CASE STUDY

ACTA Vol. 9, No. 4, 2011, 383-392
NEUROPSYCHOLOGICA

Received: 11.11.2011
Accepted: 28.12.2011

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

TEMPORAL STRUCTURE IN THE SPEECH OF A PERSON WITH DEMENTIA: A LONGITUDINAL CASE STUDY

Linda Carozza[(A,B,D,E,F)], Margaret Quinn[(A,B,D,E,F)], Julia Nack[(A,B,D,E,F)], Fredericka Bell-Berti[(A,B,D,E,F)]
St. John's University, Queens, New York, N.Y., USA

SUMMARY

Background Cognitive and language processes in dementia have been studied extensively, but motor speech degeneration in the course of dementing illness has been relatively unexplored. The potential for early dissociation of motor functions of language at the level of speech production has not been explored extensively in the research literature.

Case presentation: In an earlier pilot study of temporal structure in the speech of persons with dementia, in which our participants produced a series of short phrases that included a target word beginning with a fricative or voiced or voiceless stop consonant and ending with either /t/ or /d/, this subject demonstrated inconsistent final lengthening and effects of final consonant voicing on vowel duration, as well as a voice onset time (VOT) pattern that suggested a reduced distinction between American English /b/ and /p/. Analysis of recordings of this subject made six months later revealed a number of additional changes in sentence- and phrase-timing patterns, changes that were not observed in the earlier recording.

Conclusions: An interaction between motor speech and language production and perception changes such as that found in this case study informs our understanding of the deterioration in dementia

Key words: motor speech, dementia, temporal structure of speech

INTRODUCTION

In many clinical descriptions of adult acquired neurodegenerative disorders a distinction is drawn between the language findings and the speech findings. Motor speech disorders in the adult neurodegenerative disorders, however, may have a more intimate relation with the general breakdown of communication than heretofore described in the literature, particularly in conditions that are closely identified with other primary disturbances, such as dementia associated with probable Alzheimer's disease.

The goal of this study is to examine changes in the temporal structure of the speech of a person with early-to-mid stage Dementia of the Alzheimer's type (DAT). We know that these patients begin to demonstrate naming deficits, have early tip-of-the-tongue symptoms, and progress to vague, tangential speech, and finally, over the course of years, regress to rote speech and eventual mutism. That is, it is evident that their motor speech functions eventually succumb to this disease just as their language and cognitive abilities do, although in many patients with DAT, clinicians report no major changes in speech intelligibility until moderate stages and beyond. It is known, however, that dementia has effects on speech-motor abilities (Powell, Cummings, Hill & Benson, 1988).

Perceptual judgments of speech, even by experienced clinicians, may not be sensitive to small speech variations, and low inter-rater reliability has been reported for some disorders, including Parkinson's disease (e.g., see Harel et al., 2004). Using acoustic measurements of speech, however, it may be possible to identify changes in patterns that fall below the critical change needed to provoke a perceptual change (see Harel et al., 2004, for an example of this approach for identifying changes in PD that have not yet reached perceptual salience). Indeed, Yan et al. (2008) have reported deterioration in fine motor control (handwriting) in DAT patients. Furthermore, Taler and colleagues (2008) found that Alzheimer's disease subjects had difficulty in detecting prosodic elements, specifically within sentential segments. This was true of mild stage disease subjects; the authors reported this as possible evidence of early stage prosodic impairment. Phenomena of this nature, characteristic for early stage changes in motor-related and perceptual abilities, may be components of clinical clusters not previously considered within the dementia literature.

The question addressed in this study is whether motor speech dysfunction occurs earlier in the dementing process than previously described, and if so, to what extent it is present in the mild disease stages, and how any such dysfunction changes over time. The study explores vowel duration variation in two contexts: segmental phonetic environment and phrase position (phrase-final lengthening). Vowel duration variations in speech have been described in healthy speakers (see, e.g., Baum & Boyczuk, 1999; Byrd, Krivokapić & Lee, 2006; Klatt, 1976; Oller, 1972; Smith, Wasowicz & Preston, 1987; Watson & Hughes, 2006). Several studies have explored changes in vowel duration patterns in speakers with neurological disorders (e.g., Baum & Boyczuk, 1999; Baum, Pell, Leonard & Gordon,

1997; Bell-Berti & Chevrie-Muller, 1991; Casper, Raphael, Harris & Geibel, 2007; Danly & Shapiro, 1982; Rogers, 1997; Wang, Kent, Duffy & Thomas, 2005). There is, however, no literature on how – or if – dementing illness, and specifically DAT, affects these temporal speech patterns.

We hope that the results of this project will shed light on the presence or absence of an early motor speech deficit in dementia. The finding of such a deficit would suggest that DAT patients should be monitored for such other difficulties as dysphagia, a frequent comorbidity with motor speech disorders (see, e.g., Langmore, Olney, Lomen-Hoerth & Miller, 2007). Furthermore, establishing the likelihood of early speech motor deficit may potentially lead to reducing the personal and societal costs associated with DAT, by leading to the development of treatments for the motor deficit.

METHODS

Subject

The subject was an 82-year-old male adult and retired lawyer. His primary adult language was English and during early childhood, Hungarian. He was recruited from a day program for the memory-impaired. He was diagnosed with Alzheimer's disease and by medical evaluation as being in the moderate disease stages, with commensurate verbal abilities. He had functional visual and hearing acuity, could follow simple instructions, and repeat simple sentences modeled for him by one of the authors. His level of impairment was classified as moderate.

Speech Materials

The speech materials included seven monosyllabic English words (with a Consonant-Vowel-Consonant, or CVC, structure) that were produced within one of two short sentences; in one the target word appeared in medial position in the sentence ("Say [word] once again") and in the other the target word was the final word in the sentence "(Once again say [word]"). This allowed us to examine utterance-position effects on vowel duration (phrase-final lengthening). The seven words included three minimal pairs (words differing by only one phoneme) that differed in the voicing characteristic of the final consonant (/t/ or /d/); this allowed us to examine the effect of final consonant voicing on vowel duration. Each minimal pair had a different vowel, including a long, tense vowel (in seat and seed); a short, lax vowel (in bet and bed). And a long vowel that was neither tense not lax (in hat and had). This allowed us to examine any differential effects on vowel duration as a function of phonetic characteristics. Finally, a seventh word ("pet") was used to create a fourth minimal pair with one of the other six words ("bet"), to allow us to examine differences in initial stop consonant voicing ("pet" vs. "bet"). In addition, we examined the words of the carrier sentence, including overall utterance duration, as well as evidence of compensatory shortening of syllables occurring in phrase-initial, as opposed to phrase-medial, position.

Recording and Analysis Procedures

All CVCs were produced in each of the two carrier phrases; they were presented in random order (168 utterances: 12 repetitions x 7 CVC's x 2 carrier phrases). Each of the 168 utterances was presented on an index card (24-point font on 5"x8" cards) and modeled by the examiner, as necessary. The recordings were made in a quiet private office at the day facility with two or three examiners present. Recording Session A was in January 2010; recording Session B was in July 2010.

The subject was seated comfortably and the task was described:

- The subject would be reading or imitating sentences presented by the lead examiner one index card at a time.
- He was given examples to be sure he understood the task (e.g., "Once again say seed" and "Once again say seat.").
- One examiner marked off the responses made by each subject and recorded when an error had occurred (e.g., incomplete sentence or the wrong carrier sentence).
- The subject was given rests as needed.

Audio recordings and analysis

A Marantz PMD 670 Digital recorder (directly to CD) and a Shur 849 condenser microphone 4-6 inches from the lips (position monitored during the recording by one of the examiners) was used. Audio files were downloaded and duration measurements made using MacQuirer software and measurements made of acoustical segments of each phrase (below) from the spectrogram MacQuirer display.

Table 1. Acoustic segments measured in carrier phrase and target word. Measured carrier phrase segments (for [g], closure duration)

CVC final	[wʌn]	[s]	[ə]	[g]	[ɛn]	[s]	[e͡ɪ]	C_1 V C_2
CVC medial	[s]	[e͡ɪ]	C_1 V C_2	[wʌn]	[s]	[ə]	[g]	[ɛn]

Measured target word segments:
C_1 (stop closure for [b, p]; frication for [h, s])
V consonant release to C_2 stop closure)
C_2 (stop closure duration

RESULTS

Overall Speech Rate

Our subject's speech was significantly slower during recording Session B than during Session A (Table 2). This slower rate was observed for most of the words (except for the word "once" in medial-position carrier phrase (Table 3).

Table 2. Mean sentence durations in medial- and final-position on Sessions A & B

	session A	session B	*significance*
Medial	1255	1512	*<.0001*
Final	1240	1478	*<.0001*

Table 3. Mean word durations in medial- and final-carrier sentences in Sessions A & B

Target Medial	Session A	Session B	change	Target Final	Session A	Session B	change
Say	325	438	*+113*	Once	254	294	*+40*
CVC	297	415	*+118*	again	304	365	*+59*
once	283	275	*-8*	say	326	391	*+66*
again	350	384	*+34*	CVC	356	429	*+73*

Phrase-Level Durational Patterns

Phrase-Final Lengthening

It has been known for some time that syllables in phrase-final position are significantly longer than those occurring earlier in an utterance, and that most of the increased duration resides in the vowel (see Klatt, 1976, for a review). Examining our speaker's utterances, in Session A the CVCs were, on average, 61ms longer in final than medial position, and the word "again" was also longer in final than medial position (44ms). However, in Session B we observed substantially less phrase-final lengthening (Table 4). Furthermore, when we examined the individual CVCs, we noted that he showed only inconsistent phrase-final lengthening during Session A, and produced longer vowels in medial position CVCs in four of the seven CVC comparisons (Table 5).

Compensatory shortening

In English (as well as some other languages), the duration of phonetic segments and syllables are shorter when they are followed by more syllables than fewer syllables (see, e.g., Gaitenby,). Thus syllables that occur in utterance-initial position are expected to be shorter than when they occur in utterance-medial position. We were able to examine our subject's speech for compensatory shorten-

Table 4. Phrase-final lengthening: 'again' and 'CVC'

	Session A				Session B			
	medial	final	difference	sig	medial	final	difference	sig
'again' position	306	350	+44	p<.0001	365	384	+19	p<.05
CVC position	292	353	+61	p<.001	415	429	+14	p>.05

Table 5. Mean target word vowel durations and differences in medial and final positions at recording sessions A & B

	Session A			Session B		
	medial	final	difference	medial	final	difference
Bed	131	170	39	154	140	-14*†
Bet	142	127	-15†	133	117	-16†
Pet	103	97	-6†	110	109	-1†
Had	156	189	33*	205	191	-14†
Hat	127	192	65*	154	173	19
Seat	121	136	15	117	147	30**
Seed	154	195	41*	183	202	19

* p < .05; ** p < .01; † reversed

Table 6. Compensatory shortening – carrier-phrase words (difference = medial –initial position; negative values indicate reversal)

	Session A				Session B			
	initial	medial	difference	sig	initial	medial	difference	sig
'say' position	325	326	+1		438	391	-47	p<.001
'once' position	254	283	+29	p<.0001	294	275	-19	p<.001

ing by looking at the ensemble-average durations of "say" and "once"–words in our carrier phrases that occurred in initial position in half of the utterances and in medial position in the other half. In the recordings from Session A, our subject produced some compensatory shortening of both "say" and "once," but the shortening was significant only for "once." In Session B, he not only failed to shorten the utterance-initial occurrences of these words, they were significantly longer when they occurred in utterance-medial position (Table 6).

Syllable and Segment-Level Durational Patterns

Effect of Final Consonant (C2) Voicing

One very regular pattern in English is that vowels in syllables ending with voiced consonants have greater durations than vowels in syllables ending with voiceless consonants, on average on the order of 50-100ms (see, e.g., House and Fairbanks, 1953). Our subject, however, did not use this pattern systematically in either recording session, although he used it more systematically in Session B than in Session A (Table 7).

Table 7. Mean duration of target word vowel in words ending with voiceless and voiced stops (in medial and final positions) at recording sessions A & B

	Session A				Session B		
	CVt	CVd	difference		CVt	CVd	difference
bet-bed (m)	142	131	-11*†	bet-bed (m)	133	154	21*
bet-bed (f)	127	170	43**	bet-bed (f)	117	140	23**
hat-had (m)	127	156	29	hat-had (m)	154	205	51*
hat-had (f)	192	189	-3†	hat-had (f)	191	173	-18†
seat-seed (m)	121	154	33	seat-seed (m)	117	183	66**
seat-seed (f)	136	195	59**	seat-seed (f)	147	202	55**

* p < .05; * p < .01; † reversed

Voice Onset Time

Whereas the voicing characteristic of continuant consonants relies on the presence or absence of glottal pulsing ("voicing") during the articulation of the consonant, and the consonants are described as "voiced" or "voiceless," the situation is more complicated with stop consonants. For these consonants, when they occur pre-vocalically, the common description is of the relative time at which voicing begins in relation to the release of the stop occlusion; this measure is called "Voice Onset Time" (VOT). For the English "voiced" stops /b,d,g/ voicing generally begins between 0 and 25ms following the release of the stop occlusion, and for the English "voiceless" stops /p,t,k/ voicing generally begins between 40 and 100ms following the release of the stop occlusion (Lisker & Abramson, 1964).

We had only one word pair in which we could examine the VOT contrast in our subject's speech, *"bet"* and *"pet."* In Session A, although he produced "pet" with longer VOTs than "bet," he produced "pet" with a relatively short mean VOT. In Session B, however, he produced "pet" with significantly longer VOTs than he had in the first recording session. Perhaps this is related to the general slowing of speech – although the differences for "bet" in the two sessions are small and not significant (Table 8).

Table 8. VOT 'bet' and 'pet' in medial and final position in the carrier phrase

Session	CVC position	bet	pet
A	medial	20	40
A	final	18	43
B	medial	32	84
B	final	21	94

DISCUSSION

Although there was no overt change in our subject's speech intelligibility that was noticed by his caregivers or the Speech-Language Pathologist obtaining the recordings (the senior author of this paper), our subject's speech departs from the timing patterns of healthy adults in several ways, and these departures were more pronounced six months after the first recording.

Utterance-Level Timing

Speech Rate

The first change over time that we noted was his reduced speech rate in recording session B (Table 2). Overall reductions in speech rate have long been reported to be a characteristic of many motor speech disorders (see, e.g., Darley, Aronson & Brown, 1975). The rate reduction in our subject's speech suggests a motor speech decline, which may be an early symptom of neurological degradation in the areas underlying speech function (i.e., cortical basal degeneration). Whether this is true in other DAT patients or just represents an atypical DAT presentation in this case cannot be answered at the present time, although the motor degradation reported by Yan et al. (2008) suggests that it may be a symptom of DAT in general.

Final Lengthening

Furthermore, the reduction in rate included a reduction in phrase-final lengthening in Session B (Table 4). That is, the rate reduction was not uniform across the phrases. In Session B, the difference in duration of the CVC in final vs. medial position – pooled across all CVCs – was not significant. Looking at the CVCs individually for Session B (Table 5), the CVC was longer in medial than final position in four of seven comparisons, and in only one comparison ("seat") was the CVC significantly longer in final than medial position. Such reductions in phrase-final lengthening have been reported for other motor speech disorders (see, e.g., Bell-Berti & Chevrie-Muller, 1991).

Compensatory Shortening

In recording session A, significant compensatory shortening was observed for one of the two comparisons of carrier-phrase words ("once"). In session B, no compensatory shortening was observed for either of the comparisons; indeed, for both comparisons the word was longer in initial than medial position (Table 6).

Segment/Syllable Level Durations

C2 Voicing

Our subject essentially maintained the pattern of producing longer vowels in the CVd than the CVt words (Table 7). That is, although in Session A there was

a reversal of this pattern in two of the six comparisons, in Session B, CVd targets were significantly longer that CVt targets in five of six comparisons, and there was only one (non-significant) reversal.

VOT (initial stop consonant voicing)

Our subject maintained the /b-p/ distinction in both sessions, even increasing it in Session B. That is, whereas he produced relatively short VOTs for “pet” in Session A, he produced substantially longer VOTs for “pet” in Session B. That is, there was no reduction in his ability to maintain this distinction

It appears, then, that our subject does not have difficulty maintaining segment/syllable-level temporal patterns. Rather, his difficulties appear to reside in phrase-level temporal patterns.

These results, of course, are limited to one subject. However, they encourage us to extend this work to additional patients with DAT, to determine if objective speech measurements can shed light on early stage evaluation of DAT.

REFERENCES

Baum, S.R. & Boyczuk, J.P. (1999). Speech timing subsequent to brain damage: Effects of utterance length and complexity. *Brain and Language, 67(1),* 30-45.

Baum, S.R., Pell, M.D., Leonard, C.L. & Gordon, J.K. (1997). The ability of right- and left-hemisphere-damaged individuals to produce and interpret prosodic cues marking phrasal boundaries. *Language and Speech, 40(4),* 313-330.

Bell-Berti, F. & Chevrie-Muller, C. (1991). Motor levels of speech timing: Evidence from studies of ataxia. In H. F. M. Peters & C. W. Starkweather (Eds.), *Speech Motor Control and Stuttering, pp. 293-301*. Amsterdam: Elsevier.

Byrd, D., Krivokapić, J. & Lee, S. (2006). How far, how long: on the temporal scope of prosodic boundary effects. *Journal of the Acoustical Society of America, 120(3),* 1589-1599.

Casper, M.A., Raphael, L.J., Harris, K.S. & Geibel, J M. (2007). Speech prosody in cerebellar ataxia. *International Journal of Language & Communication Disorders / Royal College of Speech & Language Therapists, 42(4),* 407-426.

Danly, M. & Shapiro, B. (1982). Speech prosody in Broca’s aphasia. *Brain and Language, 16(2)*, 171-190. doi:10.1016/0093-934X(82)90082-7

Darley, F.L., Aronson, A.E. & Brown, J.R. (1975). *Motor Speech Disorders.* Philadelphia: Saunders.

Gaitenby, J.H. (1965). The elastic word. Haskins Laboratories Status Report, *SR-2 (April), 3.1.*

Harel, B.T., Cannizzaro, M.S., Cohen, H., Reilly, N. & Snyder, P.J. (2004). Acoustic characteristics of Parkinsonian speech: A potential biomarker of early disease progression and treatment. *Journal of Neurolinguistics, 17,* 439-453.

House, A.S. & Fairbanks, G. (1953). The influence of consonant environment upon the secondary acoustical characteristics of vowels. *Journal of the Acoustical Society of America, 25,* 105-113.

Klatt, D. (1976). Linguistic uses of segmental duration in English: acoustic and perceptual evidence. *Journal of the Acoustical Society of America, 59(5),* 1208-1221.

Langmore, S.E., Olney, R.K., Lomen-Hoerth, C. & Miller, B.L. (2007). Dysphagia in patients with frontotemporal lobar dementia. *Archives of Neurology, 64(1),* 58-62.

Lisker, L. & Abramson, A.S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word, 20,* 384-422.

Oller, D. K. (1972). The duration of speech segments: The effect of position-in-utterance and word-length. *Dissertation Abstracts International* (0419-4217).

Powell, A.L., Cummings, J.L., Hill, M.A. & Benson, D.F. (1988). Speech and language alterations in multi-infarct dementia. *Neurology, 38(5),* 717-719.

Rogers, M. A. (1997). The vowel lengthening exaggeration effect in speakers with apraxia of speech: Compensation, artifact, or primary deficit? *Aphasiology, 11(4-5),* 433-445.

Smith, B. L., Wasowicz, J. & Preston, J. (1987). Temporal characteristics of the speech of normal elderly adults. *Journal of Speech and Hearing Research, 30(4),* 522-529.

Taler, V., Chertkow, H., Baum, S. & Saumier, D. (2008). Comprehension of grammatical and emotional prosody is impaired in Alzheimer's disease. *Neuropsychology*, *22(2)*, 188-195.

Wang, Y., Kent, R.D., Duffy, J.R. & Thomas, J.E. (2005). Dysarthria in traumatic brain injury: a breath group and intonational analysis. *Folia Phoniatrica et Logopaedica, 57(2),* 59-89.

Watson, P. J. & Hughes, D. (2006). The relationship of vocal loudness manipulation to prosodic F0 and durational variables in healthy adults. *Journal of Speech, Language, and Hearing Research, 49(3),* 636-644.

Yan, J.H., Rountree, S., Massman, P., Doody, R.S. & Li, H. (2008). Alzheimer's disease and mild cognitive impairment deteriorate fine movement control. *Journal of Psychiatric Research, 42,* 1203-1212.

Address for correspondence:
Dr. Linda Carozza
St. John's University
300 Howard Avenue
Staten Island, New York 10301
USA
e-mail: carozzal@stjohns.edu