9th International Conference on Speech Prosody 2018
13-16 June 2018, Poznań, Poland

A cross-linguistic, longitudinal case study of pauses and interpausal units in spontaneous speech corpora of older speakers of German and French

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Abstract

Prosodic characteristics of older adults are highly individual, which is why longitudinal data appear to be more suited to mapping age-specific developments rather than a comparison of age groups. Using interviews featuring spontaneous speech, conducted in two waves nine to ten years apart, five German and five French speakers are evaluated. The transcripts are segmented manually and interpausal units (IPU), articulation rate (number of syllables/length of the IPU in seconds) and pauses are compared; with only intra-turn pauses being considered. Whilst the articulation rate of the German speakers decreased in the ten years, the French speakers showed a steady increase. This could be due to the increased number of filled pauses, which are used by younger speakers with the effect that the interruption of the flow of speech is avoided. The length of IPU also differed between samples, with the German speakers showing no decrease and the French speakers showing a gradual decrease. In both samples, the number of syllables/IPUs decreased. The parameters used in the longitudinal study evolved with varying dynamics in divergent directions: for a more detailed explanation it has been proven necessary to consider language-specific adaptation and compensation processes, as can be observed in spontaneous speech data.

Index Terms: aging, articulation rate, pauses, interpausal units, French, German, lifespan, panel studies, connected speech

1. Introduction

In aging Western societies, perception of age and the discussion of related stereotypes are crucial factors conditioning successful intergenerational communication. Prosodic characteristics are among the factors which play an important role for the perception of age [1][2]. In our paper, we want to challenge the notion of age-related slowing and develop a better understanding of the complex interplay between the different prosodic parameters of articulation rate, duration of interpausal units (IPU), and pauses. With few exceptions, longitudinal studies of the same speakers are rare and mostly cover short periods of time [3][4]. Data collections over longer periods are intricate [5] and run, especially with older subjects, the risk of losing participants. However, they provide precious advantages: on the level of age group [6], cohort effects can be avoided, and biographical factors with impact on voice quality, such as biological predisposition, previous health history, and professional experience [7] remain stable and ensure a high comparability between samples representing different moments in the lifespan. A longitudinal approach can contribute to a better understanding of lifespan dynamics which result in prosodic characteristics of old age. In such a framework, it is easier to deal with the heterogeneity that has been shown to be of greater significance in the domain of prosody: "the most robust finding in aging research is the extreme individual variation" [8].

A better understanding of prosodic traits and their evolution over the lifespan is relevant for applied linguistics, human-machine communication and speech recognition concerned with improvements of strategies and tools used in situational settings involving older adults.

The data samples analyzed in what follows are parts of two panel studies on German [ILSE, see section 2.1] and French [LangAge, see section 2.2]. While both studies have a different origin, size and orientation, both are longitudinal, with examination waves which lie nine to ten years apart, and both include interview data that allow for the analysis of spontaneous speech in interaction. The prosodic characteristics under examination are the articulation rate, the duration of IPU, and different breathing and non-breathing pauses. The data sample provides us with the possibility to find explanations concerning their impact in speech planning and the interplay of these characteristics that contribute to the central question, "why language processing is so well maintained in late life" [9], insofar it involves instances of adaptation, such as compensation.

Numerous studies have demonstrated that the speaking rate of older adults is slower than the one of younger adults [10][11][12]. The slow-down is explained by several factors including longer syllable duration or more and longer pauses. The increasing number of pauses is related both to physiological explanations and cognitive explanations such as discourse planning [10]. However, these studies have mainly focused on men, do not have a longitudinal approach and contradictions arise: while one study demonstrates a decline of articulation rate with aging (e.g., [13]), another does not find any relation [14]. A higher number of pauses, resulting in a reduced IPU duration, has been explained with reduced elastic recoil of lung tissue [15]. In the LangAge corpus, with forty-eight male and female speakers >70 years, the IPU duration was negatively correlated with speakers' age [16], while no significant correlation between pauses and age could be found. In the comparison of healthy late middle-aged adults and individuals with preclinical evidence of amnestic Mild Cognitive Impairment (MCI), the proportion of filled pauses increased in the MCI group, yet did not show a significant

10.21437/SpeechProsody.2018-43

difference [17]. Our cross-linguistic approach, comparing German and French data of healthy older adults, raises questions on what is language specific in prosodic aging, e.g., the use of hesitations, filled and silent pauses in French [18].

2. Methodology

2.1. German speakers: ILSE corpus

The Interdisciplinary Longitudinal Study on Adulthood Development and Aging (ILSE) is a population-based follow-up study which aims to investigate individual, societal, and socio-structural preconditions of mental and physical aging [19][20]. During the first examination wave (1993–1996), 1002 subjects from two birth cohorts in the regions of Leipzig and Heidelberg were examined [21][22]. Participants were randomly recruited from community registers with consideration of an equal distribution of birth, age, gender and regional affiliations. In 2016, the fourth examination wave was completed, and 577 subjects could be re-examined. In the ILSE, different types of data such as medical, psychiatric and neuropsychological data, among others, have been collected and extensive semi-standardized biographical interviews have been conducted.

In the present study, data from five participants from the ILSE could be included, based on the interviews of the third and the fourth examination wave (t3 and t4) which took place between 2005–2007 and 2014–2016, respectively. The interviews were recorded digitally in mp3 and later in PCM format [23]. As in the group of interest the prevalence of dementia and cognitive impairments increase, the cognitive status of the participants was considered carefully: Cognitive diagnoses were discussed under the direction of an experienced geriatric psychiatrist who considered all available data. The subsample of the present study has been selected randomly from the participants that belong to the older birth cohort (born 1930–1932), that were diagnosed as cognitively healthy at t3 and t4. The resulting sample included five males from the area of Heidelberg (see Table 1).

Table 1: *German subsample with age group 70s = t3, third ILSE examination wave, 80s = t4, fourth ILSE examination wave; edu = years of school education; MMSE = Mini Mental State Examination [24].*

speaker	age group 70s (t3)	age group 80s (t4)	edu	MMSE 70s	MMSE 80s
G1	74	83	6	30	29
G2	74	83	4	27	28
G3	73	83	7	30	30
G4	73	82	12	30	30
G5	73	82	6	29	27

2.2. French speakers: LangAge corpus

The LangAge corpus is comprised of narrative biographical interviews with older speakers of French, centered in the city of Orléans, where the biggest corpus of spoken French is available for comparative analysis of contemporary French of younger age groups (ESLO [25]). Participants included in the subsample are healthy older adults with a high education level, between 72 and 76 years (Table 2). Following the sociolinguistic orientation of the corpus [26], linguistic variables indicating healthy aging have been controlled and compared with a younger subsample of ESLO corpus extracts of equal size (500 words of five participants, age group 35–45, highest education group: bac+4/5). Vocabulary size has been shown to be stable in healthy aging [27]. No significant difference of the age groups 70s and 80s, as well as compared to ESLO control group, was found for hapax legomena, predictor of MCI [17]. The number of hapax were highest in 70s (mean 138.6, median 131), as compared to 80s (mean 120.6, median 117) and ESLO control group (mean 118.2, median 120). There was no significant difference between the 70s and 80s and the ESLO control group with regards to the proportion of nouns, another indicator of healthy aging [28]. We found an age-related decline in the noun:pronoun ratio, but the lowest value of noun:pronoun ratio in 80s was at the same level as the lowest individuum in the ESLO control group (n/pn=1.2). Part of speech-tagging was done with Cordial Analyseur [29].

Table 2: *French subsample with age groups 70s = initial examination wave 2005 and 80s = examination wave 2015; edu = years of school education; noun:pronoun ratio in 70s, 80s, and control group ESLO (mean).*

speaker	sex	age group 70s (2005)	age group 80s (2015)	edu	noun : pronoun ratio 70s-80s
F1	f	72	82	9	1.4-1.4
F2	m	73	83	9	2.1-1.4
F3	f	74	84	9	1.5-1.3
F4	m	75	85	12	2.2-2.1
F5	m	76	86	12	1.6-1.2
ESLO		35–45		12	1.7

2.3. Interview data

The interview settings of both ILSE and the LangAge corpus allow for the production of natural speech data, embedded in an intergenerational, interactional setting. The biographical interviews in ILSE were conducted in a semi-standardized way, where the experimenter asked standardized open questions to the participant. The guidelines of the semi-standardized procedure in the third and fourth examination wave were designed to focus on the current life situation of the participant and included additional questions on the past and the future [30]. LangAge corpus interviews were conducted by one interviewer, involved in “active listening” and thus stimulating the interviewee to produce larger pieces of monologues and story-telling [26].

2.4. Data annotation

Subsamples were chosen from both corpora with a size of 500 tokens (minimum). Using Praat [31], sound recordings were segmented in IPU and pauses (>200ms) [32]. For the German data, the interpausal units were then orthographically transcribed and the number of syllables within each IPU was calculated on the basis of an automatic canonic transcription of the orthographic annotations [33]. For French data, EasyAlign [34] was used for the phonetic transcription of the speech and the first segmentation into syllables. The phonetic transcription was proofread before any further segmentation in order to ensure that no not-pronounced syllable was present: the silent schwa, not realized liaison or mispronounced words were manually corrected. The automatic segmentation in syllables was revised manually for each speaker resulting in the number

of syllables for the interview and by IPU. Articulation rate was calculated as the number of syllables per second. Due to the very nature of interview data, pause duration does not depend on the interviewees preferences, but is at least partly a result of turn negotiation. Accordingly, we excluded pauses surrounded by turns [35], and took only pauses within turns into account. Pauses with backchannels were also included, since backchannels were not considered as new turns [36]. Pauses were then labeled as silent (SP), pauses where respiration was heard (RP), pauses where backchannel of the interviewer was heard (BP). Clicks (PI), laughing (LI) or other event (OI) were also labeled, but they were only included as random factors in the statistical design. For LangAge, the sample was annotated by two annotators after a double annotation and a manual inter-annotator agreement of one sample. The two samples from each speaker were annotated by the same person to ensure coherence. For the ILSE corpus all data were annotated by the same annotator. Since the audio quality of the ILSE corpus included some background noise, labelling respiratory or silent pauses was limited and we will not describe their differences in detail. Some of the German speakers provided short answers and a narrative/monologue occurred less often than in the French speakers. That means a longer temporal frame was needed to fulfil the criteria and obtain 500 tokens and ca. 50 pauses.

The statistical tests will be presented in the results. In general, we run Linear Mixed-Effects Models [37] with the *lme4* library and *ggplot2* for visualization. All data with t=|2| were considered significant.

3. Results

3.1. Articulation rate

Figure 1 shows the results for articulation rate. Except for the French speaker F3 and the German speaker G1, results for the two languages differ with respect to the examination waves.

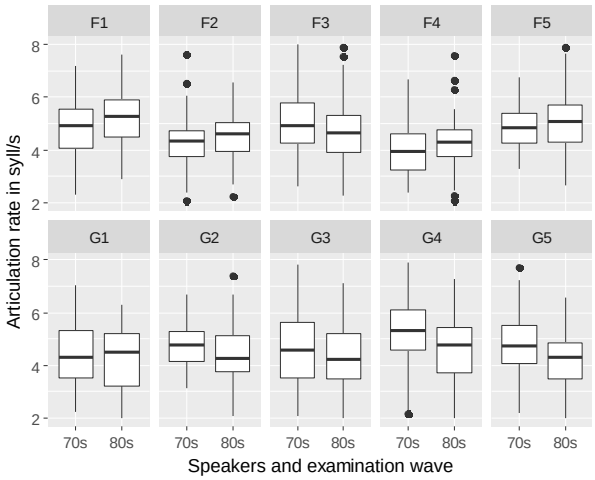

Figure 1: Articulation rate in number of syllables per *second. X-axis: Different examination waves for the speakers (in their 70s and 80s, see Tables 1 and 2 for the exact date); Upper plots are French speakers (F1-F5) and lower plots German speakers (G1-G5).*

French speakers increase articulation rate with age, while German speakers decrease articulation rate. These results have also been confirmed by a statistical analysis using Linear Mixed-Effects Models with *articulation rate* as the dependent variable and *examination wave* and *language* as well as their interaction as the independent factors. *Speaker* was considered as random factor. The analysis revealed a marginal effect of examination wave (intercept=4.6syll/s, β=0.22, t=2.04) with slightly higher values for the 70s period. The most pronounced effect, however, is the interaction between *examination wave* and *language* (β=-0.7334, t=-5.18) with a higher speech rate of the French speakers at older age and a lower speech rate of the German speakers at older age. These results might be driven by the number of syllables that are realized within an IPU (see Figure 2). To check this hypothesis, we ran a comparable analysis with *number of syllables* as the dependent variable. The number of syllables in an IPU decreased with age (β= -1.51, t=-2.44), but no language effects or interactions were found.

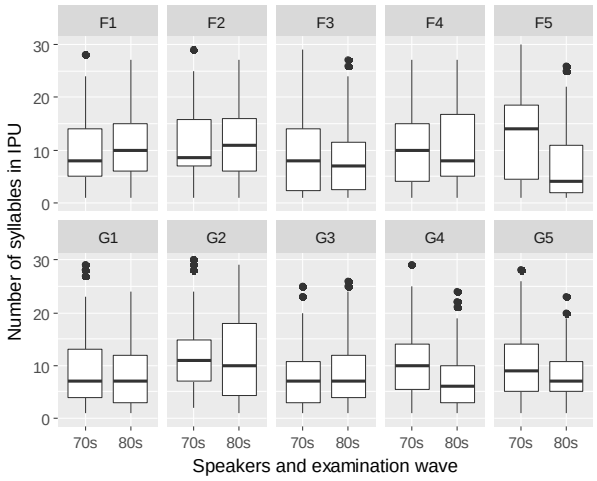

Figure 2: Number of syllables per IPU. *X-axis: Different examination time points; Upper plots are French speakers and lower plots German speakers.*

3.2. Interpausal units (IPU)

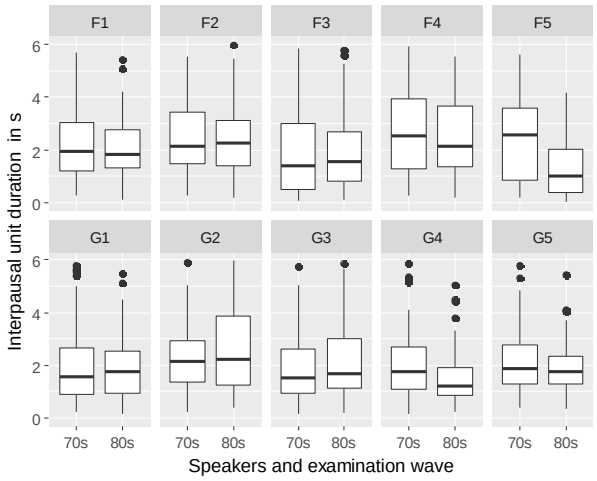

Figure 3: Interpausal unit duration in *seconds. X-axis: Different examination time points; Upper plots are French speakers and lower plots German speakers.*

The picture for interpausal unit duration is less consistent and varies a lot among speakers (see Figure 3). While speakers F5,

G4, and G5 display shorter IPUs with age, other speakers show only marginal differences or none at all.

A statistical analysis was run with *IPU duration* as the dependent variable, *examination wave* and *language* as independent variables and *speaker* and *number of syllables per IPU* as random factors. The model showed a main effect of the *examination wave* (intercept=1.31s, β= -0.057, t= -2.42) with longer IPUs at the 70s examination wave and an interaction between *examination wave* and *language* (β=0.15, t=4.92) with longer IPUs at the 70s examination wave in comparison to the 80s for the French, but not the German speakers.

3.3. Pauses

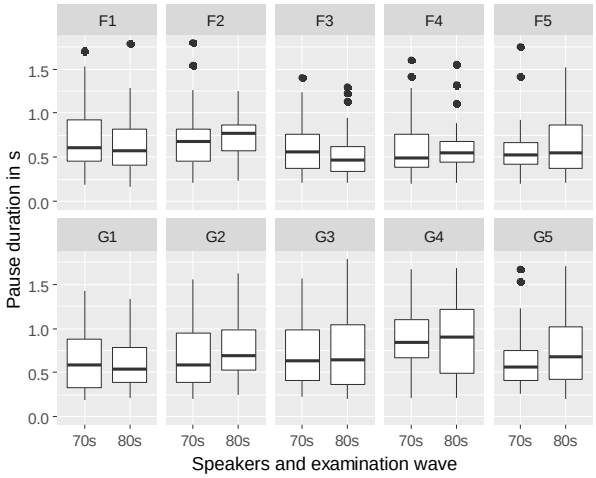

Figure 4: Pause duration in *seconds. X-axis: Different examination waves; Upper plots are French speakers and lower plots German speakers.*

In Figure 4 the results for pause duration are presented with no clear cut difference in pause duration. The statistical analysis with the logarithm of *pause duration* (to reveal a linear distribution of the residuals) as the dependent variable, *examination wave* and *language* as the independent variables and *speaker* and *pause label* as random effects revealed an interaction between the two fixed effects (β =0.17, t=2.3). While French speakers did not produce any differences in pause duration in the different examination waves, German speakers showed slightly longer pauses (significance may be driven by speakers G2, G4, and G5). Three French speakers reduced the number of filled pauses (*euh*: 70s to 80s: median -0.32%), and especially those with an increasing articulation rate and vice versa (reduction of *euh:* F1, F4, F5, increase: F3, slight difference in F2).

Furthermore, we explored the relation between preceding pause duration and the number of syllables of the upcoming IPU with *pause duration* as the dependent variable, *number of syllables, examination wave* and *language* and their interaction as independent factors, and *speaker* as random factor, but found no evidence for an effect.

4. Discussion and conclusion

In summary, our findings based on the longitudinal development from an examination wave with participants in their 70s and a follow up nine to ten years later reveal several language specific effects for German and French. In particular, French speakers show an increase in articulation rate with age and German speakers a decrease. For some speakers this result may be explained with a decrease in the number of syllables produced per IPU with older age. While the results for German speakers are in agreement with studies investigating differences between generations, results for the French speakers are in contrast to the common stereotype of declining articulation rate with age. These results further support the value of longitudinal studies and call for specific caution when making generalizations between generation studies and longitudinal development over the life span.

How can an increase in articulation rate be explained? Several explanations might be possible. Firstly, due to changes in the cardiovascular system, speaking may go hand in hand with shorter breathing cycles and flatter inhalation amplitudes. Thus, some older speakers may inhale more often, but may compensate for the reduced respiratory capacities by an increase in articulation rate to maintain information density. Secondly, another explanation might be related to the occurrence of hesitation markers (*euh* in French) and articulation rate. When the French speakers got older, they realized less filled pauses. This reduction goes along with a not only stable, but even increased articulation rate and could be considered as a way to save energy and to compensate for the greater effort that speaking demands with increasing age. The results for IPU and pause duration are generally weaker and more subject to individual variation. This result is probably due to the nature of the speech production task which involved spontaneous speech in a relatively unconstrained interview situation and thus highly depending on the dynamics of interaction. No relation could be found between pause duration and the number of syllables of the following IPU, which might be explained by the purely functional definition of an IPU. It can consist of one or several prosodic phrases and may have different prosodic and syntactic complexities. The relation between linguistic complexity and prosodic segmentation [38] in the corpus data needs to be further investigated.

While the study design imposes inevitable limits to the results and their impact, we think that the results of the cross-linguistic and longitudinal approach are encouraging, as they reveal language-specific aging effects and challenge the findings of inter-generational studies which tend to generalize, without considering intra-individual longitudinal developments.

Using data of spontaneous speech, results seem apparently heterogeneous, but they give evidence for the complex interplay of the different levels of linguistic production, a research perspective that will be continued with more in-depth linguistic analyses of the spoken data.

5. Acknowledgements

This work was supported by the Leibniz society. Thanks to Uwe D. Reichel for the automatic calculation of the number of syllables per IPU in the German dataset. The examination wave of 80s in LangAge corpus was supported by a research grant from Freie Universität Berlin. The Interdisciplinary Longitudinal Study of Adult Development and Aging (ILSE) was supported by the Research Program of the State of Baden-Württemberg, the Federal Ministry of Family, Senior Citizens, Women and Youth and the Dietmar-Hopp-Stiftung.

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