The Effects of Time on Temporal Variables in Speech Read by Subjects with Parkinson's Disease: Preliminary Results

Danielle Duez* and François Viallet§

*Laboratoire Parole et Langage, CNRS UMR 6057, Aix en Provence
§Centre Hospitalier du Pays d'Aix

E-mail: duez@lpl.univ-aix.fr

ABSTRACT

The present study investigates temporal variables in speech of three subjects suffering from Parkinson's disease (PD). Over a four-year control period, speech rate was found to increase with time, due to shorter and less frequent pauses and faster articulation rate, achieved by omitting syllables and/or a simplifying syllable structure. The distribution of pauses within paragraphs remains in conformity with the syntactic structure of paragraphs, although variances between individual subjects are observed. For example, one speaker incorporates frequent long non-syntactic pauses, whilst the others maintain a proper hierarchy in pause durations, but with a very short range in duration differences. This may be caused by a difficulty in planning temporal patterns of speech due to rhythm-planning impairment. The overall results demonstrate how deterioration of motor abilities in PD increasingly affects temporal variables in speech.

1. INTRODUCTION

Parkinson's disease (PD) is a progressive, degenerative neurological disorder resulting from nigrostriatal dopamine deficiency. Loss of this neurotransmitter can cause rigidity (muscles resistant to movement), akinesia (inability to initiate movement), bradykinesia (slowness of movement) and rest tremor.

The speech problem resulting from PD is known as hypokinetic dysarthria whose salient features are monopitch, reduced loudness, monoloudness, harsh and breathy voice, imprecise articulation and variable and disordered speech rate [1].

Until now PD effects on speech rate have been investigated by comparing temporal variables, such as pause time, articulation rate and segment durations in the speech read by control speakers and subjects with PD. Faster speech rate, shorter duration of speech segments and greater time per pause were observed for speakers with PD [2 and 3]. When subjects with PD and control speakers were asked to reduce their overall speech rate, the same tendency to shorter duration of speech segments for subjects with PD [3] was confirmed. The accelerated speech rate of people suffering from PD has crucial implications for speech intelligibility since there is a strong relationship between duration of speech segments and undershoot [4]. Hence, reduction of speaking rate is widely recommended for hypokinetic dysarthric speakers [5 and 6].

As mentioned above, alterations and variability in the speech of people with PD are usually compared with control speakers. Consequently, how PD alter speech rate within a same person over extended periods of time is still poorly understood.

To overcome this shortcoming, the present study analysed temporal variables over a four-year period in speech of three speakers suffering from Parkinson's disease (PD). It was felt that comparing speech samples produced at different moments would improve understanding of how PD progression affects speech impairment. Three specific research questions were addressed : 1) How does time affect speech rate, pause time and articulation rate ? 2) How do changes in articulation rate affect syllable structure? 3) Does time affect individuals differently?

2. METHOD

2.1. SUBJECTS

Table 1. Characteristics of subjects (S1, S2 and S3), Years post-diagnosis of PD, Month and year of first, second and third recording ((M'Y1, M-Y2 and M-Y3)

	Age	Years post-PH D	M-Y1	M-Y2	M-Y3
S1	57	12	03/98	11/01	04/02
S2	43	12	04/98	03/01	05/02
S3	67	19	03/98	11/98	08/01

The subjects were three men (S1, S2 and S3) diagnosed by a neurologist as having mild to moderate idiopathic PD.

 ISBN 1-876346-48-5

They were native French speakers and without histories of neurologic, respiratory, laryngeal, speech and voice diseases or disorders, apart from those associated with PD. Subject profile includes age, year of PD diagnosis and month and year of recording.

2.2. SPEECH SAMPLE AND RECORDING EQUIPMENT

During the recording sessions, each subjects was asked to read at their habitual rate. The selected text was written on paper and held before the subject by a research assistant. High-quality recordings were obtained in a sound-proofed room of the Hospital of Aix en Provence. The acoustic signal was transduced using an AKG C410 head mounted microphone and recorded directly on a PC. To focus on PD effects, subjects had not taken L-DOPA for at least 8 hours. The text was an excerpt of "La chèvre de Monsieur Seguin" (A. Daudet, 1869). This passage was chosen for different reasons: its sound classes approximate the frequency of occurrences in conversational speech, the various lengths and the different syntactic structures of sentences favour the occurrence of pauses of different lengths. In addition, "La chèvre de Monsieur Seguin" is a well-known story.

2.3. MEASURES

Temporal measurements and temporal variables. Having completed phonetic transcription of the tape recordings, the oscillograms and spectrograms were segmented while listening to the tapes. Speech time was subdivided into total articulation and total pause time.

A *silent pause is* defined as any interval on the oscillographic trace where the speech amplitude is indistinguishable from that of background noise. A silent pause is never shorter than the average duration of an intervocalic stop increased by four standard deviations.

An articulated sequence is any sequence of phonetic segments delimited by two silent pauses.

The *silent-pause ratio* is obtained by dividing total duration of silent pauses by total speech time. The mean number of syllables of an articulated sequence was calculated by dividing total number of syllables by number of articulated sequences. The mean duration of a silent pause was obtained by dividing total pause time by the number of silent pauses. The articulation rate was obtained by dividing total number of syllables produced by total articulation time (total speech time minus total pause time).

Syllable structure is defined as a function of components: consonant (C) and vowel (V).

Pause location. The location of silent pauses was studied by syntactic type. Five types were considered:
1) Pauses located between paragraphs, 2) between sentences, 3) between clauses, 4) between phrases and 5) within phrase, i.e. unexpected pauses within a sense group.

Disfluencies. The classification of disfluencies normally used in spontaneous speech analysis was adopted for the readings although they do not reflect the same cognitive processes. The number of occurrences was calculated for the following disfluency types:

I. *Filled pause*: any occurrence of a French language hesitation or interjection such as euh, eh, hein.
I. *False start*: any sequence of segments intended to start the next utterance but is interrupted and replaced by another that is completed.
III. *Repeat*: any unintended repetition of a sequence of phonetic segments.
IV. Lengthened syllable : any syllable abnormally prolonged.

Silent pauses located within phrases may be disfluencies. In the present study they were regrouped with syntactic silent pauses.

Omissions and additions. The total number of omitted and added segments, syllables and words was calculated. Segments were classified by type (C or V) and location within a syllable (initial, medial or final), words were separated into function and content words.

3. RESULTS

3.1. TEMPORAL VARIABLES

Table 2. Total speech time (TST) in minutes, silent pause ratio (SPR) and speech rate (SR) expressed in syll/sec for the three subjects (S1, S2 and S3) and the three readings (R1, R2 and R3).

	S1			S2			S3		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
TST	1'43	1'28	1'13	0'56	0'54	0'57	1'03	0'53	1'07
SPR	43.7	42.8	28.7	29.7	24.7	26.9	29.9	24.7	23.8
SR	2.6	3.09	3.6	4.06	4.6	4.1	3.8	4.3	3.8

Table 2 shows that subjects speak progressively faster and pause less. For example, S1 total speech time ratio decreases from R1 to R2 and from R2 to R3. For S2 and S3, SPR decreases from R1 to R2, but slightly increases from R2 to R3.

Table 3. Mean duration (M) and number (N) of silent pauses by speaker (S) and reading (R).

	R1		R2		R3		R's	
	M	N	M	N	M	N	M	N
S1	683	66	659	57	475	44	606	167
S2	621	27	493	27	616	25	577	79
S3	612	31	521	25	572	25	569	81
All	639	124	558	109	554	94	598	327

Mean pause durations reported in table 3 confirm the slight decrease found for SPR. Subjects tend to pause less when reading. However, an ANOVA performed on pause duration does not yield a significant effect of S [$F(2,318)=0.2$, $p=0.8$], R[$F(2,318)=1$, $p=0.3$].

Table 4. Mean duration (D) of articulated sequences and mean number of syllables (Syl) in articulated sequences by speaker (S) and reading (R).

	R1		R2		R3		R's	
	D	Syl	D	Syl	D	Syl	D	Syl
S1	905	4.2	864	4.6	1151	5.8	974	4.9
S2	1413	8.1	1449	8.9	1606	9	1489	8.7
S3	1385	7.5	1529	8.5	1634	8.8	1516	8.3
All	1235	6.6	1281	7.4	1464	7.8	598	

The length of articulated sequences reported in Table 4 increases significantly with time, indicating that pauses are less frequent. An ANOVA performed on the mean duration of articulated sequences confirms a significant effect of S's [F(2, 326)=30, p=0.0001] and R's [F(2, 326)=3.7, p=0.02]. The increasing duration of AS's across readings is positively correlated to an increasing number of syllables. Again, there is a significant effect of S[(F=2, 326), p=0.0001] and R [(F(2, 326)=2, p=0.05] on syllable numbers.

Table 5. Mean articulation rate by speaker (S) and reading (R).

	R1		R2		R3		R's	
	M	N	M	N	M	N	M	N
S1	4.7	67	5.7	58	5.1	45	5.1	170
S2	5.6	28	6.1	28	5.5	26	5.8	82
S3	5.3	32	5.7	26	5.2	26	5.4	84
All	5.2	127	5.9	112	5.3	97	5.3	336

The results reported in table 5 indicate faster AR in R2 than in R1, but slower AR in R3 than in R2. This finding contrasts with the results found for AS's. Articulation was based on the number of syllables acoustically produced, i.e. the number of omitted syllables was not taken into account, which may cause the observed discrepancy. A reanalysis of AR based on the number of underlying phonological syllables will be performed and its results compared to both tables 4 and 5.

3.2. PAUSE DISTRIBUTION

Figure 1. Mean pause duration (in ms) as a function of reading (R1, R2 and R3) and location (Par: paragraph, Sent: sentence,(Cl: clause, Ph: phrase and WPh: within phrase)

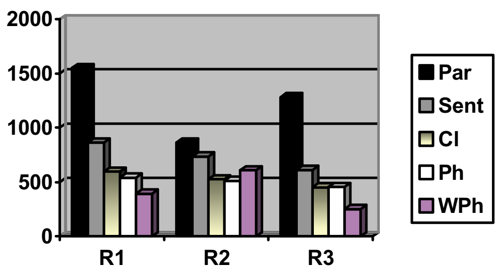

Figure 1 shows silent pause durations by location in the paragraph. The greater the syntactic break the longer the pause, which agrees with previous analyses of pause patterns [7].

An ANOVA performed on pause duration confirms the significant effect of location [F(312, 4)=27, p=0.0001]. In R1, R2 and R3 the pause distributions have a similar pattern: silent pauses between paragraphs and sentences are more frequent and longer than pauses between clauses and phrases, although differences between the three R's occur. In R2, between-paragraph pauses have a mean duration (865 ms) close to that of between-sentence pauses (737 ms); moreover, within-phrase pauses (608 ms) are longer than between-clause phrases (527 ms) and between-phrase pauses (410 ms). Within-phrase pauses are also more frequent in R2 (23) than in R1 (17) and R3 (14).

Comparing individual subject's pause patterns reveals interesting variances. There is a strong correlation between syntactic-structure hierarchy and pause duration for S1, except in R2 where non-syntactic pauses are longer than syntactic ones. For S2 and S3, there are very small differences in pause duration as a function of location. For example, for S2, the range between between-paragraph pauses and within-phrase pauses is 542 ms (R1), 477 ms (R2) and 296 ms (R3).

3.3. OMISSIONS

Table 6. Number of omitted segments (Seg) and words (W) by subject (S) and reading (R).

	R1		R2		R3	
	Seg	W	Seg	W	Seg	W
S1	14	6	24	11	13	3
S2	15	3	13	1	21	2
S3	28	4	25	6	34	4

Table 6 confirms the regular omission of of words (mostly monosyllabic grammatical ones) in the reading of each subject, but no clear effect of time. For example, there is increase in word omissions from R1 to R2 for S1 and S3, and a slight decrease from R2 to R3. However, S2 has a slight decrease from R1 to R2 and a slight increase from R2 to R3. Omissions of speech segments (mostly consonants) increases with time for S2 and S3; for S1, they increase from R1 to R2 and decrease from R2 to R3. These omitted consonants are mainly voiced or sonorants, they are intervocalic as well as C1's in heterosyllabic [C1#C2]'s, C1 or C2 in homosyllabic [C1C2]'s, and word-initial consonants. This distribution, different from those observed for consonant reduction or omission in spontaneous speech [8], suggests a difficulty in producing two-consonant sequences and initial and intervocalic consonants such as /l/ and /v/.

ISBN 1-876346-48-5 © 2003 UAB

3.4. SYLLABLE STRUCTURE

Table 7. Frequency of syllables as a function of structure and reading (R). C: consonant, V: Vowel.

	CCV	CCVC	CCVCC	CV	CVC	CVCC	V	VC
R1	61	15	0	468	74	7	81	8
R2	60	13	0	490	76	1	76	7
R3	65	14	1	497	61	5	77	6

The results shown in table 7 confirm a simplification of syllable structure in all readings. For example, the number of CV-syllables increases with time while those of CVC decreases. This simplification may be due to the deletion of coda consonants in heterosyllabic [C1#C2]'s or C2 or C1 in homosyllabic [C1C2]'s.

3.5. DISFLUENCIES

Two types of disfluencies were found: repeats (17) and false starts (5). S1 produces most disfluencies which are particularly frequent in R1 and R2. In some cases, there is a succession of false starts (partial phrases or word) and repeats. This may reflect anxiety, common in subjects with PD, lesser reading aptitude or greater PD affliction, which complicates the obtaining of valid conclusions.

4. CONCLUDING REMARKS

The present study concentrated on analysis how PD affects speech over a four-year period. The comparison of temporal variables between different patients and within individual subjects reveals comparable progressive speech acceleration: shortened pause time and increase articulation rates. This finding complement previous results on the speech rate of subjects with PD [2 and 3], thereby they have shorter speech pauses and longer articulates sequences than control subjects. These characteristics increase with time.

The distribution of pauses within paragraphs conforms to the syntactic structure of paragraphs revealing that subjects with PD have still master the distributional scheme of pauses: the deeper the syntactic break, the longer and the more frequent pauses.

However, variances between individual patients exist. One speaker incorporates long non-syntactic pauses; the others maintain hierarchy in pause durations, but with a short range of duration differences. This weak correlation between syntactic-boundary hierarchy and pause timing may result from a difficulty in planning temporal patterns of speech and reflect rhythm-planning impairment.

Increases in articulation rate are due (at least partly) to the reduction in number of syllable components and simplification of syllable-structure: patients tend to omit V-syllables or coda consonant in CVC-syllables. Such articulation rate increases are probably caused by increased rigidity and slowness in speech gestures.

Results obtained emphasise how progressive deterioration of motor abilities in PD subjects affects temporal variables during the first two years. This rapid initial evolution of the disease reinforces the importance of early diagnosis and selecting treatment to delay the onset of serious speech impediment. Extending tests to a larger selection of patients could reveal how PD-progression impacts on speech intelligibility and social communication, providing information crucial to measuring the progress of the illness and the efficacy of different treatments. It could also help evaluate the impact of new treatments under development. And finally, it might enable the medical profession reduce the trauma resulting from a patient's decreasing ability to communicate with its entourage.

Aknowledgements. The samples used in the present study are part of a data basis recorded by Ludovic Jankowski, Alain Purson and Bernard Teston.. Thanks to Anthony Scrimgeour for his stimulating rereading of the article.

REFERENCES

[1] Darley, F.L., Aronson, A.E. and Brown, J.R., Differential diagnostic patterns of dysarthria. *Journal of Speech and Hearing Research*, 12, 246-269, 1969.

[2] Speech and pause characteristics following speech rate reduction in hypokinetic dysarthria, *Journal of communication disorders,* 29, 429-554, 1996.

[3] Mc Rae, P., Tjaden, K. and Schoonings, B., Acoustic and perceptual consequences of articulation rate change in Parkinson disease, *Journal of Speech and Hearing Research,* 45, 35-50, 2002.

[4] Lindblom, B., Spectrographic study of vowel reduction, *Journal of the Acoustical Society of America*, 35, 1773-1781, 1963.

[5]Ramig, L.A. and Gould, W.J., Speech characteristics in Parkinson's disease, *Neurological consultant,* 4, 1-6, 1986.

|6]Yorkston, K.M., Beukelman, D.R. and Bell, K.R. (1988) *Clinical management of dysarthric speakers,* Austin; Pro-Ed, 1988.

|7] Grosjean, F., Grosjean, L. and Lane, H., The patterns of silence: Structures in speech production, *Cognitive Psychology*, 11, 58-91, 1979.

[8] Duez, D. Modelling Aspects of reduction and assimilation of Consonant sequences in spontaneous French speech, *SSPR, IEEE-ESCA*, Tokyo, 14-16 avril 2003, to appear.