ten females. All of them were native Hungarian speakers with normal hearing and did not have any known mental problem or speech disorder. Their level of education was similar (all of them had at least 12 years of education).

### *2.2 Material*

Recordings were made with each subject in four situations which represented different speech styles and required various cognitive skills with various levels of difficulty. (1) Spontaneous narrative (participants spoke about their own lives and families): in this speech style speakers can plan all the content and the linguistic form of their speech, and they have time for speaking without being interrupted by the interviewer. (2) Narrative recalls (the task was to recall two texts they had listened to as accurately as possible). The success of narrative recall is determined by several factors: speech processing, attentional and working memory mechanisms, and narrative competence (Juncos-Rabadán and Pereiro, 1999). (3) A three-participant conversation: Conversation is a "competition," as all participants want to speak and do not want to pass the turn on. However, speakers can plan their speech while the other one speaks (Markó, 2005). Conversation is also a joint activity of the participants, whose common aim is to maintain it, thereby to keep it going. (4) Reading aloud (a text of 234 words): in this speech style speakers do not need to plan content and linguistic form, so they have more time and mental energy for articulatory planning. The recordings were made digitally, under constant circumstances, in the same location (in a soundproof chamber). The subjects volunteered for the task. Altogether 10.5 h of speech were analyzed: 5 min of spontaneous narrative and 5 min of conversation (only of the subject's turns) from each speaker, while the duration of reading and recall was speaker-dependant (2–5 min).

### *2.3 Data analysis*

Utterances between two pauses were annotated by PRAAT 5.0 (Boersma and Weenink, 2008). Pauses were measured, speech rate (the total number of syllables divided by total speaking time including pauses) and articulation rate (the total number of syllables divided by total speaking time without pauses), the ratio of pauses in the total speaking time, and the ratio of filled pauses in the total pause duration were calculated; the frequency of pauses (the number of pauses per 100 words) and the "within speaker variability" of pause durations were defined for all speakers. The number of syllables was defined for tempo rates by counting the number of vowels with PRAAT script. The measures were based on the number of realized units, and not on the numbers of "intended" units (Koreman, 2006). The data were compared across the two age groups and four speech styles.

Statistical analyses [multivariate analysis of variance (ANOVA), repeated-measure ANOVA (within-subjects variables were speech styles and speech parameters, and the between-subjects factor was speakers' age), one-way ANOVA, and Tukey *post hoc* test] were performed by SPSS 13.0 software at the 95% confidence level.

## 3. Results

The data of speech rate and articulation rate are summarized in Table 1 and the results of pauses are in Table 2.

According to the statistical analyses, the speaker's age had a significant effect on the following.

(1) Speech rate [$F(1, 159) = 61.958$; $p < 0.001$; $\eta^2 = 0.290$]: in all speech styles the speech rate (and standard deviation except for reading aloud) was higher in young speakers' speech than in old speakers'. One-way ANOVA showed significant differences between young and old speakers in narratives [$F(1, 39) = 13.973$; $p = 0.001$], in conversation [$F(1, 39) = 16.024$; $p < 0.001$], and in reading aloud [$F(1, 39) = 60.670$; $p < 0.001$], while in the speech rate of narrative recalls there was no statistical difference between the two age groups.

(2) Articulation rate [$F(1, 159) = 135{,}485$; $p < 0.001$; $\eta^2 = 0.471$]: in all speech styles the articulation rate (and standard deviation except for reading aloud) was higher in young speakers' speech than in old speakers'; one-way ANOVA showed significant differences between young and old speakers in all speech styles [narrative: $F(1, 39) = 37.461$; $p < 0.001$; recalls: $F(1, 39) = 18.878$; $p < 0.001$; conversation: $F(1, 39) = 26.207$; $p < 0.001$; reading aloud: $F(1, 39) = 70.026$; $p < 0.001$].

(3) The frequency of pauses per 100 words [$F(1, 159) = 10.915$; $p = 0.001$; $\eta^2 = 0.067$]: old speakers had more frequent pauses than young speakers had in all speech styles except recalls [in narrative: $F(1, 39) = 6.229$; $p = 0.017$; in conversation: $F(1, 39) = 5.370$; $p = 0.026$; in reading aloud: $F(1, 39) = 12.192$; $p = 0.001$].

Speech style had a significant effect on the following.

(1) Speech rate [$F(3, 157) = 109.691$; $p < 0.001$; $\eta^2 = 0.743$]: in both age groups the fastest speech style was reading aloud, while the slowest was recall. In young speakers' group [$F(3, 77) = 27.587$; $p < 0.001$] there were significant differences between recall and the

Table 1. Speech rate and articulation rate.

| Speech style | Mean (St. dev.) | Min.–max. |
|---|---|---|
| | Speech rate (syllables/s) | |
| | Young speakers | |
| Narrative | 4.3 (0.6) | 3.2–5.3 |
| Recall | 3.6 (0.7) | 2.5–5.2 |
| Conversation | 4.7 (0.6) | 3.7–5.9 |
| Reading aloud | 5.2 (0.4) | 4.4–5.8 |
| | Old speakers | |
| Narrative | 3.6 (0.5) | 2.7–4.6 |
| Recall | 3.2 (0.6) | 2.0–4.0 |
| Conversation | 3.9 (0.5) | 2.9–4.7 |
| Reading aloud | 4.2 (0.5) | 3.0–5.0 |
| | Articulation rate (syllables/s) | |
| | Young speakers | |
| Narrative | 5.8 (0.6) | 4.9–6.9 |
| Recall | 5.4 (0.7) | 4.3–6.8 |
| Conversation | 5.8 (0.6) | 4.6–7.0 |
| Reading aloud | 6.2 (0.4) | 5.2–6.7 |
| | Old speakers | |
| Narrative | 4.8 (0.4) | 4.0–5.6 |
| Recall | 4.6 (0.5) | 3.5–5.4 |
| Conversation | 4.9 (0.5) | 4.0–5.6 |
| Reading aloud | 4.9 (0.5) | 3.5–5.6 |

Table 2. Data of pauses.

| Speech style | Mean (St. dev.) | Min.–max. |
|---|---|---|
| | Frequency of pauses (pauses/100 words) | |
| | Young speakers | |
| Narrative | 19.4 (4.7) | 13.0–30.2 |
| Recall | 27.9 (8.3) | 17.5–48.9 |
| Conversation | 13.8 (3.4) | 7.4–21.8 |
| Reading aloud | 14.4 (2.7) | 9.8–23.5 |
| | Old speakers | |
| Narrative | 23.3 (5.1) | 13.6–31.5 |
| Recall | 27.8 (7.3) | 16.6–43.3 |
| Conversation | 16.5 (3.9) | 12.0–27.7 |
| Reading aloud | 19.4 (5.8) | 11.4–32.4 |
| | Ratio of pauses in the total speech time (%) | |
| | Young speakers | |
| Narrative | 26.5 (6.7) | 18.0–42.9 |
| Recall | 34.1 (7.8) | 21.5–46.3 |
| Conversation | 19.6 (5.4) | 11.1–29.9 |
| Reading aloud | 14.9 (2.3) | 9.4–18.7 |
| | Old speakers | |
| Narrative | 24.9 (5.8) | 14.9–37.7 |
| Recall | 29.3 (8.4) | 16.9–43.7 |
| Conversation | 19.8 (5.1) | 11.9–30.5 |
| Reading aloud | 15.4 (3.6) | 8.6–23.2 |
| | Mean duration of pauses (ms) | |
| | Young speakers | |
| Narrative | 689 (186) | 485–1164 |
| Recall | 776 (178) | 461–1189 |
| Conversation | 592 (123) | 426–835 |
| Reading aloud | 551 (137) | 341–888 |
| | Old speakers | |
| Narrative | 661 (158) | 468–1124 |
| Recall | 700 (190) | 512–1151 |
| Conversation | 591 (130) | 387–866 |
| Reading aloud | 541 (112) | 384–773 |

other three speech styles ($p \leq 0.002$), between conversation and reading aloud ($p = 0.013$), and between spontaneous narrative and reading aloud ($p < 0.001$). In the old speakers' group [$F(3, 77) = 12.179$; $p < 0.001$] there were significant differences between recall and conversation ($p < 0.001$), recall and reading aloud ($p < 0.001$), and narrative and reading aloud ($p = 0.006$).

(2) Articulation rate [$F(3, 157) = 31.378$; $p < 0.001$; $\eta^2 = 0.452$]: in both age groups the fastest articulation rate was in reading aloud, while the slowest was in recall. In the young speakers' group [$F(3, 77) = 5.733$; $p < 0.001$] there was a significant difference between conversation and reading aloud ($p = 0.001$). In the old speakers' group there were no significant differences among the speech styles.

(3) The frequency of pauses [$F(3, 157) = 43.316$; $p < 0.001$; $\eta^2 = 0.461$]: in both age groups pauses were the most frequent in recall, and the less frequent in conversation. In the young speakers' group [$F(3, 77) = 30.977$; $p < 0.001$] there were significant differences between recalls and the other speech styles ($p < 0.001$), between narrative and conversation ($p = 0.006$), and between reading aloud and narrative ($p < 0.001$). In the old speakers' group [$F(3, 77) = 15.118$; $p < 0.001$] there were significant

differences between recall and conversation ($p < 0.001$), recall and reading aloud ($p < 0.001$), and narrative and conversation ($p = 0.002$).

(4) The ratio of pauses [$F(3, 157) = 58.617$; $p \leq 0.001$; $\eta^2 = 0.536$]: in both age groups the highest ratio of pauses was in recall, while the lowest ratio was in reading aloud. In the young speakers' group [$F(3, 77) = 40.230$; $p < 0.001$] there were significant differences among all analyzed speech styles ($p < 0.002$), except between conversation and reading aloud. In the old speakers' group [$F(3, 77) = 20.339$; $p < 0.001$] there were significant differences between recall and conversation ($p < 0.001$), recall and reading aloud ($p < 0.001$), as well as narrative and reading aloud ($p < 0.001$).

(5) The mean duration of pauses [$F(3, 157) = 12.286$; $p < 0.001$; $\eta^2 = 0.195$] was the longest in recall and the shortest in reading aloud in both age groups. In the young speakers' group [$F(3, 77) = 8.123$; $p < 0.001$] there were significant differences between recall and conversation ($p = 0.002$) and recall and reading aloud ($p < 0.001$), while in the old speakers' group [$F(3, 77) = 4.444$; $p = 0.006$] there was a significant difference between recall and reading aloud ($p = 0.007$).

(6) The standard deviation within speakers [$F(3, 157) = 12.052$; $p < 0.001$; $\eta^2 = 0.192$]: in both age groups it was the lowest (0.3) in reading aloud (while the other three speech styles did not differ).

Speakers' age and speech style together had a significant effect on speech rate [$F(3, 157) = 3.127$; $p = 0.028$; $\eta^2 = 0.058$], and the frequency of pauses [$F(3, 157) = 2.775$; $p = 0.043$; $\eta^2 = 0.052$].

Filled pauses occurred in young speakers' reading only four times, while in old speakers' reading only six times. Therefore, parameters of filled pauses were analyzed statistically only in spontaneous speech styles. There was no significant difference between age groups and among speech styles in the ratio of filled pauses in the total pausing time. The duration of filled pauses was not affected significantly by age, speech styles, and age and speech styles together.

## 4. Discussion and conclusion

In this paper temporal characteristics of young and old speakers were analyzed in four speech styles which require various cognitive skills. From the initial hypotheses, one was confirmed, while two were partly confirmed. The first hypothesis (the speech of old speakers is slower in all speech styles than the speech of young speakers) was confirmed. However, the ratio of pauses, the duration of pauses, and the frequency and duration of filled pauses were not affected significantly by speakers' age (second hypothesis). The speech style had the highest effect on temporal parameters (third hypothesis). The most significant differences were found between narrative recall and reading aloud.

Both parameters of rate were affected by speech styles: speech rate as well as articulation rate were the fastest in reading aloud and the slowest in narrative recall (the articulation rate of old speakers was similar in conversation and reading aloud). Standard deviation was lower in the old speakers' group than in the young speakers' group (except in reading), which means that (regarding tempo) the old speakers' group is more consistent than the young speakers' group.

The analyses of pauses showed that there were significant differences between young and old speakers only in the frequency of pauses and only in reading aloud (when there was no linguistic planning). Pauses give time for resolving difficulties of speech planning and articulation (beyond breathing and the rhetorical role). The results show that elderly speakers—although they have more difficulties in speech planning (like lexical access) than young speakers do—have speaking strategies which compensate for these difficulties, and the difficulties occur in speech parameters other than pauses.

These results show that the speech of the elderly has general features which are characteristic in all speech styles (like slower articulation rate), while other speech parameters differ from young speakers only in certain speech styles.

## Acknowledgments

The author wishes to thank Tekla Etelka Gráczi and Zsófia Koren-Dienes for their help in preparing this paper. This research was supported by the Bolyai János Research Grant.

## References and links

Boersma, P., and Weenink, D. (**2008**). "Praat: doing phonetics by computer (Version 5.0.1)," http://www.fon.hum.uva.nl/praat/download_win.html

Bortfeld, H., Leon, S. D., Bloom, J. E., Schober, M. F., and Brennan, S. E. (**2001**). "Disfluency rates in conversation: effects of age, relationship, topic, role, and gender," Lang. Speech **44**(2), 123–147.

Duchin, S. W., and Mysak, E. D. (**1987**). "Disfluency and rate characteristics of young adult, middle-aged, and older males," J. Commun. Disord. **20**, 245–257.

Gósy, M. (**2012**). "BEA—A multifunctional Hungarian spoken language database," in Phonetician No. 105-106, http://www.isphs.org/Phonetician/Phonetician_105_106.pdf, pp. 50–61.

Hartman, D. E., and Danhauer, J. L. (**1976**). "Perceptual features of speech for males in four perceived age decades," J. Acoust. Soc. Am. **59**, 713–715.

Hnath-Chisolm, T., Willott, J. F., and Lister, J. J. (**2003**). "The aging auditory system: Anatomic and physiologic changes and implications for rehabilitation," Int. J. Audiol. **42**, Suppl.2, 3–10.

Jacewicz, E., Fox, R. A., and Wei, L. (**2010**). "Between-speaker and within-speaker variation in speech tempo of American English," J. Acoust. Soc. Am.**128**, 839–850.

Juncos-Rabadán, O., and Pereiro, A. X. (**1999**). "Telling stories in the elderly. Influence of attentional and working memory processes (preliminary study)," in *Psycholinguistics on the Threshold of the Year 2000. Proceedings of the 5th International Congress of the International Society of Applied Psycholinguistics*, edited by M. da Graça Pinto, J. Veloso, and B. Maia, Faculdade de letras da Universidade do Porto, pp. 155–159.

Koreman, J. (**2006**). "Perceived speech rate: The effects of articulation rate and speaking style in spontaneous speech," J. Acoust. Soc. Am. **119**, 582–596.

Markó, A. (**2005**). "A temporális szerkezet jellegzetességei eltérő kommunikációs helyzetekben" ("The characteristics of temporal structure in different speech situations"), Beszédkutatás **2005**, 63–77.

Martins, V. D. O., and Andrade, C. R. F. D. (**2011**). "Study of pauses in elderly," Rev. Soc. Bras. Fonoaud. **16**(3), 344–349.

Ramig, L. A. (**1983**). "Effects of physiological aging on speaking and reading rates," J. Commun. Disord. **16**, 217–226.

Rodríguez-Aranda, C., and Jakobsen, M. (**2011**). "Differential contribution of cognitive and psychomotor functions to the age-related slowing of speech production," J. Int. Neuropsych. Soc. **17**, 1–15.

Schmitter-Edgecombe, M., Vesneski, M., and Jones, D. (**2000**). "Aging and word finding: A comparison of discourse and nondiscourse tests," Arch. Clin. Neuropsych. **15**, 479–493.

Xue, S. A., and Hao, G. J. (**2003**). "Changes in the human vocal tract due to aging and the acoustic correlates of speech production: A pilot study," J. Speech Lang. Hear. Res. **46**, 689–701.