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Perceptual consequences of online group speech treatment for individuals with Parkinson's disease: A pilot study case series

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Abstract

Purpose: We examined perceptual changes in the domains of ease of understanding, naturalness, and speech severity, as well as changes in self-perceptions of voice disability, following an online group speech treatment program for people with Parkinson's disease (PD) conducted during the COVID-19 pandemic.

Method: Seven speakers with hypokinetic dysarthria associated with PD participated in a university and community-based online group speech program for 10 weeks. Speech recordings occurred remotely 1 week before and 1 week after the online program. Thirty naıve listeners rated ease of understanding, naturalness, and speech severity based on the speech recordings. Speakers' self-perceptions of voice disability were also obtained at both time points.

Result: Individual analysis of the speech data showed that for most speakers with dysarthria, ease of understanding and perceptions of severity were rated the same or better pre- to post-treatment. Naturalness, however, was only perceived to be the same or better post-treatment in three out of seven speakers. Over half of the speakers reported improvements in their self-perception of voice disability.

Conclusion: This pilot study highlighted the individual variability among speakers with dysarthria and the potential of online group speech treatment to maintain and/or improve speech function in this population.

Keywords: *Teletherapy; group treatment; Parkinson's disease; ease of understanding; naturalness; speech severity*

Introduction

Parkinson's disease (PD) affects over 10 million individuals worldwide (Dorsey et al., 2018) and represents the second most common neurodegenerative disease following Alzheimer's (Dorsey et al., 2007). It is well known that approximately 90% of individuals with PD develop voice and speech difficulties over the course of the disease (Ma et al., 2020). These difficulties are characterised by hypophonia, monopitch and monoloudness, inappropriate pauses, variable speech rate, and short rushes of speech which, collectively, designate the motor speech disorder of hypokinetic dysarthria (Duffy, 2020). The presence of dysarthria significantly impacts speakers' overall intelligibility and functional communication, which may lead to social isolation and a significant decrease in quality of life (McAuliffe et al., 2017; Miller et al., 2008). A reduction in communicative interactions is significant in this population in that social isolation is also associated with faster cognitive decline in the elderly (Friedler et al., 2015). Furthermore, with the sudden onset of the global COVID-19 pandemic, the interruption of social activities, as well as access to medical care and exercise, was found to be associated with the worsening of PD-related symptoms (Brown et al., 2020). With this context in mind, three domains are hereby explored: impact of dysarthria on communication, relevance of group therapy for individuals with PD, and the shift to telehealth practices.

Perceptual dimensions affected in dysarthria

As stated above, hypokinetic dysarthria associated with PD impacts intelligibility. A moderate positive relationship between intelligibility and social participation has been reported in the literature (Borrie et al., 2022; Spencer et al., 2020). Beyond intelligibility, however, other measures such as ease of understanding (EoU), which reflects listener effort (Connaghan et al., 2021; Fletcher et al., 2022), have been shown to be impacted by dysarthria relative to neurotypical speech

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(Fletcher et al., 2022; Moya-Galé et al., 2023) and influence communicative interactions (for example, listeners may avoid challenging topics when speaking to a person with dysarthria or even avoid conversation altogether; Brady et al., 2011). Hence, EoU was a primary variable of interest in this study because it provides information about the potential success or lack thereof of communicative interactions between speakers with PD and their interlocutors. Given the sparsity of online group treatment research with people with PD, understanding how a potential group model may impact EoU is a first step into designing efficacious approaches for speech treatment in this population. Another perceptual dimension likely affected by dysarthria is naturalness, which has been defined as the degree to which speech "meets the typical patterns in terms of intonation, voice quality, rate, rhythm, and intensity, with respect to the syntactic structure of the utterance" (Stepp & Vojtech, 2019, p.2). Speech naturalness has been found to be highly correlated with monopitch, one of the hallmark characteristics of hypokinetic dysarthria associated with PD (Anand & Stepp, 2015). In other words, a decline in pitch variability has been associated with a decline in speech naturalness in this population. Additionally, reduced naturalness, as reduced ease of understanding, has been reported to detrimentally affect social participation and quality of life in speakers with PD (Anand & Stepp, 2015). To the authors' knowledge, the effects of group treatment on naturalness of speech for speakers with dysarthria have only been reported in Moya-Galé et al. (2021). In that study, five children with dysarthria received intensive, in-person, camp-based treatment for 3 weeks. Naturalness of speech did not significantly improve pre- to post-treatment. Perceptions of speech severity are sensitive to listeners' impressions of speakers' voice quality, intensity, resonance, rhythm, and articulatory precision (Sussman & Tjaden, 2012). Furthermore, scaled estimates of this construct may provide adequate documentation of disease progression even with speakers who might only present with mild changes in intelligibility (Sussman & Tjaden, 2012). To our knowledge, no online treatment studies have investigated changes in perceived speech severity in speakers with dysarthria secondary to PD.

Self-perceptions of voice disability are also very common in speakers with dysarthria associated with PD, as speakers tend to rate their voice and speech as statistically more impaired than healthy controls (e.g. Antonius et al., 1996). Of note, self-perceptions of voice disability are also common in speakers newly diagnosed with PD (Watts & Zhang, 2022), suggesting that changes in the phonatory subsystem represent early symptoms of the disease (Crosiers et al., 2020; Ma et al., 2020; Miller, 2017). Examining self-perceptions of voice and how those may change over time is, therefore, an inherent aspect of assessment and treatment in this population, especially when considering that approximately one third of individuals with PD report the presence of dysarthria as their most debilitating symptom (Kim et al., 2002), and most speakers eventually experience a negative impact of dysarthria on their overall effective communication and their quality of life (Spencer et al., 2020).

Group speech treatment for Parkinson's disease

Literature on group treatment for speakers with PD is still quite limited, although this treatment modality has been shown to have important advantages across different domains. It affords participants with the opportunity to learn from one another (Manor et al., 2005), it has been shown to be time and cost-effective, and it mirrors more closely the reality outside of the clinical setting. In general, group treatment has also been shown to benefit people with PD by reducing stress and other non-motor symptoms (Berardelli et al., 2018); improving gait measures, such as freezing of gait or stride velocity (King et al., 2015); and improving their quality of life (Hadinia et al., 2016). Group speech treatment for individuals with PD has gained increased attention in the last few years.

In a recent literature review on group interventions for adults with acquired dysarthria, Whillans et al. (2022) identified three different primary treatment approaches typically conducted in groups: those that targeted vocal intensity following the model of Lee Silverman Voice Treatment (LSVT® LOUD; Ramig et al., 2001), those that focused on singing, and those that combined voice and speech techniques with patient education (i.e. multi-components therapy). The authors concluded that a loudness approach yielded the most consistent improvements following group intervention, although choral singing has also been found to be a promising treatment modality for individuals with PD (Di Benedetto et al., 2009; Fogg-Rogers et al., 2016; Higgins & Richardson, 2019) and results varied among studies reviewed in Whillans et al. (2022). Most of the reviewed studies focused on changes in acoustic variables as primary treatment outcomes, such as sound pressure level (e.g. Shih et al., 2012), mean fundamental frequency (f0) and f0 range (e.g. Searl et al., 2011), and psychosocial variables (e.g. Edwards et al., 2018). Data from individual speech treatment programs have shown that intensive voice-focused interventions, such as LSVT LOUD, significantly improve speakers' intelligibility (e.g. Levy et al., 2020; Moya-Galé et al., 2018; Nakayama et al., 2020), supporting the idea of a distribution of effects beyond individual speech subsystems; that is, beyond the reported benefits in sound pressure level (Ramig et al., 2018), which reflects improvements in the respiratory and phonatory subsystems; f0 range (Ramig et al., 2001), indicating improved prosody; or expanded vowel space area, as an indicator of improved articulation (Sapir et al., 2007). Reductions in self-perceived communicative disability have also been reported following

LSVT LOUD in individual treatment (Moya-Galé et al., 2018; Saffarian et al., 2019). In a pilot study, however, a group treatment program (Loud and Proud; Edwards, 2014) focusing on maintenance of gains in speakers who had received individual LSVT LOUD sessions found no significant improvements for intelligibility, communicative effectiveness, or quality of life (Edwards et al., 2018). The authors suggested several improvements to the Loud and Proud protocol, including, for instance, the online delivery of group sessions to facilitate participants' access to treatment and decrease travel burden, as well as increased frequency of sessions to several times a week. Less is known about the impact of group speech treatment on listeners' perception of dysarthric speech and speakers' self-perceived degree of voice difficulties. Perceptual domains are of interest in this study because of the functional impact of dysarthria on communication. Of note, current speech perception models have established only a modest acoustic perceptual relationship in PD speech (Chiu et al., 2021), highlighting the multifaceted and complex nature of dysarthric speech and the need to examine perceptual domains in their own right.

The shift to telepractice

The onset of the COVID-19 pandemic precipitated the transition of health care services to telemedicine platforms. As noted by Cheng et al. (2022), this practice is projected to continue growing. In a large survey conducted with over 900 individuals with PD, Xu and colleagues (2022) reported equal or greater satisfaction with telehealth relative to in-person visits in over 40% of people with PD across the different health services surveyed (i.e. primary care, movement disorder specialist, neurology, physical therapy, occupational therapy, speech and language pathology, and mental health). Of note, speech and language pathology services had the highest satisfaction ratings. Telepractice has now been incorporated to facilitate accessibility to therapy services due to individuals living in isolated areas, a lack of qualified and licenced professionals, and patients with limited mobility and/or means to travel to therapy sites and appointments, although its adoption in health care has been traditionally slow (Cusack et al., 2008).

Research on online speech and language services is scarce, although preliminary work has shown significant improvements in acoustic (e.g. vocal intensity), perceptual (e.g. perceived loudness), and quality of life (e.g. measured through the Dysarthria Impact Profile [DIP; Walshe et al., 2009]; Theodoros et al., 2016) domains for individual speech sessions delivered remotely (Constantinescu et al., 2011; Theodoros et al., 2016). Findings on speech intelligibility changes have been variable across the limited literature. Theodoros et al. (2016), for instance, did not find significant pre- to post-treatment improvements in speech intelligibility in their non-inferiority randomised controlled trial (RCT), which could have been accounted for by the mild severity of impairment in most of their participants. Quinn and colleagues' (2019) pilot study reported on group treatment outcomes following telerehabilitation in a group of eight speakers with dysarthria associated with PD who had previously received LSVT LOUD. Although significant pre- to post-treatment improvements were noted for all sound pressure level measures, no significant changes in quality of life were reported. Still, high patient satisfaction rates were achieved, making online group service models potentially feasible for individuals with PD.

Aims of the study and hypotheses

The aim of this pilot study was to examine perceptual and self-reported changes in voice following online group speech treatment for speakers with PD. This case series was completed during the first waves of the COVID-19 pandemic, hence, and to the authors' knowledge, it represents the first study to be conducted online in its entirety (i.e. assessment and treatment) during a context of extreme social isolation. The primary perceptual variable of interest was EoU. Considering the social aspect of the group treatment sessions and participants' monitored engagement, EoU was expected to increase in most participants, although group data for intelligibility gains post-online group treatments in PD have been variable and nonsignificant changes have been reported in the literature (e.g. Quinn et al., 2019; Theodoros et al., 2016). Perceptions of naturalness and speech severity were secondary outcome variables in this exploratory study. Given the multifaceted nature of naturalness (Anand & Stepp, 2015) and the limited evidence from treatment studies, our hypothesis related to this secondary outcome variable was guarded. Changes in speech severity were expected to be contingent upon improvements in EoU and naturalness. It was expected that Voice Handicap Index (VHI; Jacobson et al., 1997) scores would decrease (i.e. improve) post-treatment as a result of group therapy.

Method

This study was approved by the Institutional Review Board (IRB) at Long Island University—Brooklyn (LIU-Brooklyn; IRB protocol number 22/04-057-Bkln) and is part of a larger project that examines communication changes following online group speech treatment in individuals with dysarthria associated with PD.

Speakers with dysarthria

Seven individuals (four women, three men; mean age = 72 years; age range = 58–80 years) qualified for this preliminary online group study within the general context of the Speech for PD program (see below). Inclusion criteria were: (a) having a neurological diagnosis of Parkinson's disease[1], (b) having a stable

Table I. Speakers' demographic and clinical information.

Speaker	Age	Sex	Ethnicity/race	YPD	Dysarthria severity	Medications	Attendance
P2	73	F	NH/White	15	Mild	Sinemet, pramipexole, rasagiline	18/20
P3	76	F	NH/White	11	Mild	Rytary, rasagiline, pramipexole, Namzaric	20/20
P4	72	M	NH/White	17	Mild	Sinemet, Sinemet extended release, amantadine, Aricept, rasagiline, entacapone, Namenda, duloxetine	20/20
P5	58	M	NH/White	4	Mild-Moderate	Namzaric, valsartan	15/20
P6	80	M	NH/White	30	Moderate	Sinemet, amantadine, rivastigmine, rasagiline, Mirapex, mirtazapine	19/20
P7	76	F	NH/White	8	Mild	Rytary, rasagiline, pramipexole	19/20
P8	69	F	NH/White	5	Mild	Sinemet/Entacapone	19/20

Note. YPD = years postdiagnosis; F = female; M = male; NH = Not Hispanic.

schedule of anti-Parkinson medication, (c) presenting with voice and speech concerns at the time of the study, and (d) being a monolingual English speaker. Consensus between two speech and language pathologists was established to determine dysarthria severity (McAuliffe et al., 2014). Auditory-perceptual judgements of voice and speech deficits were based on audio recordings of a monologue task (Tjaden & Wilding, 2004). Cognitive skills sufficient to complete the tasks (voice recordings and treatment sessions) were also required and determined by two speech and language pathologists (Behrman et al., 2020). All speakers demonstrated adequate comprehension of verbal instructions and none of them evidenced signs of confusion or disorganisation while engaging in any of the tasks. Those who had undergone deep brain stimulation or who had received intensive voice-focused treatment 2 years prior to the study were excluded. All speakers attended a minimum of 75% of the treatment sessions. Table I illustrates speakers' demographic and clinical information.

Procedure

Speech for PD

Speech for PD is an online university- and community-based clinical program, developed by the first author, that specialises in group speech treatment for individuals with PD and Parkinson's plus syndromes (Moya-Galé et al., 2020). The program runs for 10 weeks each fall and spring semester per academic year and offers 1-hour group sessions twice a week over Zoom. The frequency and intensity of the program were implemented following experience-dependent neuroplasticity principles (Kleim & Jones, 2008). Clinical sessions have an average of 15 speakers, but numbers may vary every session. Each session is comprised of two primary blocks: 30 minutes of voice and breathing exercises, coupled with reading of meaningful and functional phrases, and 30 minutes of cognitive-linguistic activities delivered in game format to smaller groups of participants in breakout rooms. During the first block, participants engage in maximum performance tasks, mainly eight trials of maximum phonation time, eight trials of high pitch glides, and eight trials of low pitch glides. These exercises stem from intensive voice-focused interventions, such as LSVT LOUD (Ramig et al., 2001), which have been shown to significantly increase speakers' sound pressure level (Ramig et al., 2018) and significantly improve speakers' voice quality (Moya-Galé, Spielman, et al., 2022) and speech intelligibility (Levy et al., 2020). Subsequently, participants engage in tasks to increase their respiratory drive, that is, three trials of maximum inhalation and exhalation exercises and four trials of maximum production of the /s/ sound (Ramig et al., 2001). The first block of each session is then completed with the reading of seven meaningful phrases that vary every session. Participants are instructed to take a deep breath before reading each sentence, and to use a strong and clear voice to maximise intelligibility. Clear speech is used as a cue in the group sessions because this speech modality has been shown to maximise articulatory skills (Lam & Tjaden, 2016) and improve intelligibility in speakers with PD (Lam & Tjaden, 2013). The second block of each session is conducted in breakout rooms, where the group size is reduced to maximise opportunities for individual feedback and speaking time for participants (Edwards et al., 2018). In the fall of 2020, when the study was conducted, each breakout room was restricted to a maximum of seven participants. Graduate student clinicians were trained to promote speakers' engagement and to ensure turn taking during the sessions. Students called on individual participants to provide an answer and fostered collaborative thinking and problem-solving during the completion of cognitive-linguistic activities. These tasks ranged in difficulty level and encompassed word retrieval exercises (e.g. verbal fluency tasks), riddles, planning (e.g. organising a weekly calendar), short-term memory, mental calculation, and creative work (e.g. group elaboration of a haiku). Students were also trained in providing feedback so as to promote motor learning and skill generalisation (Maas et al., 2008). As such, knowledge of performance was provided during the first sessions (approximately the first 3 weeks of treatment), followed by a transition to knowledge of results. In addition to students' guidance, participants were always encouraged to provide each other with verbal feedback regarding each other's intelligibility and ease of understanding (Quinn et al., 2019).

Speech stimuli

Within the context of a global pandemic, voice recordings were conducted remotely 1 week before

initiation of the online speech program and 1 week after treatment completion using the VoiceEvalU8 app (Grillo, 2017), a specialised app designed for speakers with voice disorders. VoiceEvalU8 has been successfully used in clinical settings (Schneider et al., 2021) and has been shown to be a valid measure to capture intraspeaker voice variations across various time points (Grillo, 2021). Therefore, using remote voice recordings to assess perceptual domains in dysarthric speech was deemed appropriate for this study. Speakers completed the recordings in a quiet space in their homes using their own smartphones, which were placed 4 cm from their mouths. The first author monitored the recording procedures over Zoom to ensure recording fidelity and to trouble shoot any difficulties when needed. Care partners were recruited to assist in recordings if speakers presented with Parkinson-related motor problems (e.g. tremors; Moya-Galé, Walsh, et al., 2022). Speakers were instructed to read the Rainbow Passage (Fairbanks, 1960) using their typical or habitual voice. A brief familiarisation task was presented at the beginning of the recording procedure to ensure speakers felt at ease using the app. For the purposes of this study, familiarisation consisted of brief speech tasks provided by the app, like vowel prolongation or reading of the sentence "we were away a year ago." Acoustic .wav files were generated by the app at a sampling rate of 44 kHz (Grillo, 2020).

Voice Handicap Index

Self-perceptions of voice disability were measured using the VHI (Jacobson et al., 1997), a patient-reported outcome measure that examines the psychosocial impact of voice disorders and that has been administered to a wide variety of clinical populations, including speakers with PD (e.g. Di Pietro et al., 2022). Speakers with PD completed the VHI ratings following their speech assessment.

Listeners

Thirty neurohealthy adults (23 women, seven men; mean age = 20.5; age range = 18–23 years) participated in the study. All listeners passed a bilateral pure-tone hearing screening at 25 dB HL at 500, 1000, 2000, and 4000 Hz (American National Standards Institute, 2004) and spoke English as their primary language. Listeners had no history of speech, language, or communication problems nor learning disability, and reported no experience with motor speech disorders.

Perceptual assessments

The middle excerpt of the reading passage (Tjaden & Wilding, 2004) consisting of 55 words was presented to listeners free field via loudspeakers (Logitech Z150). Listeners sat in a quiet room in the Communication Sciences and Disorders Research Lab at LIU-Brooklyn and maintained a constant distance of 85 cm from the loudspeakers, as that has been reported to be a typical distance between conversational partners (Hall, 1966). Listeners were exposed to stimuli at a comfortable listening level (Tjaden & Wilding, 2004), as determined by the investigator, and were not allowed to adjust the volume from the loudspeakers. Recordings were not intensity-normalised prior to the listening experiment in order to preserve the effects of audibility on EoU. Preserving audibility is a key feature in treatment studies focusing on intelligibility (e.g. Levy et al., 2020).

Listeners were provided with a brief familiarisation phase consisting of two recordings of the same section of the reading passage produced by two female speakers with dysarthria who were not included in the experimental stimuli. Listeners were instructed to listen carefully to each excerpt and rate three perceptual dimensions on a visual analogue scale (VAS) that was presented on a MacAir 13-inch laptop computer: EoU, naturalness, and speech severity. The VAS was developed via the following app: http://www.vasrrp.net. Prespecified definitions of each perceptual construct were provided by the examiner (second author), together with examples. Additionally, endpoint labels were provided for each construct on the VAS. The experimental stimuli were blocked by speaker and randomised across listeners (Moya-Galé et al., 2021). Order of presentation within speaker (e.g. P2_pre, P2_post) was counterbalanced and randomised across listeners. A Dell computer (Inspiron 15 3000) operated by the second author was used to play the stimuli and complete the experimental task, which took approximately 30 minutes.

One audio file was played for reliability analysis at the end of each listener's experimental block.

Data and statistical analysis

Individual analysis was prioritised for this pilot study as it allows for a more descriptive narrative, typical of case series (Torres-Duque et al., 2020). However, group analyses are also provided, as those can be useful when few data exist per individual (Cohen et al., 2008). Intra- and interlistener reliability was analysed with intraclass correlation coefficient (ICC) estimates. Two-sample t tests were computed for each speaker to examine pre- to post-treatment changes in EoU, naturalness, and speech severity. Figure 1 illustrates the data on which the two-sample t tests were conducted. The boxplots were reasonably symmetric for most data. Additionally, given that the two-sample t test is robust to departures from normality for small sample sizes, especially if the distribution is symmetric, this type of test was deemed appropriate for the current case series.

All data analyses were conducted in the R statistical programming language (R Core Team, 2021).

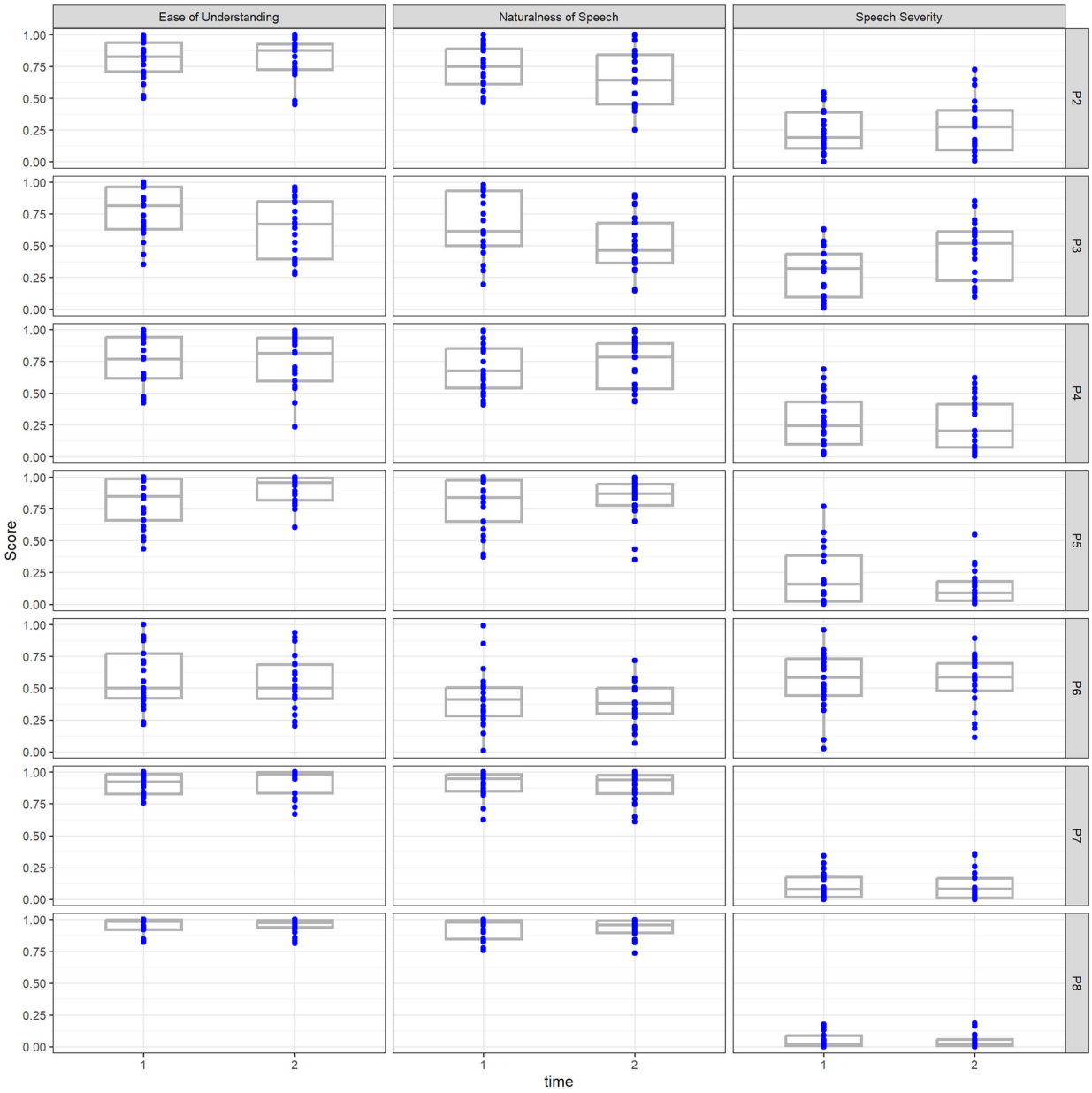

Figure 1. Boxplots for two-sample *t* tests for each speaker on ease of understanding (EoU), naturalness, and speech severity.

Result

Reliability

Intralistener reliability

One speech file was elicited twice for each perceptual construct from each listener to examine intralistener reliability. Figure 2 shows a quantile-quantile plot with 95% confidence interval on the intralistener differences for each target variable. Listeners L8, L10, L11, and L25 exhibited poor intralistener reliability (i.e. poor self-consistency) on at least one of the constructs. These listeners were therefore removed from the data. The ICC was subsequently computed, with listener as the explanatory factor in the ANOVA. Intralistener ICC estimates are provided in Table II. Results showed a strong degree of internal consistency for each perceptual domain (> 90%).

Interlistener reliability

Scores on the three perceptual constructs were elicited on three separate sound files (F1 and F2, which were part of the familiarisation phase, and P2_pre, which was a speaker-specific file provided to all listeners) for reliability purposes. Figure 3 shows boxplots of interlistener reliability data across F1, F2, and P2_pre. An initial screening for poor interlistener reliability was conducted to identify unreliable listeners, and any score that was 1.5 times the interquartile range past the lower quartile (25^{th} percentile of scores) or upper quartile (75^{th} percentile of scores) was flagged as being inconsistent with the population of listeners. Five listeners were identified: L4, L12, L20, L22, and L28. Therefore, these listeners were removed from the study. Consequently, the total final number of listeners included for statistical analysis was 21. Ease of understanding showed a high degree of agreement

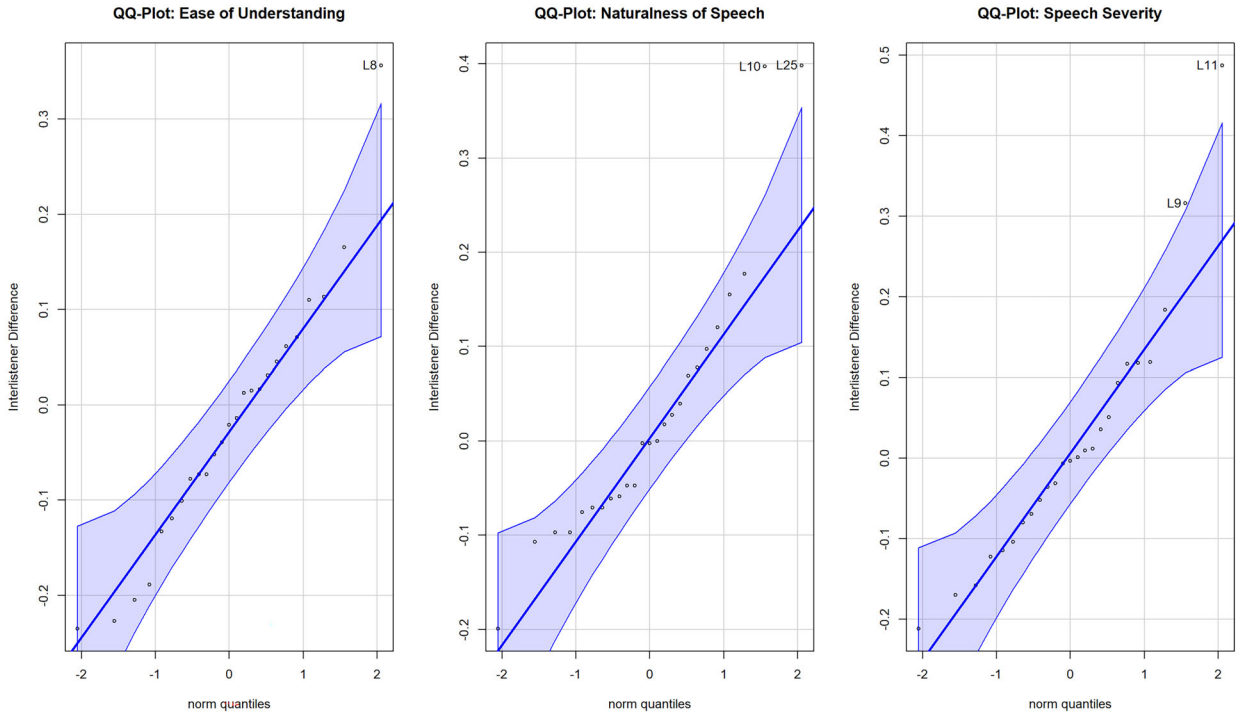

Figure 2. Quantile-Quantile plot with 95% confidence interval on the intralistener differences for ease of understanding (EoU), naturalness, and speech severity.

Table II. Intraclass correlation coefficients quantifying the average degree of agreement within and across listeners.

Reliability	Perceptual construct	ICC
Intralistener reliability	Ease of understanding	92%
	Naturalness	98%
	Speech severity	95%
Interlistener reliability	Ease of understanding	77%
	Naturalness	46%
	Speech severity	25%

across listeners, while naturalness showed a moderate agreement, and speech severity a low level of agreement. Interlistener ICC estimates are also provided in Table II.

Perceptual findings: Ease of understanding, naturalness, and speech severity

Individual speaker analysis

Descriptive information on pre- and post-treatment results for each speaker can be found in Table III.

To analyse the effects of the group treatment, listener score averages were computed for each speaker per construct and pre-/post-treatment time point. A graphical representation of the pre-post effect profiles for each speaker/construct is also provided in Figure 4. The dotted line indicates the mean of the pre- and post-treatment listener means. For EoU and naturalness, if the profiles have a positive or 0 slope, the data provide evidence that speech was perceived as being the same or improved following treatment. If the slope is negative, the average listener consensus represents a degradation of speech on that construct. For the speech severity construct, an increasing slope reflects worsening of speech severity. Evidence of maintenance or improvement for EoU was noted in five out of seven speakers, a result that was replicated for perceptions of speech severity. Naturalness was perceived to be the same or better post-treatment in three out of seven speakers.

A formal hypothesis test was conducted for each speaker/construct to determine, given the uncertainty/variability across listeners, whether negative slopes (for EoU and naturalness) and a positive slope for speech severity indicated a statistically significant degradation after group treatment. A two-sample t test with null and alternative hypotheses for EoU and naturalness was the following:

> H_0: mean pre-score $\leq$mean post-score (i.e. speaker maintained or improved on construct after treatment)
>
> vs.
>
> H_a: mean pre-score $>$ mean post-score (i.e. speaker degraded on construct after treatment).

Therefore, for these constructs, failure to reject the null hypothesis indicated that perceptual domains remained unchanged or improved. The scale for speech severity is obverse, where larger scores mean worse speech disability, and thus for this construct the competing hypotheses were:

> H_0: mean pre-score $\geq$ mean post-score (i.e. speaker maintained or improved on construct after treatment)
>
> vs.

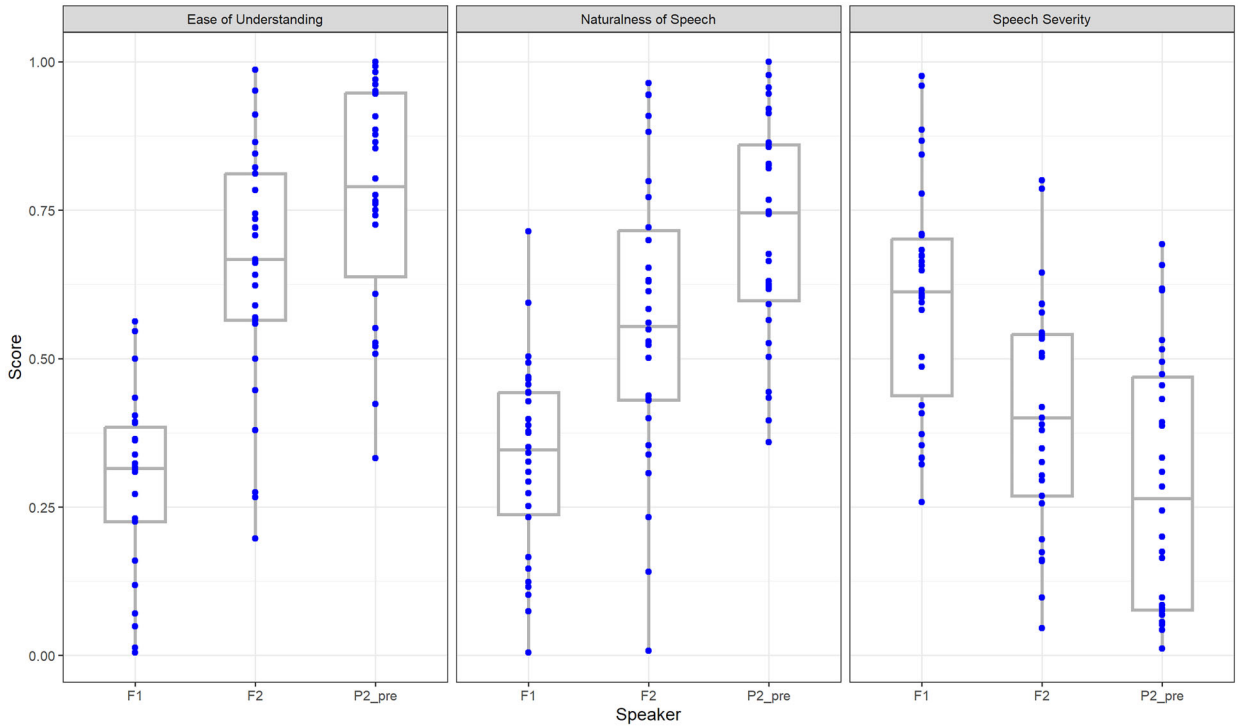

Figure 3. Boxplots illustrating interlistener differences for ease of understanding (EoU), naturalness, and speech severity.

Table III. Summative statistics (mean, standard deviation, and range) for ease of understanding (EoU), naturalness, and speech severity ratings per speaker.

	Ease of understanding						Naturalness						Speech severity					
	Pre			Post			Pre			Post			Pre			Post		
Speaker	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
P2	81	15	50–100	83	16	45–100	74	18	47–100	67	22	25–100	24	17	0–55	27	21	01–73
P3	77	20	35–100	64	24	28–96	67	25	20–98	51	22	15–90	28	20	01–63	46	24	10–85
P4	74	20	42–100	75	21	24–100	71	20	41–100	73	20	43–100	28	20	02–69	26	21	01–62
P5	81	19	44–100	91	11	61–100	79	21	37–100	83	17	35–100	21	23	0–77	13	14	0–55
P6	59	24	21–100	53	22	20–94	42	22	01–99	38	16	07–72	56	23	02–96	56	21	11–89
P7	90	08	76–100	92	11	67–100	91	10	62–100	89	12	61–100	11	10	0–34	10	11	0–36
P8	95	07	82–100	95	06	81–100	93	09	76–100	93	07	74–100	05	06	0–17	05	06	0–19

H_a: mean pre-score < mean post-score (i.e. speaker degraded on construct after treatment).

Two-sample t statistics, degrees of freedom, and p values are reported for each speaker/construct in Table IV. Only P3 showed statistically significant evidence of degradation on EoU.

Group level analysis

Speaker pre-post scores were condensed into a difference, and the distribution of differences was inspected to test whether there was evidence of degradation on any of the perceptual constructs after treatment.

For EoU and naturalness, the hypothesis was the following:

H_0: post-pre score difference ≥ 0 (i.e. the average speaker maintained or improved on construct after treatment)

vs.

H_a: post-pre score difference < 0 (i.e. speaker degraded on construct after treatment).

For speech severity, the hypothesis was:

H_0: post-pre score difference ≤ 0 (i.e. the average speaker maintained or improved on construct after treatment)

vs.

H_a: post-pre score difference > 0 (i.e. speaker degraded on construct after treatment).

Therefore, for these domains, failure to reject the null hypothesis indicated that perceptual domains remained unchanged or improved. Test statistics and p values are reported in Table V.

A diagnostic graphic depicting a quantile-quantile plot of the test data versus the theoretical quantiles from a normal distribution is presented in Supplementary Material Appendix A (Figure A1).

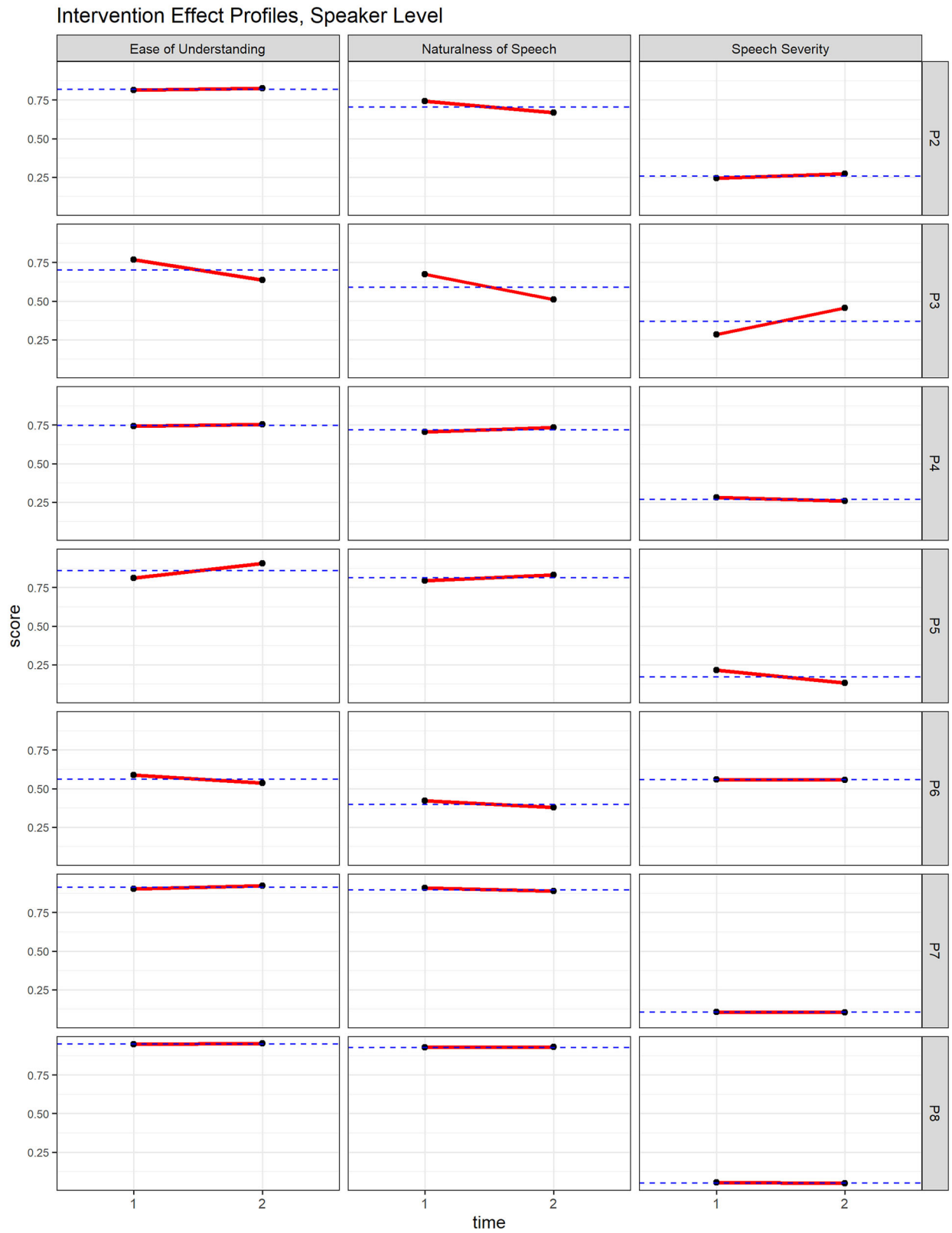

Figure 4. Pre-/post-treatment effect profiles for each speaker and perceptual domain.

Voice Handicap Index

Descriptive information on group self-reports on the VHI is presented in Table VI.

Individual speaker analysis showed over half of the speakers (four out of seven) maintained or improved their self-perceptions of voice disability after treatment. Inspection of the questionnaire's subscales revealed that both the Functional and Emotional components of the VHI were perceived as being the same or better than pre-treatment by most speakers with dysarthria

Table IV. Two-sample *t* tests output for each speaker/construct.

Speaker	Perceptual construct	*t* statistic	*df*	*p* value	Conclusion
P2	Ease of understanding	0.29	39.88	0.6135	No evidence of degradation
P3		−1.966	38.49	0.0283	Evidence of degradation
P4		0.186	39.81	0.5734	No evidence of degradation
P5		1.984	31.92	0.972	No evidence of degradation
P6		−0.738	39.76	0.2325	No evidence of degradation
P7		0.7	37.72	0.7557	No evidence of degradation
P8		0.328	38.82	0.6276	No evidence of degradation
P2	Naturalness	−1.184	37.85	0.8781	No evidence of degradation
P3		−2.27	39.68	0.9856	No evidence of degradation
P4		0.475	39.98	0.3187	No evidence of degradation
P5		0.633	38.86	0.2653	No evidence of degradation
P6		−0.706	35.94	0.7576	No evidence of degradation
P7		−0.592	39	0.7214	No evidence of degradation
P8		0.204	39.02	0.4199	No evidence of degradation
P2	Speech severity	0.475	38.31	0.6812	No evidence of degradation
P3		2.535	39.13	0.9923	No evidence of degradation
P4		−0.331	39.98	0.3711	No evidence of degradation
P5		−1.432	32.82	0.0807	No evidence of degradation
P6		−0.01	39.58	0.4962	No evidence of degradation
P7		−0.144	39.74	0.4431	No evidence of degradation
P8		−0.309	39.67	0.3794	No evidence of degradation

Most speakers' data indicated evidence of maintenance or trend towards improvement on each construct.

Table V. Test statistics and *p* values for hypothesis tests assessing evidence of perceptual construct degradation across speakers.

Perceptual construct	*t* statistic	*df*	*p* value	Conclusion
Ease of understanding	0.236	6	0.417	No evidence of degradation on average
Naturalness	−1.219	6	0.1342	No evidence of degradation on average
Speech severity	0.51	6	0.2401	No evidence of degradation on average

Table VI. Mean (and standard deviation) of total Voice Handicap Index (VHI) scores and scores for the functional, physical, and emotional subscales.

	Pre-Treatment		Post-Treatment	
VHI subscale	*M*	*SD*	*M*	*SD*
Functional	13.71	8.44	12.14	8.43
Physical	12.86	8.17	13.57	7
Emotional	8	9.61	9.14	10.85
Total	34.57	24.02	34.57	24.11

(i.e. five out of seven speakers). The opposite pattern was noted for the Physical subscale, for which only three out of the seven speakers noted gains. Individual speaker profiles on the VHI are shown in Figure 5.

Discussion

This pilot study reported on perceptual consequences and self-perception of voice disability following an online group speech treatment program for speakers with dysarthria associated with PD conducted through the first waves of the COVID-19 pandemic. Speech for PD, an online university- and community-based program for speakers with PD, was delivered twice a week for an hour over a 10-week interval remotely and speech assessments were conducted remotely pre- and post-treatment via the VoiceEvalU8 app (Grillo, 2017) under direct supervision and monitoring from the first author over Zoom. To the authors' knowledge, this is the first group study for speakers with PD conducted remotely in its entirety during an unprecedented context of extreme social isolation. A conservative approach, which set up hypotheses tests with the best power to detect worst possible outcome, was implemented given the small dataset. Group data for this small sample of participants revealed overall pre- to post-treatment maintenance of the perceptual constructs of EoU, naturalness, and speech severity, as rated by naive listeners with no collective improvement in the target measures. A similar trend was observed for self-perceived ratings of voice disability, as measured by the VHI. Taken together, these group data yielded similar findings from previously reported group treatment studies, in both face-to-face and remote modalities. For instance, Edwards et al. (2018) found no significant improvements for intelligibility, communicative effectiveness, or quality of life in 12 speakers with PD receiving face-to-face group speech treatment once a week for 8 weeks. Similarly, Theodoros et al. (2016) reported no significant improvements in intelligibility or ease of understanding in their noninferiority RCT comparing online and face-to-face treatments, a result that was attributed to the fact that most speakers in their study experienced mild dysarthria, which was also the case for our sample of participants.

Worsening of motor and non-motor signs in individuals with PD over the first 6 months of the global COVID-19 pandemic has been reported in the literature (Shalash et al., 2022). This adverse context also affected people's social dynamics, including the amount of time spent talking to others. It is, therefore, worth noting that opportunities for communicative interactions and skill generalisation were more limited during this period, which could have impacted our speakers' ability to fully benefit from a group speech program, even if such program was delivered remotely. Still, the

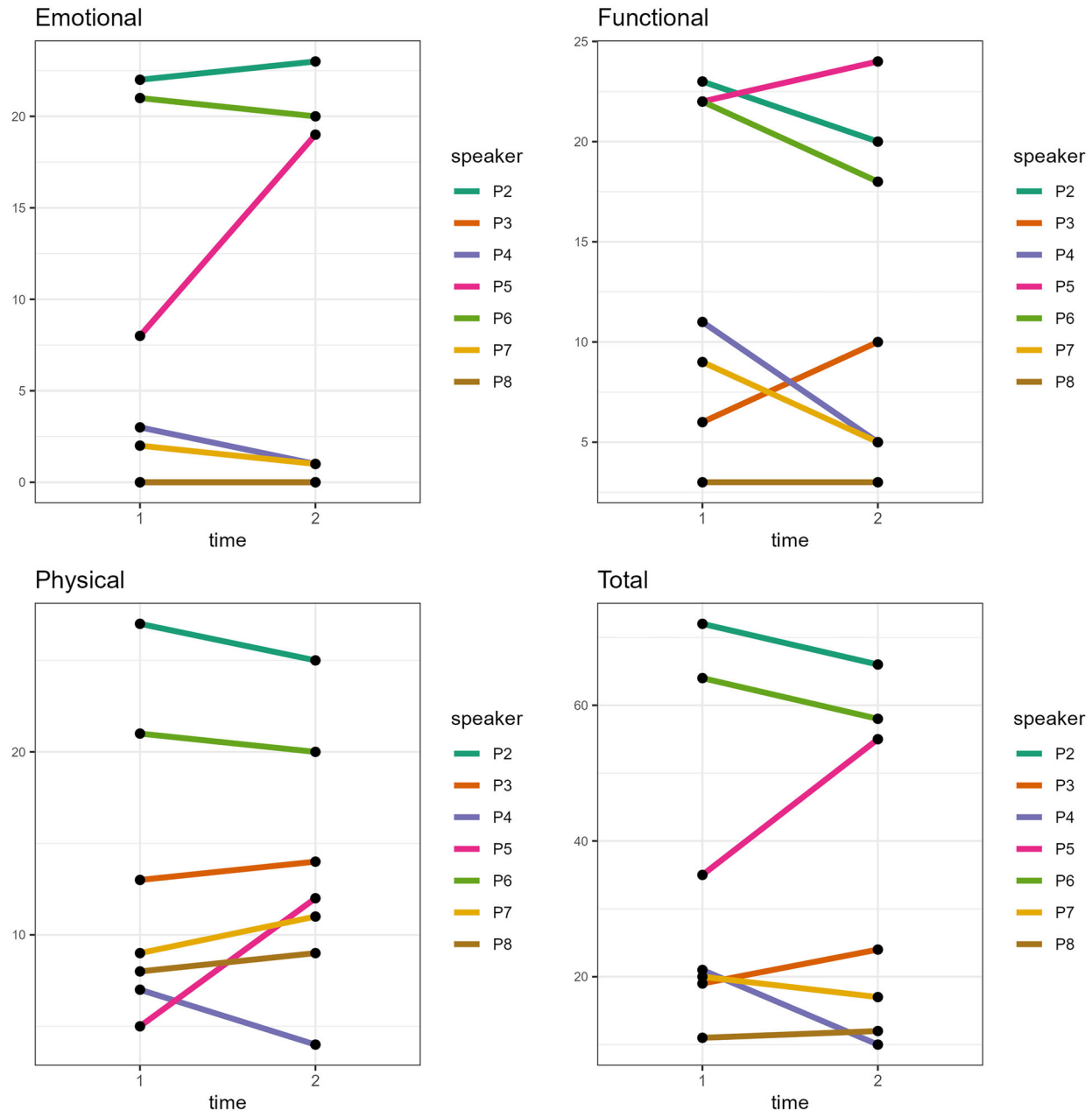

Figure 5. Individual speaker profiles on the Voice Handicap Index.

fact that maintenance of the target perceptual constructs was observed in our sample is encouraging for this pilot study.

Perceptions of naturalness were only observed to improve in three out of seven speakers upon visual inspection of the data, as shown in Figure 4. Although naturalness is a common perceptual construct of interest in many areas within the field of communication disorders (Klopfenstein et al., 2020), it has been relatively less studied than other perceptual domains, such as EoU, in dysarthria treatment research. Additionally, a "trade-off" relationship has sometimes been established in therapeutic interventions, when clinicians must prioritise between improving intelligibility and improving naturalness of speech (Stepp & Vojtech, 2019). In a recent study with children with dysarthria, naturalness was not found to significantly change following speech treatment that aimed at increasing loudness and articulatory excursion, even when intelligibility significantly improved post-treatment (Moya-Galé et al., 2021). Similarly, in the current study, EoU appeared to improve for most speakers, while the same effect was not noted for naturalness. As stated in Klopfenstein et al. (2020), recent definitions of naturalness have placed a special emphasis on prosodic features, suggesting that suprasegmental variables have a significant contribution to this percept. Treatment approaches based on prosody have been traditionally regarded as promising strategies for improved naturalness (Liss, 2007) and the perception of natural speech is also based on typical vocal intensity (Patel et al., 2011).

Although Speech for PD incorporates maximum performance exercises aimed at reducing the perception of monopitch (through pitch gliding exercises) and increasing vocal intensity, it is possible that the frequency and intensity of the group sessions may not have been sufficient to drive changes. Our current study did not include acoustic measures of speakers' productions. It is also possible that intonation, rhythm, or use of stress could have influenced our current results. Future work should relate naturalness changes with acoustic parameters and examine ways in which to maximise this perceptual construct in treatment.

Our contrastive findings regarding intra- and interlistener reliability may illustrate the "internal yardstick" phenomenon (Miller, 2013), by which intralistener reliability is stronger than interlistener reliability when processing the degree of intelligibility distortion in speakers with dysarthria (Hirsch et al., 2022). In our pilot study, intralistener reliability was excellent for all the perceptual dimensions examined, hence evidencing consistency within each listener as to any perceived changes in EoU, naturalness, and speech severity. Interlistener reliability, however, was low for naturalness and speech severity. We hypothesise that these perceptual dimensions possess a higher degree of subjectivity than EoU, for which listeners are only required to gauge how easy or how difficult an item is to understand. Additionally, speakers' overall severity (i.e. five out of seven presented with mild dysarthria) may have contributed to the lower interlistener reliability results, given that greater listener agreement has been reported when speech is either typical or severe versus when it contains mild or mild-to-moderate deviations (Bunton et al., 2007).

Group results for the VHI did not show improvements following online group treatment and, thus, parallel findings from a study by Shih et al. (2012). A lack of improvement in psychosocial outcomes, besides those documented by the VHI, following group treatment has also been reported in prior literature (e.g. Edwards et al., 2018; Quinn et al., 2019), a result that has been related to speakers' increased self-awareness of communicative skills post-treatment. Of note, however, individual analysis of the data showed that four out of seven speakers experienced an improvement in their overall self-perception of voice disability, with more substantial gains observed in the Functional subscale, suggesting that, in general, the impact of the voice disorder on activities of daily living in over half of the speakers was noted to have improved post-treatment. Individual inspection of the data also highlighted opposing results for some of the speakers. For instance, listeners perceived the speech of P5, who was later on diagnosed with Lewy body dementia (DLB), as easier to understand, more natural, and less severe post-treatment. In fact, P5 benefitted the most from this online group speech program. Dysarthria latency in idiopathic PD averages 7 years post disease onset, but it tends to occur earlier in DLB (Müller et al., 2001). This was shown in P5's case, for whom speech diagnosis reflected mild-to-moderate dysarthria only 4 years post-diagnosis. Individual results from P5 are, therefore, encouraging when proposing a feasible treatment program conducted remotely for these patients. Nonetheless, P5's self-perceptions of voice disability did not align with naive listeners' impressions, which could reflect the fact that their awareness of dysarthria and its overall impact on quality of life was heightened as a result of participating in the program. An opposite pattern was evidenced by P6, whose speech was overall perceived to be slightly more difficult to understand and slightly less natural post-treatment. Their VHI results, however, showed improvement across all subscales, which suggests a positive internal response to the program on the speaker's perception of the functional, physical, and emotional impact of dysarthria. P6 was the only speaker with a speech diagnosis of moderate dysarthria and the speaker with the most years post PD diagnosis (30). Listeners' perceptions of P6's speech, therefore, reflect the documented deterioration of voice and speech over time in this population (Skodda et al., 2013). Four of the speakers in this case series were women of similar age with mild dysarthria. Two of them had been diagnosed with PD within the last 10 years, whilst the other two had been living with the disease for over a decade. P3, who was 11 years post PD diagnosis, was the only female who experienced deterioration of the perceptual speech dimensions and the VHI. Based on anecdotal self-reports, we speculate that aspects beyond this study's control may have impacted results.

This study represents a preliminary step into developing an efficacious online group speech program for speakers with PD. In contrast with Edwards and colleagues' (2018) study, which provided eight 90-minute group sessions weekly, our group met for 1-hour sessions twice a week for 10 weeks. This amount of practice, however, may not have been enough to achieve significant changes as perceived by naive listeners, especially when considering the effects of extreme social isolation during the time the study was conducted. Additionally, group work in the second half of each session, which was focused on the implementation of individual cognitive-linguistic exercises rather than choral reading, may have induced a reduced response rate of conversational interactions in some speakers, even though graduate students were trained to ensure equal opportunities for turn taking and engagement among participants. The severity range of the speakers' dysarthria is likely another factor to have influenced results, as most of our speakers (five out of seven) presented with mild dysarthria. Subtle changes in voice may be more difficult to perceive in cases of mildly dysarthric speech (Bunton et al., 2007). Home practice or explicit instructions for carryover activities outside the speech

program were not provided during the duration of the study. It is possible that explicitly assigned extra practice could have induced greater changes in our population. As reported in Searl and colleagues' (2011) study, VHI scores and amount of home practice have been found to be strongly correlated. Therefore, "homework" assignment may be beneficial to maximise results and should be incorporated in future work.

Limitations and future directions

This study presented pilot data on an online group speech treatment program for people with dysarthria conducted through the COVID-19 pandemic. Still, the small sample size for speakers ($N = 7$) and listeners ($N = 21$) for this case series is a limitation and results can only be interpreted as exploratory. Case series do not provide the most robust source of evidence for a new treatment approach given the absence of a control group; however, this type of design allows for more descriptive information and contributes to the generation of new hypotheses and to the building of knowledge, both crucial elements for developing treatment research given the limitations imposed by the first and second waves of the COVID-19 pandemic (Torres-Duque et al., 2020). Although intralistener reliability was excellent and interlistener reliability for EoU was adequate, interlistener reliability for naturalness and speech severity was low. Efforts were made to familiarise listeners with the testing procedures and each perceptual construct. Condensing listener VAS score averages for a specific speaker was also implemented to decrease uncertainty. No follow-up data were collected for this study and no controls were included for comparison purposes. Future work should examine whether voice changes following an online group program may be maintained longitudinally, and if increasing duration in an online treatment group may yield different findings. Additionally, based on our preliminary evidence, future work should examine the effects of this type of online group speech treatment program on individuals for whom dysarthria may progress more rapidly (e.g. DLB, progressive supranuclear palsy). Finally, social dynamics in the home (e.g. living alone versus living with extended family) should be further explored as inclusion criteria in future work.

Conclusion

Online group speech treatment for people with dysarthria has potential to maintain and improve some perceptual domains affected by this motor speech disorder and self-perceptions of voice disability. Although overall results from this pilot study may have been restricted by speakers' overall severity of dysarthria, the exceptional context of extreme social isolation in the early stages of the pandemic, and length of time participating in the program (as the amount of practice may not have been enough to achieve significant changes), findings are promising to support further work in this area.

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Note

1. One of the speakers (P5) was diagnosed with Lewy body dementia (DLB) after the initiation of the study.

Author contributions

GMG was responsible for study conceptualisation, recruitment of speakers with PD, remote voice recordings, treatment cosupervision, data organisation and analysis, and manuscript elaboration and editing. GP was responsible for listener recruitment and testing, as well as final manuscript editing. SJW was responsible for data preparation and analysis, and manuscript elaboration and editing.

Declaration of interest

No potential conflict of interest was reported by the author(s).

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Data availability statement

Data are available on request from the authors.

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