MOTOR SPEECH DISORDERS IN THREE PARKINSONIAN SYNDROMES: A COMPARATIVE STUDY

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ABSTRACT

This paper presents results of an acoustic investigation of speech in progressive supranuclear palsy (PSP), multiple system atrophy (MSA) and idiopathic Parkinson's disease (IPD). The study had two aims: (a) to provide a first acoustic description of the speech of people with PSP and MSA, (b) to compare acoustic characteristics of the dysarthria associated with PSP and MSA with classic hypokinetic dysarthria. Four acoustic parameters (voice quality, pitch range, vowel space and alternating motion rate (AMR)) were investigated in 17 patients with PSP and 9 patients with MSA and compared with data from a large-scale study of IPD patients. Participants with PSP and MSA performed significantly worse than the PD group on AMR tasks. In addition, the pitch range of PSP participants was restricted. These results show potential for early differential diagnosis.

Keywords: Parkinson's Disease, PSP, MSA, hypokinetic dysarthria, acoustic analysis

1. INTRODUCTION

Hypokinetic dysarthria, the motor speech disorder associated with idiopathic Parkinson's disease (IPD), has been studied extensively using perceptual, acoustic, and articulatory methods. IPD is only one of a family of related disorders that are named Parkinsonian syndromes. Two of these syndromes are of particular interest: progressive supranuclear palsy (PSP) and multiple system atrophy with prominent parkinsonism (MSA-P). Previous work indicates that they tend to be associated with mixed dysarthrias rather than pure hypokinetic dysarthria [8, 9]. Unfortunately, there have only been very few studies of speech patterns in PSP and MSA-P.

1.1. PD, PSP, and MSA

Parkinsonism is characterised by a combination of four main symptoms: rest tremor, bradykinesia (problems with initiating movement or slow movement), postural instability, and rigidity. The early symptoms of PSP and MSA-P are very similar, leading to frequent misdiagnosis [7]. Due to increased midbrain atrophy in PSP [22] and increased ponto-cerebellar atrophy in MSA-P [22] the three syndromes can be differentiated more clearly as the disease progresses. PSP patients exhibit spasticity as well as hypokinetic features, while MSA-P patients show symptoms of ataxia, neither of which would be expected in IPD. PSP and MSA-P also differ from IPD in other respects: Not only is the clinical prognosis for PSP and MSA-P less favourable [14], but PSP and MSA-P patients also need a different medication regime, since they respond less well to L-Dopa, the standard medication for managing IPD [7].

1.2. Dysarthrias in PD, PSP, and MSA

Although hypokinetic dysarthria in people with IPD has been investigated extensively, the resulting picture is complex. A central factor in motor speech disorders associated with PD appears to be articulatory undershoot [1, 4]. It can lead to spirantisation of plosives [19], decreased vowel space [11], persistent voicing [1], and a perceived fast speaking rate [16]. Phonation is also affected, in particular pitch range [4].

Previous perceptual studies [5, 8, 9] have shown that PSP and MSA-P patients exhibit characteristics of spastic and ataxic dysarthria in addition to hypokinetic dysarthria. Kluin et al. found that MSA-P patients were more likely to score highly on perceptual features characteristic of ataxic dysarthria (such as irregular articulation and excess and equal stress) [9] than PSP patients, who were more likely to score highly on features associated with spastic dysarthria such as harsh voice or slow speech rate [8]. Hartelius et al. [5] confirmed this assessment of PSP speakers. However, both the PSP and MSA-P groups they examined scored equally high on features associated with ataxic dysarthria.

Our study extends these perceptual findings with a comparison of theacoustic characteristics of PSP, MSA-P, and IPD using measures derived from the standard, easy-to-administer speech tasks, syllable repetition, production of sustained vowels, and frequency glides.

2. METHOD

2.1. Participants

From local movement disorder clinics we recruited 17 people with PSP and 9 people with MSA-P. Each individual was matched as closely as possible for disease duration, age and gender with a person with IPD from a previous study. Table 1 summarises information on the participants.

Table 1: Information on participants

	PSP	MSA-P	IPD
number of participants	17	9	26
gender distribution	6 female, 11 male	3 female, 6 male	11 female, 15 male
age (years)	71 +/- 7	59 +/- 11	67 +/- 10.5
disease duration (years)	5 +/- 2	4 +/- 3	5 +/- 2

All participants were assessed in their homes before taking their morning dose of medication ("off drug" condition) on a battery of standard neurological and neuropsychological tests, followed by language assessments and a set of standard speech tasks. Here, we only report results from the speech tasks. Speech was recorded with digital card recorders (Edirol R1 Digital and Marantz Professional) using a head mounted microphone (AKG-C420L). Background noise was eliminiated by first applying a notch filter (50Hz), followed by further processing using the Noise Reduction function in Adobe Audition (2003). Individual noise filter files were created for each speaker from a suitable speech free period.

2.2. Speech Tasks and Acoustic Analysis

The speech tasks we are focusing on here are: sustained production of /a/, glissando productions of /a/, repetitions of the syllables "pea" and "key" (Alternating Motion Rate (AMR)), production of four vowels (orthographic prompts a, ee, oo, ou). All tasks were administered by a research nurse who had received specific training. Phonetic measurements were taken using speech analysis software wherever possible because we are interested in exploring the usefulness of speech tasks for semi-automated diagnosis aids. Therefore, we are looking for differences between groups that can be reliably detected using automatic acoustic analysis procedures.

All **voice quality** measurements were derived from the sustained vowel /a/. Participants were asked to hold "ah" at a comfortable level for as long as possible. Vowel boundaries were annotated by hand by two phoneticians working from the same labelling guidelines. Jitter, shimmer, irregularity of voicing, and glottal noise were calculated from the middle two seconds of both productions using the Goettingen Hoarseness analysis software [13]. The lowest values were used for analysis.

Pitch range was measured from glissando productions of /a/. Participants were asked to glide to their highest pitch twice, and then to their lowest pitch twice. Register changes into creaky or falsetto voice were excluded. PRAAT was used with standard parameters to calculate pitch over the labelled area. In addition to the maximum and minimum, the 95^{th}, 90^{th}, 10^{th}, and 5^{th} quantile were also extracted. Three ranges were computed: maximum-minimum, 95^{th}-5^{th} quantile, and 90^{th}-10^{th} quantile. Quantile ranges were used because automatic pitch extraction algorithms are susceptible to octave jumps, which result in overestimated extrema.

In order to determine **vowel space**, participants were asked to produce five instances of each of the four vowels /a/, /i/, /u/ and /o/ at a comfortable pitch level. The first and second formant were measured at the middle 30 ms of each vowel using the PRAAT procedure "To Formant (Burg)" with maximum formant frequencies of 5500Hz. Acoustic working space was computed following Turner et al. [18].

Two **AMR** tasks were analysed. In the first, participants repeated the syllable 'pea' (/pi:/, lip movement) for five seconds as fast as possible, in the second, the syllable 'key' (/ki:/, tongue body movement) was used. All participants produced the sequences twice. Closure boundaries and vowel boundaries were labelled following a validated annotation scheme [21]. Deviations from the standard pattern such as devoicing or spirantisation were annotated during manual labelling. Syllables were marked using a PRAAT script. A Python script was used to compute the number of syllables

in the first second, the last second, and the middle three seconds of each trial.

3. RESULTS

Below, we report first analysis results. We found significant differences with respect to voice quality, pitch range, and AMR, but not for vowel space. Even when using normalisation procedures that reduce inter-individual differences [2, 18] but still reveal clear differences between IPD speakers and controls [20], our negative result in vowel space persists. Due to limited space, we will only discuss those three measures in detail where we found significant differences. All statistical tests were performed using the free statistics package R [15].

3.1. Voice quality measures

The results of the measurements with the GHD showed no statistically significant differences in voice quality except for shimmer, which was slightly lower in people with PSP than in people with IPD and MSA (Kruskal Wallis test, $p<0.05$).

Table 2: Voice Quality Results

Voice Quality	IPD	MSA	PSP	IPD/MSA/ PSP
Jitter	1.298	2.1	0.27	n.s.
Shimmer	6.94	8.61	2.9	P<0.05
Irregularity	3.79	3.89	3.2	n.s.
Noise	2.236	1.95	2.08	n.s.

3.2. Pitch range

Paired T-Tests (IPD vs. PSP; IPD vs. MSA) and a repeated measures ANOVA (IPD vs. PSP vs MSA) were used to examine differences in pitch range. There is a significant difference between the three conditions ($p<0.005$ for all three measures of pitch range). Both PSP and MSA speakers appear to have a smaller pitch range than IPD speakers (cf. table 3). While the difference is not significant for MSA ($p>0.32$ for quantile ranges), it is highly significant for PSP speakers ($p<0.001$ for maxmin range, $p<0.0005$ for quantile ranges).

Table 3: Pitch range results

Variable	Max-min	Q95-05	Q90-10
IPD	241.83	221.59	208.79
MSA	247.38	184.50	171.63
PSP	142.94	121.53	115.00

The increase in significance is due to the elimination of sparse extrema in the quantile measures. This corresponds to our expectation that PSP patients are more likely to exhibit voice symptoms than MSA patients.

3.3. AMR

The clearest differences between IPD patients and people with PSP/MSA were obtained on the AMR data. Participants with IPD achieved significantly more repetitions of each syllable than PSP/MSA patients. Table 4 summarises results for all variables (best performance only). Differences between conditions are most marked for the number of repetitions produced during the mid three seconds: IPD patients produced a third more repetitions than patients with PSP or MSA. Tallying the number of repetitions over a whole try also gives significant, but less conclusive results ($p<0.05$ for both "key" and "pea"). This is consistent with previous results, which showed that both patients with spastic dysarthria and patients with ataxic dysarthria produce fewer syllables per second than patients with hypokinetic dysarthria [17].

Table 4: Number of completed syllables in syllable repetition

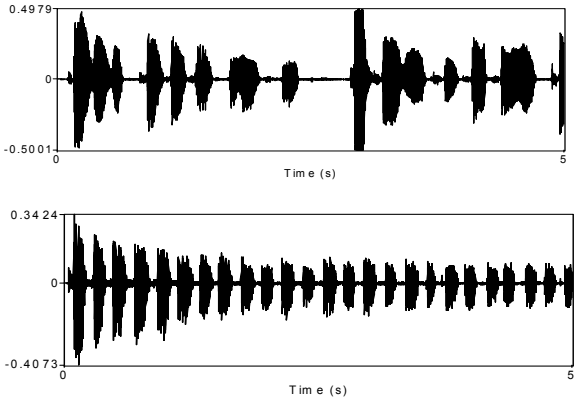
PEA	IPD	MSA	PSP	IPD vs MSA vs PSP	
First sec	5.0	3.0	4.0	F=2.0891	n.s.
Mid 3 s	15.0	10.0	9.0	F=18.102	p<0.00001
Last sec	4.5	3.0	3.0	F=0.06202	p<0.1
Total	25.0	22.0	19.0	F=4.21	p<0.05
KEY	IPD	MSA	PSP	IPD vs MSA vs PSP	
First sec	4.5	3.0	3.0	F=8.945	p<0.001
Mid 3 s	14.0	8.0	8.0	F=24.193	p<0.00001
Last sec	4.0	3.0	3.0	F=5.096	p<0.05
Total	23.0	22.0	19.0	F=4.21	p<0.05

4. DISCUSSION

The acoustic findings confirm our predictions: There are clear differences in articulation between IPD and PSP/MSA-P, and differences in pitch range between PSP and MSA-P/IPD. The voice quality results fit with previous findings [10] that PSP patients present with increased voice irregularity (larger SD of F0). However, a significant problem in all voice measures is their sensitivity to noise, making them less useful in clinical diagnosis. Our findings on vowel space suggest that the three groups do not necessarily differ in their ability to reach articulatory targets in sustained, isolated vowel productions. DDK tasks seem more fruitful: Not only are production rates far lower for PSP/MSA-P as opposed to IPD, but DDK analysis should also allow quantification of irregularities in speech rhythm as expected in

ataxic dysarthria, which may be a key feature for differentiating PSP from MSA-P patients.

Figure 1: Oscillogram of syllable repetition on "key" in a speaker with MSA (top) and a speaker with PD (bottom)



5. CONCLUSION

This is one of the first studies to compare systematically and in detail the speech of people with IPD, PSP and MSA-P. Pitch range and measures derived from AMR data have shown great potential for differentiating between the three conditions. In future work, we will compare pitch range measures based on glissando tasks with more ecologically valid pitch range measures based on the analysis of longer stretches of speech [12] and investigate speech rate and regularity of speech rhythm [6] in more detail.

We also plan to investigate the potential of the variables investigated here for early differential diagnosis of PSP/MSA-P versus IPD. Since misdiagnosis is still widespread [7], there is a clear need for reliable, non-invasive tests that can be administered easily and combined with a number of other straightforward assessments. To achieve this goal, we need to examine all speech measures for sensitivity and specificity and compare different ways of determining them. Once this groundwork has been laid, we plan a longitudinal study to assess diagnostic potential.

6. REFERENCES

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