Improved status following behavioural intervention in a case of severe dysarthria with stroke aetiology

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Abstract

There is little published intervention outcome literature concerning dysarthria acquired from stroke. Single case studies have potential for more detailed specification and interpretation than is generally possible in larger studies so are informative for clinicians dealing with similar cases. Such research also contributes to planning of larger scale investigations. Behavioural intervention is described which was carried out between seven and nine months after stroke with a 69 year old man with severe dysarthria. Pre-intervention stability between five and seven months contrasted with post-intervention gains. Significant improvement was demonstrated using randomized, blinded assessment by 10 judges on measures of word and reading intelligibility and communication effectiveness in conversation. A range of speech analyses were undertaken (rate, pause and intonation characteristics in connected speech and single word phonetic transcription), with the aim of identifying speech components which might explain the listeners' perceptions of improvement. Changes were detected mainly in parameters related to utterance segmentation and intonation. The basis of post-intervention improvement in dysarthria is complex, both in terms of the active therapeutic dimensions and also the specific speech alterations which account for changes to intelligibility and effectiveness.

Stroke is a main cause of acquired, non-progressive dysarthria, with reported prevalence of 25-53% (Mackenzie, 2011). Disruptions to intelligibility and effectiveness of communication are frequently persistent and are associated with psychosocial handicaps (Dickson, Barbour, Brady, Clark & Paton, 2008). Given its high prevalence, and the defined role for the speech-language pathology (SLP) profession (Royal College of Speech and Language Therapists, 2005), it is surprising that there has been little published robust research into the management of dysarthria in the stroke population. Although there is much literature outlining management approaches which may be used in dysarthria, even frequently used techniques enjoy popularity “for reasons no stronger than tradition or fervent advocacy” (Duffy, 2005, p. 435). Evidence of benefit of intervention with the dysarthric stroke population is limited to some single case and case series studies; there are no published randomised control trials (Mackenzie, 2011; Palmer & Enderby, 2007; Sellars, Hughes & Langhorne, 2005).The paucity of research in this area may relate to the inter-participant variation in dysarthria (Yorkston & Baylor, 2009), as regards features, severity, co-existing disabilities and recovery patterns. Attention to dysarthria may also be reduced through the recent marked increase in dysphagia referrals to SLP departments, which has affected resources for management of speech and communication disorders (Palmer & Enderby, 2007).

According to the Medical Research Council recommendations (Medical Research Council, 2008) for evaluation of complex interventions in health care, small scale exploratory research without external controls is an important preliminary to randomised control trial (RCT) (Craig, Dieppe, Macintyre, Michie, Nazareth & Petticrew, 2008). Moreover, some authors have questioned the usefulness of the RCT for heterogeneous clinical populations, such as dysarthria, given the diversity in presentation and the multi-target and multi-technique nature of interventions (Yorkston & Baylor, 2009). The level of detail which may be included in single case reports, with respect to participant profile, therapy program and interpretation, provides stimulus for clinicians who may seek to replicate a treatment protocol within their own caseloads.

The individual described here is drawn from a larger study (Mackenzie & Lowit, 2007). This case was selected for further analysis and evaluation because he had the lowest connected speech intelligibility and communication effectiveness ratings of the participant group and showed significant post-intervention gains in both intelligibility and communication effectiveness. The paper aims to guide and stimulate SLPs who may deal with similar cases. A further aim of the study was to identify components of this patient's speech production which might be contributing to listeners' judgements of improved speech status.

Methods

Case profile

Client PC was a 69 year old monolingual English speaking man who attended speech and language therapy following a stroke. A computerised tomography (CT) scan showed PC to have bilateral infarcts, mainly affecting frontal, temporal and parietal lobes and the putamen in the right hemisphere. A smaller infarct in the left hemisphere affected the frontal lobe, as well as the cerebellar hemisphere. There was a history of transient ischaemic attacks but no additional remarkable medical history. Following hospital admission his communication was assessed by SLP. Dysarthria was diagnosed from performance on the *Frenchay Dysarthria Assesssment* (Enderby, 1983). He scored within the normal range on the *Mini Mental State Examination* (Folstein, Folstein, & McHugh, 1983) and the hospital's informal aphasia screening test. He received basic advice about maximising communication attempts. After discharge he attended three individual sessions, which focused on advice and practice in slowing speech rate.

PC was motivated to receive further SLP input and at 5 months after stroke entered a dysarthria in stroke intervention research program. The results for this participant are reported in this paper. At recruitment there was no indication of hearing impairment. Glasses were worn for reading and afforded adequate correction. He walked without aid, but with some restriction of left arm and leg movement. He lived at home with his wife. He reported to the SLPs that his dysarthria had a profound effect on self image, confidence, and dependency on others. He felt that people behaved in a condescending way towards him and thought he was drunk. However he did not avoid social and speaking situations.

Assessment

Assessment data were collected at four points at five (Pre 1), seven (Pre 2), nine (Post 1) and eleven months post stroke (Post 2), by a research assessor who was not involved in the therapy program or the data analysis. Intervention took place between seven and nine months only.

The assessment materials consisted of:

Task A: 70 item single word intelligibility test (*Multi-Word Intelligibility Test* (MWIT), Kent, Weismer, Kent & Rosenbek, 1989)

Task B: 150 word reading passage (Lowit-Leuschel & Docherty, 2001)

Task C: a conversational sample.

Recordings were taken at the participant's home using a Sony Digital Audiotape Recorder, Model TCD-D8, and a Sony electret condenser microphone, model ECM-MS907, positioned approximately 30 cms from the speaker's mouth.

Outcome measures and analysis

As part of the larger study (Mackenzie & Lowit, 2007) the data were evaluated perceptually for word and connected speech intelligibility (Tasks A and B) and communication effectiveness (Task C). Additional acoustic analysis was carried out for this individual study with the aim of explaining improvements in speech.

Perceptual analysis

The four recordings of each task were randomised within series of 31 dysarthric speech samples of the same nature, from a total of eight speakers, and rated independently by 10 experienced final year SLP students. Thus raters were blind to the assessment point of the samples they evaluated. None had been involved in the data collection or intervention.

Task A rating involved word identification from sets of four choices as prescribed by the test authors, for example stimulus *bad*: *bad, bed, bet, pad* (Kent et al., 1989). The researchers' experience with this test indicated that listeners sometimes did not make a choice if they thought the response not to be one of the four options provided, so a fifth option (none of those listed) was added to allow for this.

Task B was rated for overall intelligibility, using the procedure of direct magnitude estimation (Weismer & Laures, 2002), relative to a speaker with moderate to severe dysarthria who was notionally rated at 100. This standard was played repeatedly after every four recordings.

Task C was rated for overall effectiveness of communication, considering both intelligibility and naturalness, using a single 7 point equal-appearing interval scale, based on the work of Ball, Beukelman and Pattee (2004), where 1 = not at all effective and 7 = very effective.

Inter-rater reliability was assessed by intraclass correlation coefficient. For this participant correlations were Task A: 0.88, Task B: 0.88, Task C: 0.96. Mean ratings calculated across the ten listeners are given in table 1.

Phonetic acoustic analyses

To investigate the relationship between articulatory accuracy and perceptual multiple choice identification of target items in Task A, each word was transcribed phonetically in a narrow way by means of perceptual evaluation aided by spectrographic analysis, and the number and type of phoneme errors noted. This analysis was performed by a separate investigator. As part of the larger study, two samples were transcribed by a second listener. This analysis showed good inter-rater reliability with an overall agreement of 94% of phonemes. Discrepancies mainly included minor issues such as recognition of partial devoicing or weak spirantisation.

The connected speech tasks, B (reading) and C (spontaneous conversation), were matched in length based on number of syllables produced. Calculations were made of mean articulation rate (syllables/sec), and articulation-pause time ratio (expressed as % articulation time in relation to total speaking time). The latter measure could only be taken from the reading passage, as most of the pauses in the conversational sample were inter-turn pauses. As a consequence, the mean length of utterance (MLU) was investigated as a further measure for both reading and spontaneous speech, with the assumption that shorter utterance lengths would reflect a higher incidence of pauses.

Two experimenters independently analysed one reading and one conversational sample. Reliability was calculated for the number of syllables counted in each sample, as well as the duration of utterances and pauses. Inter-rater agreement for conversational speech was syllables: 86.2%, duration: 98.3% and for reading: syllables: 96.4%, duration: 99.7%.

The analysis furthermore focused on the intonational characteristics of the speech samples as monopitch and excess stress were noted in preliminary perceptually evaluation (see below). Due to the time consuming nature of the procedures involved, this analysis was result-driven. First, only the reading samples for Pre 2 and Post 1 were perceived to show a difference in intonational behaviour, thus conversation was not included in this analysis. Second, the analysis was only widened to the other assessment points if the results for Pre 2 and Post 1 suggested differences between these two datasets. As a result, pitch accent and boundary tone distribution was investigated for tasks B and C for Pre 2 and Post 1 data, and F0 excursion data were collected for task B for all four assessment samples.

The investigation included an intonational analysis in line with the autosegmental metrical framework (AM) approach (Ladd 2008), focusing on both phonological categories (the distribution (number and type) of pitch accents and boundary tones) and the phonetic realisation of these elements (the extent of F0 excursion for pitch accents). In addition, a novel approach was used to capture the overall F0 variability across utterances by applying principles from the quantification of rhythm. Pitch accents and boundary tones were identified in line with the system used for intonational transcription of British English in the Intonational Variation in English (IViE) project (Grabe, Nolan & Farrar, 1998; Grabe, 2001). The F0 excursion measure represents the mean F0 range implemented on the final pitch accents across all utterances. To capture F0 variability the mean absolute difference in F0 between consecutive high and low tones within each utterance was calculated, and the Pairwise Variability Index (PVI, Low, Grabe & Nolan, 2000) was subsequently applied to these data. A similar approach has been used by Ballard, Robin, McCabe and McDonald (2010) to evaluate stress patterns in single word stress, and unpublished analyses by one of the authors suggest that this procedure is also better able to capture differences in F0 variation within longer utterances than the commonly applied standard deviation measure.

Pre-intervention status

Statistical analysis, using the ratings from the 10 listeners, indicated stability between Pre 1 and Pre 2 for both Tasks A (MWIT) and B (Reading) (Wilcoxon signed rank tests, n.s, $p > 0.05$). There was deterioration between Pre 1 and Pre 2 for Task C (communication effectiveness in conversation: $p < 0.01$). (Table 1)

The ratings for Tasks B and C indicated a severe compromise of PC's ability to communicate intelligibly and effectively. Listeners informally reported understanding to be higher for single words than connected speech.

table 1 about here

Initial perceptual analyses of the data undertaken for the purpose of treatment planning suggested that the main detriments to intelligibility and effectiveness were, at the segmental level:

- velopharyngeal incompetence, leading to predominating hypernasality and nasal emission: oral consonants commonly had nasal realizations, especially voiced plosives (e.g. /b/ → [m]; /d/ → [n]);
- Slow, effortful articulatory movements, affecting co-articulation and frequently resulting in intrusive nasals in the case of stop consonants (e.g. bad → [mand]) epenthetic vowel insertion in consonant clusters (e.g. wax → [wakəs]) or slow release of final stops resulting in an additional schwa vowel at the end (e.g. dock → [nɔkə] or

audible exhalation/aspiration after both voiced and voiceless final stops (rip ➞ [ɹɪpʰ] , side ➞ [sɑidʰ];

- articulatory imprecision affecting consonants and to a lesser extent, vowels, reflecting to a large extent articulatory undershoot, e.g. /tʃ/ ➞ [ʃ] ;
- syllable omission in multisyllabic words, e.g. Aberdeen ➞ [agɪn]; heavy ➞ [he]; yesterday ➞ [jesneɪ]; very ➞ [ve]; experience ➞ [espɪn].

At the suprasegmental level:

- harsh strained voiced quality;
- reduced speaking rate combined with short rushes;
- short utterance length;
- monopitch;
- excessive stress, with nearly every word in an utterance being stressed.

This presentation is consistent with the literature on dysarthria in stroke, whereby imprecise articulation and slow speaking rate are standard features, and voice disturbances and reduced prosodic variation are also common. Data which are confined to stroke populations indicate that these characteristics are present in individuals with differing lesion locations (Mackenzie, 2011).

Intervention program

The principal aim was to maximise the comprehensibility of natural speech.

Not all of the disordered parameters could be addressed in a short period of intervention. The following general goals were set for this individual, which in the opinion of the authors had the greatest potential to contribute to the attainment of this aim:

- improvement in accuracy of single words production, progressing to short connected utterances, with specific attention to plosive consonants;
- improvement in clarity and syllabic structure of multisyllabic words;
- further reduction of rate of speech, with a view to maximising speech accuracy (Duffy, 2005);
- maximisation of participation in dialogue, sharing responsibility for the communication exchange.

Throughout all sessions, both in practice of set stimuli and where appropriate during more spontaneous events, including conversation, four communication maximization strategies were emphasized via direction, encouragement and therapist modeling:

- speak more slowly
- pause for breath between sense groups
- articulate sounds deliberately with wide mouth opening
- avoid long sentences

An individualised behavioural therapy program of 16 sessions of 45 minutes, over an eight week period was offered. PC attended 14 of these sessions, which were led by two experienced SLPs, in close liaison. Sessions included 1) practice of set stimuli and 2) activities to generate spontaneous utterances. Table 2 shows main targets throughout the program, with examples of stimuli and any special therapeutic approaches. Clear descriptions were given of articulatory placements for targeted consonants, accompanied by illustrations.

Stimulus sets were provided in written form, clearly and repeatedly modelled by the therapist, progressing from unison production, through imitation, to reading aloud without model and responding to questions using the stimulus words. All practice stimuli were elicited at least four times in each session. Stimuli from previous sessions were regularly reviewed, randomly, in succeeding sessions. Spontaneous utterances were elicited through description of event pictures selected by another therapist, so unknown to the intervention therapist, question and answer dialogues in which participant and therapist acted as both requestor and provider of information, and participation in conversation and discussion. In these more spontaneous situations the emphasis was on the four selected maximisation strategies (see above). Special attention was also given where words of similar structure to the stimulus sets arose in spontaneous speech, in that these were revisited and practised. As far as was possible stimulus material was maximally relevant to the individual and his life activities and social circle. Feedback was given both in relation to overall quality of response and to specific components. As therapy progressed the patient was increasingly involved in evaluating his responses. Home practice relevant to each session was issued. Fifteen minutes daily of this stimulus practice was advised, in addition to making conscious effort to apply the maximisation strategies in all speaking situations.

table 2 about here

Results

Based on performance during the final treatment sessions, the therapists reported progress in articulatory precision with the achievement of a minimum of 70% rated accuracy in all stimulus sets. In spontaneous speech, rate reduction was noted to facilitate comprehensibility but continued prompting was required to achieve this. It was observed that conscious implementation of the maximisation strategies, especially where repetition was requested, was often accompanied by increased inappropriate emphasis on words and increased volume. Some of these observations were confirmed by the independent perceptual and acoustic analysis of the separate post-treatment assessments as detailed below.

Perceptual Analysis: Intelligibility and Communication Effectiveness

As detailed earlier, there were no significant improvements to word and reading intelligibility or communication effectiveness across the non-intervention baseline assessment (Pre 1 and Pre 2). At the conclusion of the intervention program (Post 1), significant improvement relative to Pre 2 was present for reading intelligibility and conversation effectiveness ($p < 0.01$). Following the succeeding eight week non-intervention period there were no further significant changes in these measures, but improvement relative to Pre 2 was maintained ($p < 0.01$). For word intelligibility (Task A) the Pre 2/Post 1 change was not significant, however there was evidence for improvement from Post 1 to Post 2 ($p < 0.01$), and as a consequence, the change from Pre 2 to Post 2 was also significant ($p < 0.01$). (Wilcoxon signed rank tests).

Phonetic acoustic analysis

Single word production

There was no clear correspondence between the listeners' improved ability to identify the target words from Task A at Post 2 and the quantitative analysis of the phonetic transcription. The overall percentage of misarticulated phonemes was found to have marginally increased after intervention (see table 1) rather than showing the expected decrease in phonetic error rate. A qualitative analysis of the errors with regard to the nature and severity of the misarticulations did not reveal any reasons for the improved listening scores either. Randomisation procedures in the listening experiment exclude the possibility of a learning effect from early to later assessments and results thus remain inconclusive as to why listeners were more successful in identifying single words post-treatment.

Articulation rate

Values for articulation rate indicate that PC successfully reduced rate in spontaneous conversation immediately post-treatment (Post 1), but increased it again to near pre-intervention levels at Post 2. For reading, his rate showed a slight increase from Pre 2 to Post 1. However both post-intervention measures are similar to the initial assessment (Pre 1), suggesting that there was in fact little change. Overall, PC's rate in reading was slower than in conversation, except at Post 1, where values were identical. The acoustic results for the assessment tasks thus are not consistent with the therapists' impression of PC's performance during therapy.

Pausing

The articulation-pause time ratios for the reading task (table 1) suggest that there was little change in the overall percentage of pause time in this task. On the other hand, the MLU data indicate that PC increased his mean utterance length and thus produced fewer pauses in the post-intervention assessments in both tasks (Post 1 & Post 2 in reading, and Post 2 in conversation). To illustrate his performance further, figure 1 shows the distribution of utterance lengths for conversation. In Pre 1 and Pre 2, PC produced similar amounts of very short (1-4 syllable) and slightly longer (5-9 syllable) utterances. Only after treatment did he produce utterances longer than 10 syllables (maximum 13 syllables in Post 2). This result appears to suggest that the treatment strategy of shortening his utterances was not successfully implemented. However, the pattern for Post 1 shows that although he started to produce longer utterances at this point, the sample also contains the highest percentage of very short utterances (figure 1), suggesting that PC did in fact reduce the length of his utterances as advised in therapy. The Post 2 data, on the other hand, show a definite shift towards longer utterances, compared to all three previous assessments.

figure 1 about here

Intonation Analysis

The intonation analysis shows a highly limited pattern of intonation contours, which largely consisted of high initial boundary tones (H%), a falling pitch accent (H*L) and level final boundary tones that followed on from the low of the pitch accent, as illustrated in figure 2. The intensity contours closely matched those for F0, with both parameters being characterised by a similar magnitude of rising-falling movements. This pattern suggests that F0 and intensity variation was physiologically rather than phonologically determined, i.e. movement in both parameters paralleled the amount of effort and air pressure exerted during the utterance. PC thus had very little volitional control over his F0 or intensity. The figure furthermore demonstrates that nearly every word received a pitch accent, resulting in a very low number of syllables per PA measure (Table 1). The repetitive intonation pattern combined with the high number of accents in the sample relate directly to the perception of monopitch and excess stress.

figure 2 about here

However, the lack of distributional differences between the Pre 2 and Post 1 samples did not concur with the researchers' perception of slightly more expressive, less monotonous speech in the post-treatment reading passage. Instead, this was captured by the phonetic analysis (table 1). The data show that F0 variation across utterances increased immediately post-intervention (Post 1) compared to both baseline measures (Pre 1 & Pre 2), although it dropped again to pre-intervention levels at the 2 months follow up assessment (Post 2). Given the high frequency of H*L accents in the sample, the extent of F0 excursion for PAs mirrors these results.

In summary, the acoustic phonetic investigations of the data showed little change over time except for the distribution of utterance lengths and the extent of F0 excursion. The relationship between perceptual impressions and phonetic acoustic analyses was complex. There was no correspondence between the listeners' ability to identify single words and the phonetic error analysis. On the other hand, perceptions of monopitch and excess stress were confirmed by the analysis, as was the greater extent of intonational variation in one of the samples.

Discussion

Following the intervention period, blind listeners rated PC's speech as improved, in measures of connected speech intelligibility during reading and communication effectiveness during spontaneous conversation. These outcome measures have face validity and the demonstration of gains relative to pre- intervention suggests that behavioural therapy has a place in the management of stable dysarthria with stroke aetiology. The therapists' sessional records document improved levels of accuracy during stimulus practice and at the conclusion of the intervention period they were of the opinion that PC's communicative ability was enhanced. At his post-intervention assessment PC volunteered that he thought his speech had improved.

The discussion of improved status focuses on two components. Firstly a consideration of variables which may influence the therapeutic process and its outcome is included as a stimulus for clinical reflection. Secondly the additional acoustic analysis is discussed in terms of its potential to explain the improvements in speech which listeners discerned.

The therapeutic process

Where improvement occurs following therapy determining the ‘active ingredients’ which have contributed to the change in status is challenging. Interacting variables of natural recovery, participant, therapist and intervention may be relevant.

Natural recovery: After a stroke the natural course is for some spontaneous functional recovery to occur, varied in timescale and extent. Rate of recovery is fastest in the first few weeks (Wade, 1992), but the limits of spontaneous change are unknown. There has been little controlled examination of the natural course of dysarthria with stroke aetiology. Canbaz, Celebisoy, Ozdemirkiran and Tokucoglu (2010) found that 53% of those rated as having dysarthria acutely were classed as having normal speech at three months. As no subsequent follow up data are presented it is not known whether further change occurred. PC began the therapy program at seven months after stroke, so the likelihood of spontaneous progress is less than would be the case at an acute stage. In small data sets and without external controls, the influence of natural change cannot be ruled out and it is possible that the demonstrated gains were achieved naturally, regardless of input. However, given that pre-intervention status during the two months preceding intervention was stable for intelligibility and deteriorating for communication effectiveness some therapy effect seems likely.

Participant: Stroke patients who are considered by rehabilitation professionals to have high motivation are more likely than those with low motivation to view their own efforts as important for progress (Maclean, Pound, Wolfe & Rudd, 2000). Participants who enter research studies are usually well motivated and may apply special effort in the knowledge that they are the subject of research. Even if the intervention is inert, a placebo effect may be observed. In the current case, motivation noted at recruitment and throughout the program may have been an influencing factor.

Therapist: Motivation, effort and belief are applicable also to the treating therapist and it is possible that the active constituent is the therapist rather than the therapy provided. Clinicians are unlikely to deliver therapy which they believe to be ineffective. The research therapists were interested in the program and stimulated by working with the motivated participant. They incorporated no specific psychological management techniques but delivered the intervention in the encouraging, empathetic and supportive manner, which is typical of clinicians (Duffy, 2005).

Intervention: Unless controlled comparisons are made of differing therapy amounts and intensities, positive or negative outcomes can only be viewed in relation to the program provided. For PC, fewer therapy sessions might have been less or just as effective, or more therapy sessions might or might not have resulted in further improvement. The results of behavioural intervention might be affected by the methods used, including variables such as content of practice material, mode of presentation, number of trials, feedback, reward, and reinforcement schedules. Results might have been different for PC with alterations to such therapeutic variables. However the specifics of the intervention method and materials might be irrelevant and the influencing components in therapy might include increased opportunity for conversation, heightened self- monitoring, application of maximisation strategies or practice and encouragement in the home, as well as the participant-therapist relationship. Future research might compare results of a specific intervention program and an equivalent amount of therapy time devoted to non-specific conversational practice.

In addition to the above, many personal variables have been suggested as having the potential to impact on prognosis in dysarthria (Murdoch, Ward & Theodoros, 2009). Amongst the variables relevant to this case which might be regarded as positive are the absence of noted cognitive and language changes, the presence of a communication partner at home and his retained social activity. The severity of PC’s brain damage, affecting the cerebellum and both cerebral hemispheres would be viewed as an important negative prognostic factor (Murdoch et al., 2009, p.15). However firm evidence is lacking as to the effects of any of these variables in recovery in stroke related dysarthria.

Explanation for improved speech

The additional acoustic phonetic analysis aimed to explain the improvements in intelligibility and effectiveness with reference to segmental and suprasegmental parameters of speech production. However, many measures were similar before and after intervention and no clear picture arose as to what aspect might have contributed to increased communicative ability. Single word intelligibility improved despite little observable changes in the phonetic makeup of these words. Listener familiarity cannot explain this result as the samples were randomised in order as well as amongst the output of another seven speakers with dysarthria. There was also no clear relationship between the phonetic measures and perceptual impression based on the targeted treatment outcomes, e.g., intelligibility and communicative effectiveness improved despite increases in articulation rate and MLU, where the opposite pattern had been expected (i.e. intervention targeted reduced rate and utterance length).

These inconclusive results suggest that a combination of factors might have led to the improved perceptual impressions. Consistent with recommendations for improvement of intelligibility, rate reduction was a therapy target (Duffy, 2005), using methods of verbal instruction and hand tapping. The results showed that articulation rate in conversation was lower after therapy (Post 1), mirroring Van Nuffelen, De Bodt, Vanderwegen, Van de Heyning and Wuyts' (2010) findings that hand tapping is an effective strategy to reduce rate. However it returned to close to the pre-therapy level at Post 2. Nevertheless improvement in communication effectiveness was maintained at Post 2. At this point it is possible that increased mean utterance length (MLU), consistent around 4.5 syllables through Pre 1, Pre 2 and Post 1, but 6.3 at Post 2 may have played a part in the improved effectiveness rating. It is possible that given the short MLU naturally displayed by PC, an increase in utterance length actually aided listeners because speech output was less disjointed. By providing larger parts of the utterance in one event, listeners might have been better able to make sense of any unintelligible segments using the contextual information provided. This hypothesis might to some degree explain van Nuffelen et al.'s (2009, 2010) findings that rate reduction techniques did not necessarily result in intelligibility improvements. If rate reduction was achieved by segmenting the speech signal into smaller units (i.e. separating words or syllables, inserting a high number of pauses into utterances), this might have resulted in essential contextual information being removed to the detriment of comprehensibility. The treatment had seemed entirely appropriate in PC's case, given that his spontaneous utterances could be quite long and word boundaries were difficult to detect. It cannot be firmly established why his performance in reading differed so extensively from that in conversation; possible factors could be increased cognitive load, reading difficulties or the fact that PC was applying a strategy acquired during his previous speech treatment, but not generalised to spontaneous speech. Due to the fact that different scales were used to evaluate the two speech samples, no direct comparison is possible to evaluate whether the rate reduction / utterance shortening strategies displayed in reading had a significant effect on his intelligibility. However, the across assessments comparisons discussed above signal the need to closely monitor the effects of rate reduction strategies on intelligibility.

Explaining improved reading intelligibility rating is more challenging. Instead of a reduction in articulation rate there were marginal increases from pre-treatment levels here too. In addition, MLU in the reading task only increased minimally between Pre 2 and Post 1, with further small changes in Post 2. MLU increases thus did not contribute to the same degree as might have been the case in conversation. However, in the reading data there were also improvements in F0 excursion, which might have further aided listeners in understanding the speech signal. Most of the speech perception literature focuses on stress placement as a cue to utterance segmentation and word recognition (see Harley, 2008; Weismer & Martin, 1992 for reviews). Reductions in intelligibility are consequently attributed to impairments of realising stress sufficiently as listeners can find it difficult to segment the signal without those markers. PC’s pattern was quite the opposite in that he produced excessive and equal stress on nearly each word in his utterances. Although he thus provided adequate cues to word boundaries, listeners might have had difficulties identifying the important information in the utterance. However, the observed increase in F0 variation noted in PC’s post-treatment reading data might have helped the identification of information in focus in his utterances. A similar pattern was described for a case with brain haemorrhage by Heselwood (2007). This speaker showed a very similar F0 profile to PC, with intrusive stresses and rising - falling F0 patterns for each stress. Heselwood (2007) reports that despite these limitations, the speaker was able to use intonation linguistically by highlighting focused information with higher F0 peaks than other stressed words. PC’s F0 peak variation is not as high as noted for Heselwood’s (2007) client, but post-treatment data show a change in the right direction, which might explain the higher intelligibility scores.

An additional parameter which might be considered as relevant to improved status is loudness. Mouth to microphone distance had not been controlled at the time of recordings, and no formal measure of intensity manipulation across samples could thus be included in this paper. In addition, loudness was not a focus of treatment, as the level was more than adequate. As discussed earlier, loudness control was an issue, resulting in the peak and valley pattern tied in with F0 production demonstrated in figure 2. However, in contrast to F0, there was no perceptually noticeable change in behaviour across assessment samples, and it is therefore unlikely that loudness contributed in any significant way to the observed changes in intelligibility in reading and conversation.

Although the current data thus appear to go some way in explaining the perceptual impressions of the listeners, none of the interpretations are conclusive. There might have been other parameters not currently under investigation that had a perceptual impact. Furthermore, the significance of the contributing factors identified above will need to be validated by further data from people with and without speech impairments.

Conclusion

At the end of an eight week intervention period PC, who had chronic dysarthria following stroke, was rated as more intelligible in single words and connected speech and communicatively more effective in conversation. These gains were maintained after withdrawal of treatment. Interacting variables including natural recovery, participant and therapist psychological factors and the specific therapeutic intervention are possible contributors to improved status, none of which can be discounted or substantiated. No single acoustic phonetic variable could explain the observed improvements in perceptual measures, but there are some signs that different combinations of factors might have had an influence. If the current assumptions about the effects of MLU on intelligibility are valid, it will be important for clinicians to consider this aspect when choosing an appropriate rate reduction strategy for their clients.

Severity of dysarthria remained severe-profound. Comprehensibility was much limited, particularly in situations where context was not readily established. The program in which PC participated was behavioural; its aim was to maximise the comprehensibility of speech through practice targeting some of the impaired parameters and the incorporation of a set of strategies. For this individual several other SLP approaches might be considered. PC certainly fulfils criteria for the introduction of augmentative forms of communication as a means of supplementing his frequently unintelligible speech. In view of his retained language status and absence of dementia, it would be appropriate to encourage the use of simple measures such as writing and also discuss with him the introduction of a computer based system (Hustad & Weismer, 2007). Communication partners were not actively involved in the program and where dysarthria is as severe as in this case, this may be particularly relevant (Yorkston, Beukelman, Strand & Hakel, 2010). Intervention directed at the communication pair rather than just at the individual with dysarthria maximises potential for the partner to act as a co-therapist, the implementation of environmental changes and co-construction of communication messages. No specific efforts were made to address the psychosocial impact of dysarthria, such as the effects on self image, and confidence which PC described. Dysarthria intervention tends to be impairment focused, though the inclusion of psychosocial issues is recommended (Dickson et al., 2008) and this aspect too might be incorporated into future programs, at both individual and group level.

No assumptions of generalisation can be made from single case studies of this type. Outcomes may be affected by variables, including participant and therapist factors, which are not readily controllable. Rosenbek and Jones (2009) include as a principle of speech treatment that “treatment should be organized so that each patient’s response contributes to the next patient’s care.” (p. 272). This report may provide stimulus and ideas for clinicians who have similar cases. Even after the conventionally considered spontaneous improvement period, people with very severe dysarthria with complex stroke history, may make gains which are discernible in assessments of intelligibility and communication effectiveness.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Table 1: Summary of perceptual and acoustic measures across tasks (A, B & C) and assessment points (Pre 1 and 2 and Post 1 and 2)

	PRE 1	**PRE 2**	**POST 1**	**POST 2**
Task A: MWIT				
Intelligibility (% words correctly identified)	70% (8.18)	69% (10.69)	73% (6.04)	79% (5.96)
Transcription (% incorrect phonemes)	57%	64%	68%	66%
Task B: Reading				
Intelligibility (relative to standard of 100)	29	15	44	48
MLU (syll)	2.3	2.2	2.5	2.7
Articulation Rate (syll/sec)	2.9	2.6	2.9	3.0
Articulation - Pause Ratio (% artic. time)	49%	58%	57%	55%
Frequency of PAs (in syllables per PA)		1.7	1.8	
PA type		H*L : 100%	H*L: 97%	
Boundary tone type		Initial: H%: 100% Final: level: 100%	Initial: H%: 100% Final: level: 100%	
F0 excursion for H*L (Hz)	69.0 (19.1)	70.4 (20.8)	74.2 (28.2)	71.3 (19.3)
F0 variation (Hz)	43.6 (26.5)	46.1 (28.1)	50.7 (32.6)	43.3 (25.2)
Task C: Conversation:				
Effectiveness (max = 7)	2.0 (0.67)	1.1 (0.32)	2.6 (0.97)	3.0 (0.82)
MLU (syll)	4.4	4.6	4.4	6.3
Articulation Rate (syll/sec)	3.6	3.5	2.9	3.3

Abbreviations: MLU = mean length of utterance; syll/sec = syllables per second; PA = pitch accent; H*L = falling tone with accent on the high syllable; H* = level high tone; !H*L = downstepped tone; H% high rising boundary tone

Table 2: Intervention session summary

Sessions	Targets	Stimuli	Examples	*Specific therapeutic approaches
1-3	Differentiation of voiced plosives and nasal homorganic consonants	Minimal word pairs practised singly and as pairs: CV, VC, CVC	mike/bike; no/dough; rag/rang; lamb/lab; side/sign	Therapist identification of targeted item from written alternatives
3-4	Precision of clusters which include a voiced plosive	Single words: CV/CCV, CVC/CCVC Phrases including practised words	Bow/low/blow; dye/rye/dry; gay/ray/gray; gas/lass/glass; bite/light/blight; gain/rain/grain Here is the glass/Dry the glass ; A bright light/ dry and bright	practice of CV, followed by CCV Therapist identification of targeted item from written alternatives
5 -7	Syllabic structure of multisyllabic words	2 and 3 syllable words Short sentences including practised words	Foot/football; Com/compute/computer; Grand/grandchild I watch football She wants a computer	Practice of individual syllables, then whole word Hand tapping to aid rate reduction
7-9	Spontaneous sentences	Generated through conversation and discussion, with therapist and participant taking turns to contribute Conversational extracts	We watched Coronation Street; She usually chooses the programs	Focus on low intelligibility words, practising these repeatedly in isolation, then in 2/3 word context, then in full context Words/syllables for emphasis highlighted on

	Stress pattern			transcript
10 -14	Overall effectiveness in spontaneous speech in a) Response to questions b) Describing picture stimuli provided by another therapist c) barrier tasks d) conversation	Q: What are your three favourite sports? Q: What are your children's names? Q: Tell me four places you would really like to visit Patient and therapist have identical picture sets e.g. people, where correct identification necessitates detailed description	Football, darts, swimming A young girl wearing a small hat; A woman with blue eyes; A man with a short beard	Responses recorded and played back for review and revision Responses transcribed for review and revision Therapist selects picture from patient description Reduction in sentence length

*additional to standard methods of unison, imitation, reading aloud, question response and response monitoring and evaluation
Table provides main additional focus and therapeutic approaches of sessions. Stimuli were regularly reviewed in succeeding sessions.

Abbreviations: CV = consonant, vowel; VC = vowel, consonant; CVC = consonant, vowel, consonant; CCV = consonant, consonant, vowel; CCVC = consonant, consonant, vowel, consonant;

Figure 1: Distribution of mean length of utterance results for conversational samples across the four assessment points (Pre 1 and 2, Post 1 and 2)

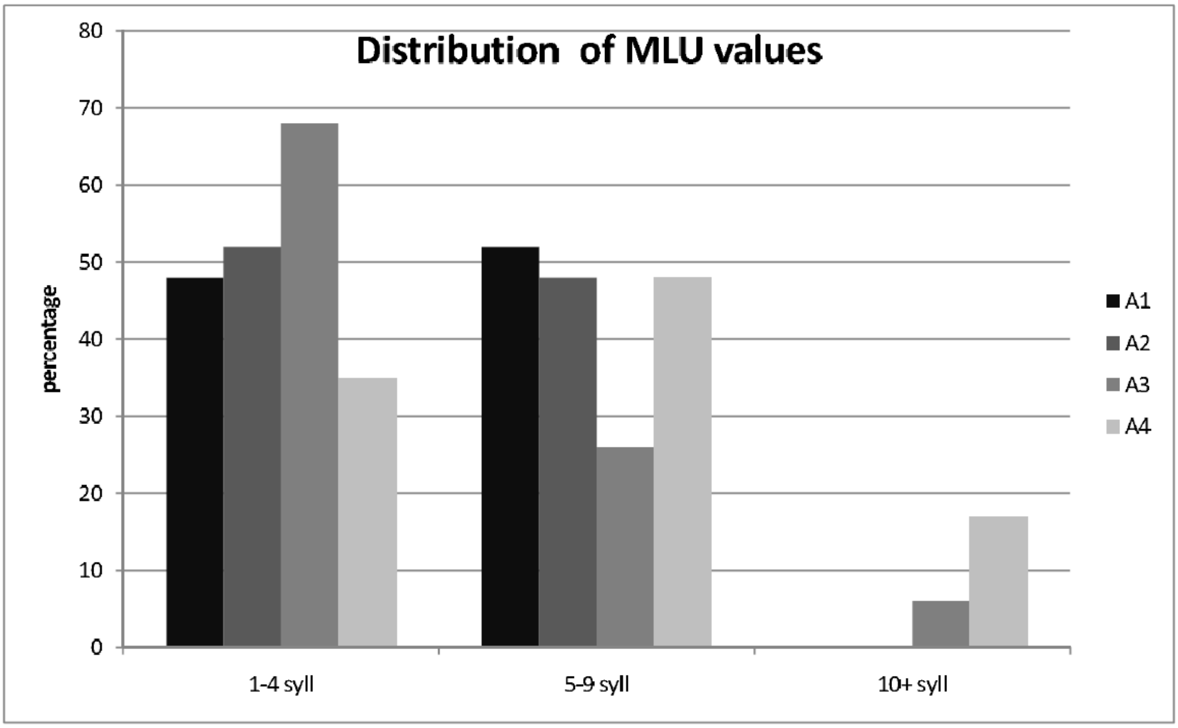

Figure 2: Excerpt from the reading passage ("yes thanks – we went down – town – to see – a film") showing F0 (dark grey) and intensity contours (light grey) at Pre 2.