Between-word processes in children with speech difficulties: Insights from a usage-based approach to phonology

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Abstract

There are some children with speech and/or language difficulties who are significantly more difficult to understand in connected speech than in single words. The study reported here explores the between-word behaviours of three such children, aged 11;8, 12;2 and 12;10. It focuses on whether these patterns could be accounted for by lenition, as suggested by a usage-based approach to phonology. The children carried out a repetition task, with sentences containing environments that can trigger assimilation and elision. Speech elicited was examined using a combination of perceptual and electropalatographic analysis. All of the children produced instances of word boundary behaviours reported in adult speech, as well as some which are considered to be atypical. It is argued that all of these phenomena can be viewed as lenition, and that a usage-based approach to phonology has potential for providing a valuable framework for the description of between-word processes in disordered speech.

Introduction

Communication takes place primarily through the medium of connected speech, rather than isolated words. Despite this, the traditional focus of clinical work with children with speech difficulties has been the single word, and connected speech is not routinely investigated (Flipsen, 2006). Some of this work may have a carry-over effect into connected speech, and there is increasing emphasis on determining whether articulatory improvements at the single word level are generalised into the context of connected speech (see, for example, the Diagnostic Evaluation of Articulation and Phonology; Dodd, Zhu, Crosbie, Holm and Ozanne, 2002). Findings concerning children's ability to generalise to connected speech are mixed however, and while Dodd and Bradford (2000) observed improvements in accuracy and intelligibility in connected speech after therapy focused on single words in children with developmental phonological disorder, Pascoe, Stackhouse and Wells (2005) report no such gains in a child with persisting speech difficulties.

There are some children with speech and/or language difficulties who are significantly more difficult to understand in connected speech than in single words, despite good performance on single word articulation tests (Grunwell, 1987). For example, there is anecdotal evidence of children with specific language impairment who present with few (e.g. gliding) or no errors at a single word level, but several more – and reduced intelligibility – in a language sample. Reduced accuracy of articulation in connected speech may be due to the increased demands on the speaker in formulating a sentence. Several researchers (e.g. Crystal, 1987) have suggested that the increased demands of syntactic (and semantic) processing in such contexts disrupts phonology, and as a result articulatory accuracy and intelligibility are diminished. Alternatively – or additionally – reduced intelligibility in connected speech could be the result of disrupted prosody or fluency (Barnes et al., 2009). A further possible explanation is that such children may have particular problems with the junctures between words. Wells (1994), for example, reports the case of Zoe, a child of 5;11 with a severe developmental speech disorder whose connected speech is characterised as being 'disjointed', and who exhibits features (e.g. insertion of glottal stops before vowel-initial words; lengthening of final syllables) that make her connected speech lack the phonological cohesion found in adult speech. Wells and Stackhouse (1997) present the case of Richard, aged 11;8, who has dyslexia, and who omits vowels and consonants (and sometimes whole syllables) when combining words, which cause his connected speech to sound 'mumbled'. Despite presenting with contrasting phenomena at word boundaries, the consequence for both children is reduced intelligibility in connected speech. The research reported in this paper explores the connected speech of three children with speech difficulties, focusing specifically on whether the realisation of between-word junctures is particularly problematic for them. Their behaviours will be considered in relation to word boundary phenomena commonly found in the connected speech of adults.

Between-word processes

The range of phenomena evident in adult connected speech (including, for example, 'weak forms' such as "are" produced as [ə]) has been widely reported in the literature (e.g. Cruttenden, 2008;

Shockey, 2003). Often referred to as connected speech processes, the occurrence of these phenomena has traditionally been seen as optional, governed by a combination of factors relating to rate, style and accent and described in terms of the application of a phonological rule or process (e.g. Kohler, 1990). The research reported in this paper concentrates on two of these phenomena which occur at word boundaries:

- (Anticipatory) assimilation of word-final alveolar consonants (/t/, /d/ and /n/) to following word-initial bilabial or velar oral and nasal stop consonants. For example, "brown bear": /braʊmbɛə/; "red car": /rɛgkɑ/.

- Elision (or final consonant cluster reduction) of word-final alveolar consonants (/t/ and /d/) in the environment /C_#C/. For example, "left leg": /lɛflɛg/; "robbed the (bank)": /rɒbðə/.

Assimilation and elision were selected to be the focus of this study because both involve changes in the realisation of alveolar plosives at word boundaries, and so they are particularly well-suited to the analysis of linguapalatal contact patterns provided by an electropalatogtraphic investigation. These phenomena are termed here 'between-word processes' to distinguish them from other phenomena occurring in connected speech but not specifically at word boundaries. As with other research which has focused on between-word processes (e.g. Thompson & Howard, 2007; Wells, 1994) and following Sprigg (1957), in this report, close juncture is used to describe instances where adjacent words are bound together by the occurrence of assimilation and elision (e.g. "brown bear": /braʊmbɛə/; "left leg": /lɛflɛg/). The term open juncture is used to describe instances where adjacent words are separated by a pause and/or by the absence of a process in a relevant context (e.g. "brown bear": /braʊnbɛə/; "left leg": /lɛftlɛg/).

Between-word processes in typical development

Early single case diary studies examining the phonological phenomena which occur when children begin to combine words focused on idiosyncratic processes. Stemberger (1988), for example,

examined processes that occurred both within words and between words in the connected speech of an English-speaking child aged between 1;1 and 4;3. He noted that the between-word processes used by the child (e.g. word-initial /θ/-deletion) were similar to those produced by adults in connected speech but not in English connected speech. More recent studies have explored the occurrence – or otherwise – of selected boundary phenomena which have been reported to be prevalent in adult speech. Newton and Wells (1999) found that the children in their study, aged between 3;2 and 7;11, produced both adult-like assimilation and elision and that they either produced close juncture with the appropriate assimilation or elision or adult-like open juncture in the relevant environments. They did not find any significant differences between the age groups of the children studied. A developmental trend in younger children was observed by Thompson and Howard (2007) in their study on a range of juncture sites, suggesting that there was a shift in preference from open juncture to close juncture between the ages of 2;3 and 3;3. They tentatively suggest that open juncture is the default realisation of process contexts when children first produce utterances of two words and longer. In contrast, Newton and Wells (2002) conclude that close juncture is the default realisation in contexts for assimilation and elision in a child aged between 2;4 and 3;4. They found that open junctures were generally produced later (at age 2;7) and even then were used rarely. Bryan, Howard and Perkins (2010) also observe the early emergence of assimilation and elision in their single case study. Idiosyncratic patterns were evident in both these studies (e.g. "in box": [ĩʔbɒks]) from the first appearance of two- and multi-word utterances.

Between-word processes in atypical development

Much has been written on intelligibility in connected speech of various clinical populations of children (e.g. Barnes et al., 2009). In contrast, there is a small but growing literature examining production of between-word processes in clinical populations, difficulties with which may be a significant factor contributing to reduced intelligibility in connected speech contexts. Howard (2004; 2007) has explored the characteristics of word boundary phenomena in young people with a range of severe speech impairments. In addition to observing the processes reported in the speech of

adults and typically-developing children, the children's intelligibility in connected speech was affected by 'abnormal' behaviours at word boundaries. These phenomena include those described by the author as hyperelision (where the entire coda in a word is elided; e.g. "and she's" = [ã ʂɪʐ]), lenition (where a consonant is produced with reduced stricture; e.g. nasal lenition in /nd#C/ contexts) and hyperarticulation (e.g. avoiding the weak forms of words such as "her" and "to"; preserving all the consonants across the word boundary in "next to"). Electropalatographic evidence also confirmed segmental misarticulations and articulatory undershoots, some of which were observed in the children's production of single words. The author highlights the relationship between changes made at the segmental level in an utterance and the prosody of that utterance and notes that some of the 'abnormal' phenomena observed may be the result of abnormal prosodic behaviour (e.g. unusual rhythmic patterns). She suggests that children with speech impairments may forfeit articulatory accuracy for the sake of syntagmatic fluency in order to facilitate conversational interaction. In the most recent published study of its kind, Klein and Liu-Shea (2009) add to the body of evidence on atypical connected speech with another small-scale study, focusing on the occurrence of word-boundary patterns previously reported in the connected speech of adults and typically-developing children. The most commonly occurring simplification pattern in their sample was the deletion of a coda consonant within a consonant sequence across a word boundary (in, for example, "lost Bertie"). The authors note that word-final consonants are vulnerable to deletion or change in single word production and that therefore it is not surprising that they are particularly susceptible to deletion in the context of other consonants in connected speech.

Theoretical approaches to between-word processes

Some authors have attempted to provide theoretical interpretation of the patterns observed in the developmental literature. For example, Newton and Wells (2002) draw on the principles of Articulatory Phonology (Browman and Goldstein, 1992) to account for the idiosyncratic patterns they observed in a typically-developing child, suggesting that these are imperfect attempts at close juncture. They attribute this to the combination of the child's imprecise articulation of individual

gestures and imprecise overlap of these gestures in the relatively new context of connected speech. A similar account could be made for the frequency of coda consonant deletion found by Klein and Liu-Shea (2009). Here, the combination of articulatory gestures required in the target and their relative timing provides a challenge which is not encountered in the production of isolated words, and proves particularly problematic for these children. Differences between these studies in what appears to constitute children's default realisation of process contexts (i.e. open juncture versus close juncture) may be related to differences between children in terms of learning style (holistic versus analytic) or to the status of the utterances in question: Howard, Wells and Local (2008) suggest between-word processes may be produced initially in formulaic utterances and subsequently extended to newer word combinations. These interpretations are compatible with a usage-based approach to phonology. Indeed, in concluding their overview of work to date on connected speech Howard and colleagues (2008) propose that a usage-based model may also be particularly useful when applied to connected speech, not least as such a model might provide insight into the relationship between phonology and morpho-syntax. While there has been some success in identifying morpho-syntactic contexts where a high degree of phonological cohesion between words occurs (see, for example, Kaisse, 1985), no single syntactic factor has been identified which accounts for the range of phenomena observed. A usage-based approach, in contrast, would account for connected speech processes with reference to the way language is used and, specifically, would propose that strings of words that occur with high frequency are more likely to involve the occurrence of processes (Bybee, 2001).

One of the most recent theoretical approaches to phonology is the usage-based model proposed by Joan Bybee (2001), elsewhere termed Cognitive Phonology (e.g. Ball, 2003), and related to functional or usage-based linguistic models which emphasise the importance of language use in shaping elements of language structure. In contrast to generative accounts, Cognitive Phonology proposes that the mental representations of individual items (tokens) are phonetically fully specified; the framework is therefore most compatible with a gestural model of representation such

as Articulatory Phonology (Browman and Goldstein, 1992), where representation consists of a gestural score which specifies the magnitude and temporal duration and coordination of articulatory gestures. Associations between tokens are formed on the basis of phonetic similarity and patterns of use, and categories emerge from these relationships so that they provide the basis for phonological structure. Cognitive Phonology has been shown to have potential as a framework for the description of disordered speech, as demonstrated in case studies with an adult with progressive speech degeneration (Ball, Code, Tree, Dawe and Kay, 2004) and with a child with unintelligible speech (Ball, 2003). Fuller details on how Cognitive Phonology might be applied to clinical data are given in Sosa and Bybee (2008), but importantly for the purposes of this study, Bybee (2001) suggests that all phonological processes (including those observed between words) are accounted for by temporal and/or substantive reduction of the gestures involved. This gestural account is consistent with the notion in the usage-based approach that phonological knowledge – like all grammatical knowledge – is procedural knowledge rather than an abstract psychological system and is therefore subject to the same factors that affect other motor skills. Bybee (2001) also claims a practical advantage to the gestural account of phonological processes in that it provides a more insightful and coherent description than a traditional analysis based on segments and features. The focus on actual articulatory movements allows understanding of the mechanisms that underlie processes and therefore processes described differently in terms of segments can be seen to involve similar gestural patterns (see, for example, Studdert-Kennedy & Goodell (1992)).

The study reported here aims to provide an additional contribution to the body of knowledge on the connected speech of children with speech difficulties, and specifically to investigate whether all the between-word phenomena produced by the children included can be accounted for by lenition, as suggested by Cognitive Phonology.

Method

Participants

The participants for this study were three boys aged between 11;8 and 12;10, all pupils at a residential school for children with speech and language difficulties in the South East of England. The children were all monolingual English speakers. All three were undergoing speech therapy intervention (using electropalatography) at the time of the study for speech sound difficulties which affected their intelligibility. The children are described in summary in table 1, and can be seen to present with a variety of impairments which impact variably on the intelligibility of both their production of single words and connected speech.

Table 1. Description of study participants[1]

Child	Age	Brief description of articulatory characteristics
Eric	11;8	Verbal dyspraxia and concomitant reduction in speech intelligibility. Imprecise articulation of palato-alveolar consonants. Execution of sequences of sounds deteriorates as the length and complexity of the sequence increases.
Jack	12;2	Severe oro-motor difficulties. Particular problems with tongue-tip control and tip versus back of tongue articulation. Observed to use accessory movements of the lower lip and jaw.
Patrick	12;10	Motor problems in tongue control which affect his production of certain speech sounds, particularly sibilants.

Materials

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[1] In order to preserve anonymity of participants, pseudonyms are used.

The task used in this study consisted of the assimilation and elision items from the sentence repetition task devised by Newton (1999). The use of tailored picture description tasks such as those used in previous published studies in this area (e.g. Howard, 2004) constitutes arguably a more ecologically valid means of eliciting connected speech, as does the collection of a spontaneous sample of conversation. However, sentence repetition was selected as a means of eliciting data in order to ensure that sufficient evidence was gathered about different between-word processes. In this sentence repetition task, two-word environments for potential assimilation or elision are included in each sentence. Two sentences were created for each type of environment, for example, /n#g/, where /n/ might be realised as /ŋ/ as a result of velar assimilation (e.g. "Ja<u>ne g</u>ave me an ice-cream"), and /st#C/ where word-final /t/ might be elided (e.g. "You mu<u>st cl</u>ean your teeth"). The sentences are no longer than seven words each and they are constructed so that the process site never carries the tonic syllable (as such stress may result in the speaker producing an open juncture). The task is described in full in Stackhouse, Vance, Pascoe and Wells (2007).

Simultaneous audio and electropalatographic (EPG) recordings were made of each participant. Each session was audiotaped onto Digital Audio Tape (DAT) using a Sony ECM-909 microphone and Sony TCD-D10II portable DAT recorder. EPG data were collected using the Reading EPG3 system (Hardcastle and Gibbon, 1997), in which the data display function enables the researcher to view the dynamically-changing EPG frames produced during an utterance.

One important criterion for inclusion in the study was that each child already had his own EPG artificial palate and was experienced in using it (Hardcastle, Gibbon and Jones, 1991) so that, in the view of the children's speech and language therapist, speech was not noticeably affected when the palate was being worn. It was therefore reasonable to assume that the speech samples collected here were representative of spontaneous speech production as far as possible given the context.

Data analysis

Audio recordings of the sentences produced formed the basis for perceptual analysis of the data and all of the assimilation and elision sites in the sentences were transcribed with the International Phonetic Alphabet (IPA) and its extensions. EPG data were used to observe lingua-palatal contact patterns in the phonetic environments of interest, thus providing additional information on the participants' productions which was especially useful in instances where the phenomena were difficult to identify by perceptual analysis alone. Dynamic EPG patterns are provided with the results of the study to illustrate some of the between-word processes produced by participants.

Results

The sentence repetition test provided 30 and 27 potential sites for assimilation and elision respectively; not all of the relevant word combinations were produced by the participants in their repetitions of the sentences presented. Note particularly that because of his problems with tip versus back of tongue articulation, several velar assimilation contexts were not realised by Jack, as target onset velar consonants were replaced by alveolar consonants. Analysis of the data revealed instances of word boundary behaviours reported in adult speech: elision and assimilation as well as open juncture and partial assimilation (Kerswill, 1985). All but the latter have also been reported in the connected speech of much younger typically-developing children. Other behaviours observed had not been included in previous descriptions of 'normal' connected speech, and therefore might be described as atypical. Some of these patterns are similar to those that have been reported elsewhere in the output of children with speech difficulties (e.g. Howard, 2004). There was also some variation both between and within speakers with respect to the strategies used on encountering word boundaries. Findings are described in more detail below, grouped by type of behaviour observed.

Assimilation

Detailed analysis of environments for assimilation of word-final alveolar consonants (/t, d, n/)

reveals that all three speakers produced instances of bilabial and velar assimilations (as common in

many varieties of British English, word-final /t/ was usually realised as [ʔ]; see Wells, 1986). An

example of this is Eric's production of the word combination "cloud covered": perceptual analysis

suggested velar assimilation had occurred resulting in the production [klʲaʊgkʰʌdədʲ], an analysis

which is confirmed by examination of the EPG patterns at the word boundary shown in figure 1.

These show contact in the alveolar region (frames 60-70) for the [lʲ] of "cloud" but no contact at the

end of that word as would be expected in Eric's production of [d]. Velar closure can be observed

(frames 109-113), indicating that assimilation has taken place. This can be contrasted with Eric's

open juncture realisation of "red gates" ([ʊedgeɪts]; also given in figure 1) which shows complete

closure for the voiced alveolar plosive produced in coda position (frames 45-49). All three

participants produce instances of open juncture, though this is by far the minority realization,

accounting for a total of 4/50 bilabial and 3/29 velar assimilation environments across the speakers.
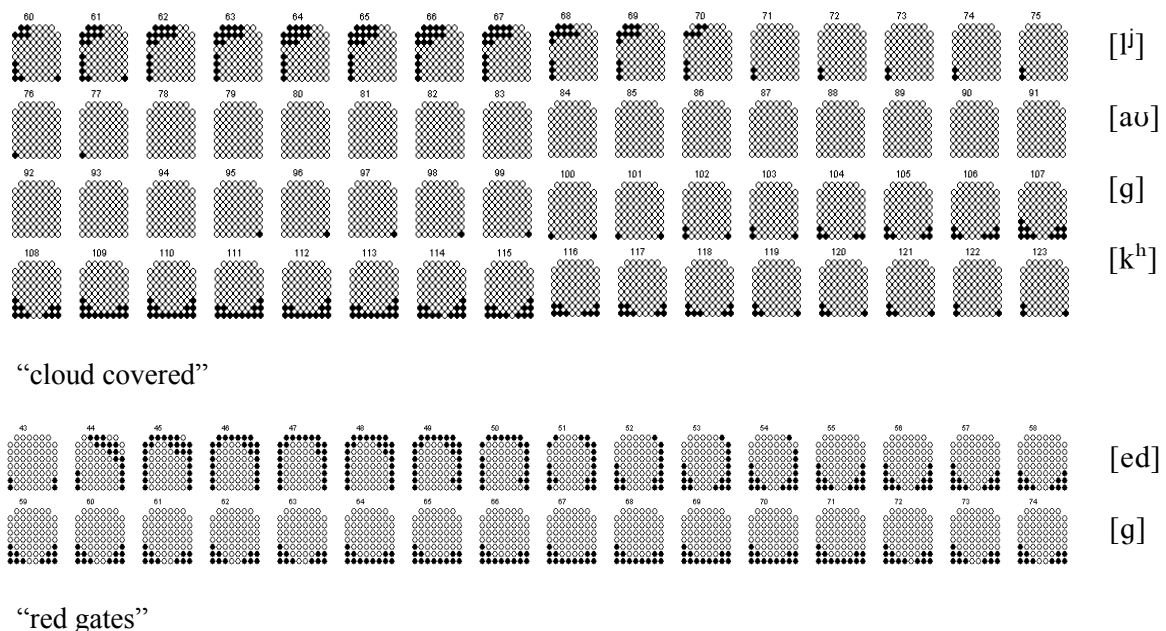

Figure 1. Linguapalatal contact patterns for Eric's realisation of "cloud covered" and

"red gates"

Retracted assimilation

In addition to straightforward assimilation as described above, ten of the 20 alveolar-velar

assimilations produced by the participants appeared, in perceptual analysis, to involve a retracted

tongue-body articulation for the velar plosive. This was confirmed by reference to the linguapalatal

contact patterns shown in the EPG data. An example of this can be observed in the EPG frames for

part of Patrick's production of the string "cloud covered": [klaʊg̚k̟ʰədəd] where the closure is

from frames 182-197, compared with the velar closure in frames 113-116 of "red gates": [ʋegeɪts]

(figure 2). Consideration of the phonetic contexts involved suggests that the occurrence of this

retracted velar in assimilations is not related either to the coda or onset consonants or to the quality

of the preceding vowel and that these productions simply reflect variation in the speakers'

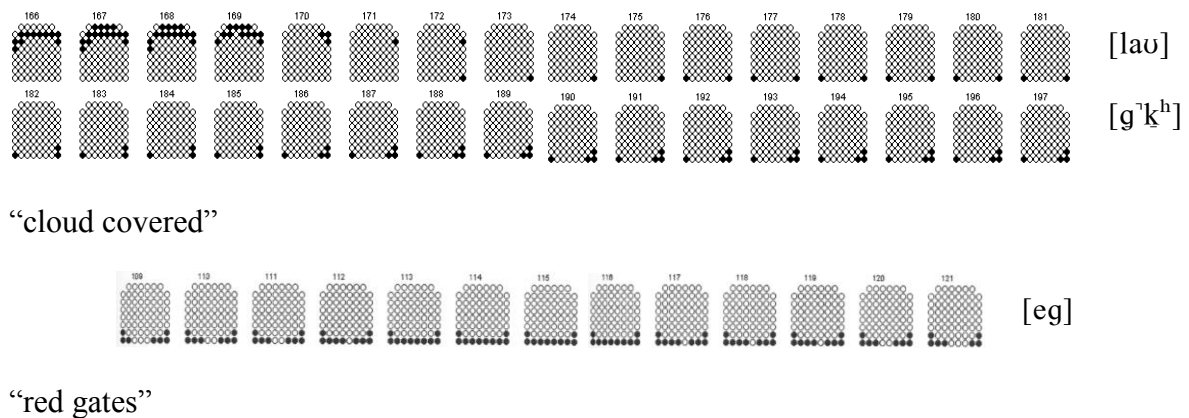production of velars at least in the context of connected speech.

"cloud covered"

"red gates"

Figure 2. Linguapalatal contact patterns for Patrick's realisation of "cloud covered" and

"red gates"

Partial assimilation

A total of 16 of the /d/ and /n/ bilabial assimilation environments produced by Patrick, Eric and Jack

were originally transcribed as being open juncture realisations. However, in nine of these cases,

examination of the linguapalatal contact patterns revealed that the coda consonant was not produced

with a full alveolar closure. These productions seem to match the phenomenon partial assimilation observed in adult connected speech and which was first described by Kerswill (1985) as involving more lateral and/or alveolar contact than in non-assimilatory environments. Figure 3 shows an example from the data in this study. Note the gesture at the word boundary (frames 104-117) in Jack's production of "read my" ([ʋidmaɪ]), perceived as [d]. There is no closure in the alveolar region but the contact at the lateral borders of the palate suggests evidence of a gesture of the tongue body. Compare this with the full alveolar closure (frames 115-139) for [d] in his open juncture version of "mud made". Partial assimilation was not observed in alveolar-velar environments.
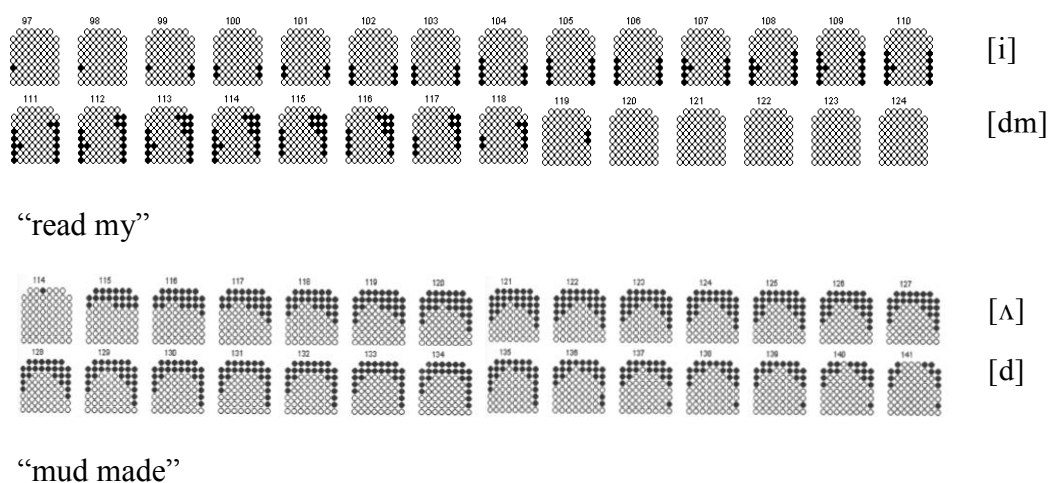

"read my"

"mud made"

Figure 3. Linguapalatal contact patterns for Jack's realisation of "read my" and "mud made"

Lenition

One instance of a lenition occurring over a word boundary was observed in the output of Eric, in the utterance "had bacon". Instead of an assimilation or open juncture, Eric produced a single consonant at the word boundary: a voiced bilabial fricative, rendering the utterance thus: [hæβeɪkʰən]. Inspection of the patterns of linguapalatal contact provided by the EPG shows no evidence of any alveolar contact at the juncture. Atypical realizations such as this appear to be

limited to assimilation environments. The sentences in the repetition task provide some scope for observing the participants' realizations of target word-final alveolar consonants in pre-pausal and prevocalic positions. Examination of these environments indicated that all participants routinely used complete closures for [n] and [d] for targets /n/ and /d/, and [t] and [ʔ] for target word-final /t/ (see, for example, Eric's realisation of pre-pausal /d/ in the utterance "They argued all day" in figure 4).
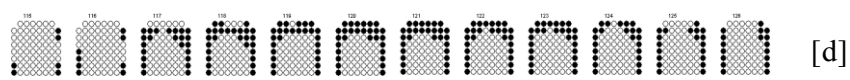
 [d]

Figure 4. Linguapalatal contact patterns for Eric's realisation of pre-vocalic word-final /d/ in the utterance "They argued all day"

Analysis concerning the potential relationships between type of coda and onset consonants and type of realisation in assimilation environments revealed only one clear pattern: potential /n/ assimilation sites were almost always realised with assimilation (13/16 bilabial and 8/9 velar assimilation environments across all three speakers).

Elision

Data collected using the sentence repetition task indicate that all three speakers produced complex codas pre-pausally and prevocalically, in non-elision environments (see, for example, Patrick's production of target /ʃt/ in the sentence "the yellow aeroplane crashed" in figure 5 below). Therefore the atypical patterns described below appear to be limited to elision environments, though it should be noted that not all cluster types are accounted for in these positions in the task.

Instances of elision of word-final alveolar plosives in consonant sequences crossing the word boundary were observed in the output of all three participants. For example, "left leg": [lefleg]

(Eric); "loved to": [lʌvt⁼ə] (Jack); "understand the": [ʌndəstæ̃nðə] (Patrick). In some elision

contexts, where /t/ or /d/ was elided, there was also evidence of lenition of the remaining coda

consonant, always a fricative. For example, the voiceless postalveolar fricative in the word

combination "washed my" (as in "I washed my hair last night") was also audibly weakened; an

analysis confirmed by examination of the relevant EPG frames (129-136 in figure 5). This lenition

did not occur in single word production or pre-pausally (see figure 5 for the frame of maximal

contact for [ʃ] in Patrick's production of "wash" in isolation and for linguapalatal contact patterns

for utterance-final "crashed").
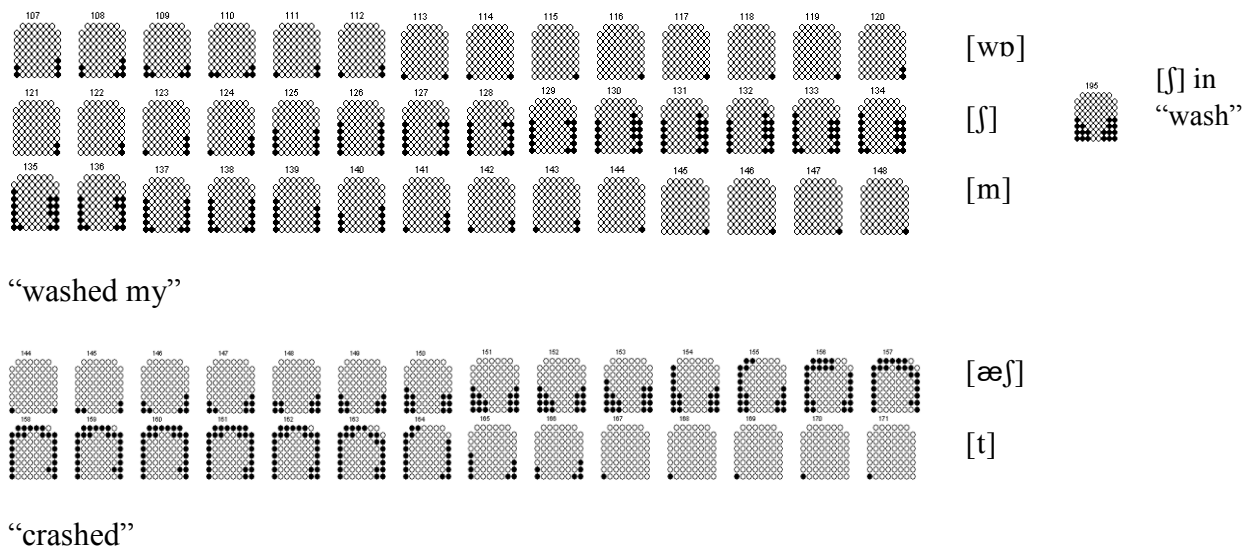

"washed my"

"crashed"

Figure 5. Linguapalatal contact patterns for Patrick's realisation of "washed my" and utterance-final "crashed", with the frame of maximal contact for target /ʃ/ in "wash" in isolation

In contrast to assimilation environments, where all speakers produced at least some instances of

open juncture, in elision environments only Patrick produced more than one instance of open

juncture (accounting for 8/26 elision environments); for example, "wrapped the": [ʋæptðə]. Eric

produced only one open juncture ("sneezed very": [sn̥izdveʋi]), and Jack none. Other phenomena

were observed in elision environments elicited by the sentence repetition test: glottal replacement,

hyperelision and lenition.

Glottal replacement and hyperelision

The data show that all three participants in the study produce phenomena at word boundaries which affect the whole word-final consonant cluster in the elision environment either by deleting or replacing it. The speakers show a pattern of production of some of the word boundaries where the entire coda (i.e. both consonants in the word-final cluster) is replaced by a glottal stop. The following onset consonant(s) is produced. For example, "judged the": [dʒʌʔdə] (Eric); "last train": [laʔtʃeɪn] (Jack); "picked some": [pʰɪʔsʌm] (Patrick). The linguapalatal contact patterns for the word boundary in Jack's production of "watched television" are given in figure 6 and show a single alveolar closure (in frames 123-136) which corresponds to the onset of the first syllable of "television", but no contact for the coda of "watched". Examination of phonetic contexts showed no relationship between the voicing of the coda cluster (e.g. voiceless "left leg" or voiced "understand the") and the occurrence of glottal replacement. The stimuli in the sentence repetition test include a range of word-final clusters which include as their first element plosives (e.g. kt#C as in "picked some"), fricatives/affricates (e.g. st#C as in "must clean"), nasals (e.g. nd#C as in "understand the") and approximants (e.g. ld#C as in "old man"). The only clear relationship that was observed when this was taken into account was that glottal replacement never occurred where the first consonant in the cluster was either a nasal or an approximant.
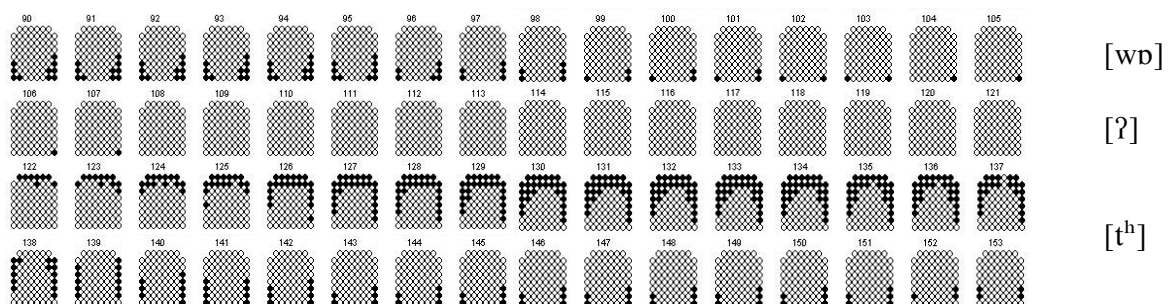

Figure 6. Linguapalatal contact patterns for Jack's realisation of "watched television"

Six of all the elision sites produced by Eric and Jack were realised with hyperelision (see Wells & Stackhouse, 1997) where the entire coda was elided (and yet in the few non-elision environments included in the sentence list, Eric and Jack realised such codas with both consonants). This can be

seen in, for example, "dragged the" produced by Eric as [dʊædə] and "hugged me" produced by Jack as [hʌmi]. Hyperelision only occurred in instances where the /t/ or /d/ in the target coda was preceded by a plosive. Patrick did not produce any examples of hyperelision.

Lenition

Jack and Eric also produced word combinations where there was lenition of the consonant sequence across the word boundary. A full list of word combinations realised in this way is shown in table 2. As with Eric's production of "had bacon" described above, inspection of the relevant EPG frames for "robbed the", "hugged me" and "washed my" showed no evidence of any alveolar contact at the word juncture. Interpretation of lenition appears to be appropriate: fricatives produced are related by the place of articulation to the target consonants at the juncture. The fricatives in "hugged me" and "washed my" appear to have assimilated in place to the following onset consonant. Eric's realisation of the pre-pausal coda /ʃt/ in "crashed" is shown in figure 7 for comparison. Note that though the post-alveolar fricative is not realised accurately (in line with Eric's production of this type of phoneme at single-word level; see table 1), both coda consonants are produced in this context.

Table 2. Instances of word boundary lenition produced by Eric and Jack

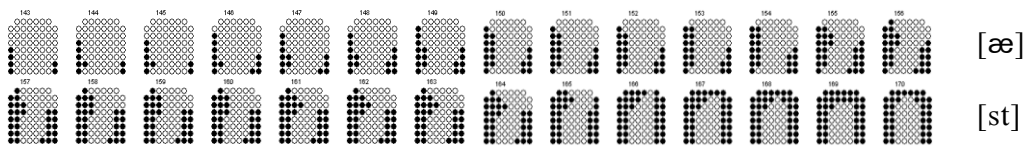|	Target	Realisation
Eric	"robbed the"	[ʊɒβə]
	"hugged me"	[hʌβmi]
	"washed my"	[wɒɸmaɪ]
	"watched television"	[wɒsheəvɪzən]
Jack	"can't play"	[kʰɑnʌeɪ]

[æ]

[st]

Figure 7. Linguapalatal contact patterns for Eric's realisation of

"crashed"

Figure 8 provides an overview of the prevalence of adult-like between-word processes (including

retracted and partial assimilation) at the relevant junctures across the speakers. The figure highlights

that while all speakers produce some examples of adult-like realisations, there is variation between

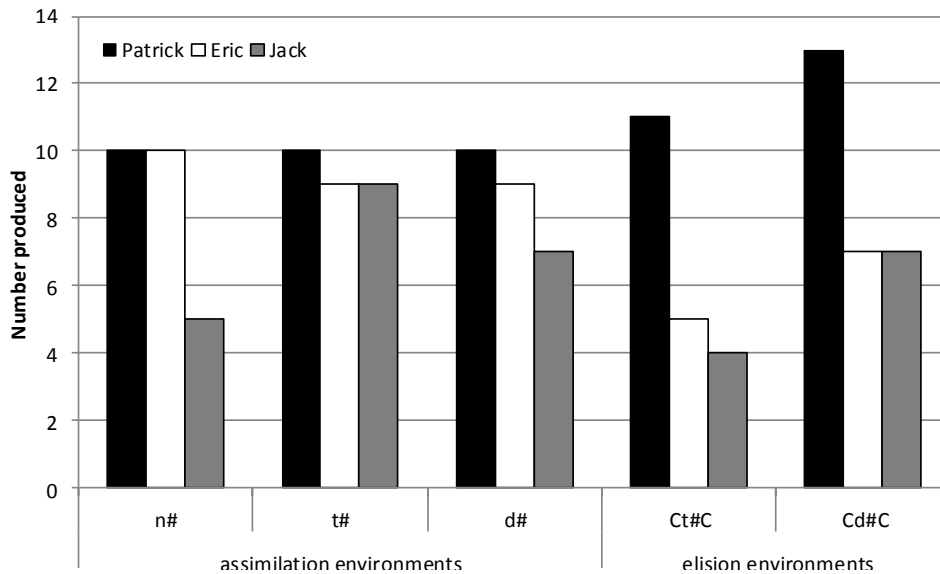them in the quantity of these, as well as qualitative differences (as shown in the EPG data above).

Figure 8. Distribution of adult-like juncture realisations across elision environments for

individual speakers (maximum number of assimilation environments=10; maximum

number of elision environments, Ct#C=14; Cd#C=13. Note that, because of difficulties

with velar consonants, Jack does not produce the maximum number of assimilation

environments).

Discussion and Conclusions

The participants in this study were all described as having problems which were particularly evident in connected speech contexts. The data collected by means of the sentence repetition test provided a rich source of information about the word boundary behaviours of the speakers. Though each sentence was presented to them with the relevant assimilation or elision produced, they exhibited a range of patterns of realisation. All speakers produced adult-like assimilation (including retracted and partial assimilation) and elision (including that involving lenition). Open juncture also occurred but was less frequent, and particularly scarce in elision environments. However, it is also clear from the analyses carried out that the speech difficulties of the speakers did appear to have an effect on their production of some between-word process environments. Though assimilation environments seem to present fewer problems to the children, the elision environments included in the task were clearly more challenging for all three. In the latter type of environment some between-word phenomena were observed that have been reported in the developmental literature. The realisation of the coda consonant cluster in elision environments as [ʔ] was reported by Newton and Wells (2002) in the connected speech of two-year-old CW, while he was in the process of mastering these types of juncture. Hyperelision has been reported previously in research on children with speech difficulties (Howard, 2004; Wells and Stackhouse, 1997). Lenition of the kind described here, which results in articulatory weakening of the whole of the juncture, has not been described in previously published work (though see Howard (2007) for other examples of lenition in connected speech). The usage-based approach to phonology provided by Cognitive Phonology may provide insight into the range of both typical and atypical between-word behaviours observed. In this account Bybee (2001) proposes that all phonological processes are accounted for by temporal and/or substantive reduction to the gestures involved, i.e. lenition.

All the between-word patterns observed in this study can arguably be viewed as lenition. For example, accounts in connected speech phonology in German (Kohler, 1990) and Russian (Barry, 1992) have characterised a range of processes (including assimilation and elision) as articulatory

reductions (see also Shockey, 2003). Articulatory Phonology (Browman & Goldstein, 1992) proposes that connected speech patterns, including between-word processes of assimilation and elision, are the result of increased temporal overlap when speech is produced at a faster rate. For example, in the case of apparent elision in the word combination "last bus" (transcribed in fast and 'fluent' speech as [lɑsbʌs]) the articulatory gestures are subject to temporal reduction and overlap. The result is that though the alveolar constriction gesture for the /t/ heard in the careful version ([lɑstbʌs]) is still present, it is completely overlapped (hence 'hidden' to the listener) by the following bilabial gesture. Instances of perceived assimilation can be described similarly with reference to gestures being 'hidden' as a result of temporal reduction. There is also experimental evidence that in these environments the relevant articulatory gestures are subject to reduction in magnitude (Jun, 1996; Jaeger and Hoole, 2007), which may make them more susceptible to being 'hidden' by another gesture. Instances of lenition of the whole juncture (e.g. Eric's production of "had bacon": [hæβeɪkʰən]) may also be viewed as involving both reduction in magnitude (in this case reducing the stricture of the bilabial gesture) and increased overlap of gestures. In instances such as this one, it is possible that Eric has produced a tongue tip gesture corresponding to the alveolar closure but that it is also reduced (resulting in no palate contact) and that the gestures overlap to such an extent that this gesture is hidden by the bilabial gesture. Of course, in the absence of data which shows the position of tongue when not in contact with the palate this remains speculative.

In addition to full adult-like assimilation, the partial and retracted assimilation described above have also been described as involving a substantive reduction of the articulatory gestures involved. It has been suggested that instances of partial assimilation in normal adult speech involve a reduced coronal gesture which results in the lateral contact with the hard palate observed here (Ellis and Hardcastle, 2002). The retracted production of velar plosives has been observed in connected speech in adults in both single syllable production (Liker and Gibbon, 2008) and connected speech (Hardcastle, 1994), and in other children with speech difficulties (Howard, 2004) and is likely to

reflect inter- and intra-speaker variation. Despite gaps in tongue–palate contact in the velar region, it is possible that the tongue body raising gesture occurred but could not be measured by EPG alone. Liker and Gibbon (2008) suggest that closure does occur in these cases but in a location posterior to the area covered by the EPG electrodes. It is also possible, of course, that the incomplete closure observed in the linguapalatal contact patterns indicates a laxer articulation of the velar consonant. A combination of data collected using EPG and Electromagnetic Articulography (EMA) might shed light on whether the tongue body is raised in such productions (Ellis and Hardcastle, 2002).

In the case of glottal replacement, the coda is replaced by what has been described as a default production for young children (Bernhardt and Stoel-Gammon, 1994). This is the most minimal type of closure available to the speaker and, in commenting on this pattern in their study, Newton and Wells (2002) suggest ease of articulation may be the overriding aim of the child. Use of [ʔ] in place of the coda certainly results in a weakening of the overall gestural score of an utterance; a point made by Ball (2003) in his study of a child with unintelligible speech. For example, figure 9 shows possible gestural scores (according to the framework provided by Articulatory Phonology) for both adult-like elision in the utterance "stopped the" (where overlapping gestures result in the final stop /t/ being 'hidden') and Jack's production of this combination, where the coda is replaced with a glottal stop.

Both replacement with a glottal stop and the complete deletion of a consonant are described in the literature on lenition as the result of effort minimisation (termed debuccalisation and elision respectively; see Kirchner, 2004). When more than one consonant is elided, as is the case here, the resultant weakening of the gestural score of the utterance is perhaps the most extreme form of lenition in this context.
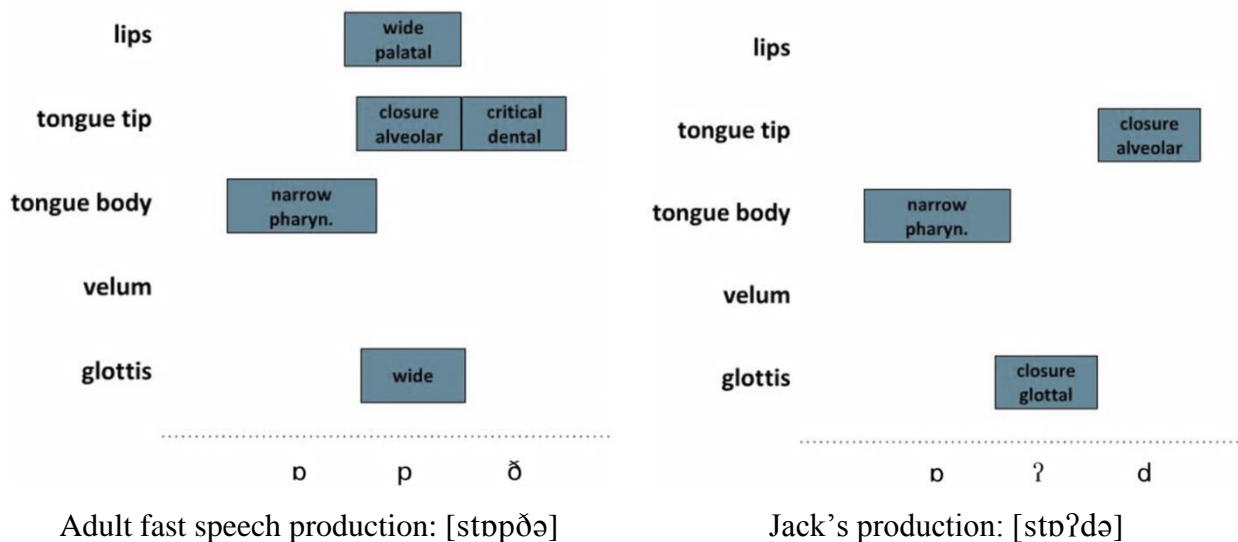
Adult fast speech production: [stɒpðə]   Jack's production: [stɒʔdə]

Figure 9. Gestural scores for the word boundary in "stopped the" in adult speech and Jack's production

The proposal that all the behaviours exhibited in this study may be thought of as lenition suggests that the abnormal patterns are extreme versions of the behaviours which are exhibited by adults and children without speech disorders (a conclusion which echoes that made by Howard, 2007), or what might be termed here 'hyperlenition'. This conclusion supports Bybee's (2001) assertion that all phonological processes are reductive in nature, and that a gestural description allows phenomena which appear disparate in a segmental account to be seen as involving similar underlying patterns, and suggests that the hyperlenitions might be seen as motor-based over-reductions. Thus a gestural account seems to provide a coherent description of all the behaviours produced by these three children with speech difficulties.

Newton and Wells (2002) comment that the typically-developing speaker in their study was faced with new articulatory challenges in the transition from single-word to multi-word utterances: gestural articulations and intergestural relationships needed to be mastered over word boundaries. The challenge for the children in this study, attempting to transfer gains made in the clinic in single-word environments, appears to be similar: they must master the amount of reduction (both temporal and substantive) which is appropriate in a given context. Therefore, in order to address connected speech intelligibility in these children, intervention might usefully include a focus on hyperlenition

at word boundaries. A note of caution is of course required here. A sentence repetition test as a means of collecting data, whilst providing a rich source of information, lacks the ecological validity of a sample of spontaneous speech, not least by providing a model of the processes. It was not possible in this study to collect a sample of spontaneous speech with which to make a useful comparison. However, it may be that in conversational speech, especially in longer utterances, the speakers produce different patterns at word junctures, more of those reported here, or a combination. Other limitations of this study include the small numbers of participants included and tokens generated, though both allow for the level of qualitative analysis required in this kind of investigation. There is also a lack of comparable EPG data from typically-developing children. This is an area that would benefit greatly from further research, which has however been constrained by the ethical issue of subjecting children with typical development to the intrusive procedures of EPG. However many of the behaviours observed here have been reported previously either in perceptual studies (e.g. Newton and Wells, 2002) or in other EPG studies of disordered speech (e.g. Howard, 2004).

More research in this area is warranted, but Cognitive Phonology seems to have potential for providing a valuable framework for the description of between-word processes in disordered speech. In addition to the fully-specified nature of the representation of words, the role of frequency of items is central to the model. As mentioned above, Bybee (2001) claims that frequency of use provides a superior explanation for instances of connected speech processes than morpho-syntactic factors. Forms with higher frequency are most susceptible to changes caused by articulatory forces than low frequency items. Low frequency items change by analogy with the high frequency items with which they are associated. In the case of connected speech, this would mean that word combinations that occur more frequently would be more susceptible to the kinds of articulatory reductions described above (Bybee, 2002), a suggestion which seems to be borne out by recent research (Mücke, Grice and Kirst, 2008; Jaeger and Hoole, 2007). It has not been possible, however, to ascertain whether the frequency – or the morpho-syntactic characteristics – of the

relevant word combinations affected their production by the children included in this study. The sentences in the repetition task do not allow scope for such an exploration: the combinations included do not vary systematically in their frequency and, while it was possible to examine syntactic factors, no observable patterns emerged. It has been suggested previously that the realisation of junctures (i.e. close versus open) may be related to how formulaic or productive an utterance is (Howard et al., 2008), and research on the role of frequency in children's productions of between-word processes would also be valuable, in both normal and atypical speech. Sosa and Bybee (2008) suggest that frequency could also be exploited in intervention. In the case of difficulties with between-word processes this could mean that treatment might focus on high frequency combinations (e.g. "last week") with an expectation that changes might spread by analogy to other, less frequent, items of the same type (e.g. with a similar coda).

The findings from this study provide support for the assertion made by previous studies (e.g. Klein & Liu-Shea, 2009; Howard, 2004) that connected speech is an appropriate context for the assessment of a child's phonology, and that the analysis of between-word behaviours is necessary in a comprehensive phonological assessment. The findings also suggest that even at the single-word level speech and language therapists may need to reconsider what is accepted as the "correct" production of a word. Since the usual context for the production of a word is in connected speech rather than in isolation, the citation form of a word may be an unrealistic – and arguably unnecessary – expectation, and it may be useful to take into account the effects of lenition in connected speech. If only the citation form is accepted and reinforced then that may itself, in some cases, have a carry-over effect to connected speech, leading the speaker to hyperarticulation rather than hyperlenition which may also affect intelligibility.

In contrast to the wealth of knowledge that exists on the characteristics of connected speech in adults, there is a shortage of similar information on connected speech in children with and without speech difficulties. This is a slowly growing field, but there is a need for more research here; on the kinds of behaviours that can be observed, the relationship between phonological patterns and other

linguistic factors, what constitutes an 'abnormal' pattern and how such patterns might be addressed in intervention. The research outlined here provides, it is hoped, a further step towards providing tools with which clinicians can enable children with speech difficulties to communicate more effectively through the medium of connected speech.

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