CONSONANT CLUSTERS IN DISORDERED L1 ACQUISITION: A LONGITUDINAL ACOUSTIC STUDY

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ABSTRACT

We report a longitudinal instrumental study of the acquisition of English word-initial consonant clusters by children with phonological disorders. Interim results pertaining to /st/ are given for four children with phonological disorders and two normally-developing children. Duration measures show that before the successful acquisition of /st/, the stop closure is similar to that of the independent stops, but after, the stop closure duration for /st/ is shorter than for /t/ or /d/.

INTRODUCTION

This longitudinal instrumental acoustic study is motivated by the relative paucity of detailed quantitative information about the phonetic strategies used in the acquisition of consonant clusters by speech-disordered children. Most analyses of cluster acquisition in normal and disordered speech are transcription-based.

It is essential to explore *both* these aspects of the acquisition of phonological contrast. The developmental maturation of a speaker's ability to render adult-like phonetic encodings of a contrast, and the perceptual discontinuity at which the speech community (or phonetician) judges a contrast to be successfully acquired are separate processes.

Macken and Barton [1], for example, show that in the acquisition of the stop-voicing contrast, differences in VOT which are imperceptible to adult listeners are produced by some children. Such 'covert contrast' has also been demonstrated in [2,3,4]. The children then proceed to the production of an acceptable contrast, though initially it is not adult-like.

Applying these findings to consonant cluster acquisition, we might expect a stage of covert contrast in which the phonological contrast between cluster and singleton is expressed phonetically in a manner which can be detected instrumentally but is effectively imperceptible. Weismer [4] discusses a case in which, for example, [t] realising reduced /st/ has greater closure duration than [t] realising /t/. We would also expect to observe the gradual approximation of the child to the adult model.

The detection of covert contrast and the discovery of the ways in which children approach phonetically mature expressions of contrast would have important clinical implications [2].

The results presented here are taken from a larger study which will be able to explore the issues raised in greater depth.

METHODOLOGY

The four experimental subjects DB (4;1), SR (5;7), KG (4;1) and IB (4;3) were from the Edinburgh area, speaking varieties of Scottish English. The subjects were the age indicated at the start of the study. All exhibited functional cluster reduction of /st/ to [d] or [t], although subject KG had resolved already by the first session. All were undergoing courses of speech and language therapy having been diagnosed as phonologically disordered. In addition, we refer to two normally-developing children, RM (4;0) and JS (3;3).

The children uttered nine target words (forming minimal triples, Table 1) in a naturalistic manner as part of a series of ten picture-naming games, each game comprising three dissimilar targets from a larger dataset. No minimal pairs appeared in the same game. The carrier phrase was 'give me *x* (please)'.

Table 1. Coronal targets.

sty	tie	dye
steer	tear	deer
store	tore	door

Multiple tokens of each target were elicited within a game in random order, except for IB, who produced several tokens of one target together before moving on to the next. The recordings took place in a sound-treated booth, and used a Sony DAT DTC-690 tape deck, Alice microphone amplifier MIC-AMP-PAC-2 and a Sony ECM-77 lavalier microphone placed for optimum recording clarity.

Six tokens of each target were digitised at 40960Hz on a KAY CSL 4300. The waveforms were annotated to indicate the boundaries of significant acoustic events for durational analysis. Seven annotation points (t1-t7) were chosen (Table 2) and are illustrated in Figure 1. Often, annotation points were coincident.

Table 2. Annotation Point Definitions

t1	Start of breathy vowel offset at the end of carrier 'give me', if present.
t2	End of breathy vowel offset.
t3	Start of frication noise, if present.
t4	End of frication noise or beginning of stop closure, if present.
t5	Release of stop closure (burst).
t6	Onset of periodic phonation after burst.
t7	End of target word.

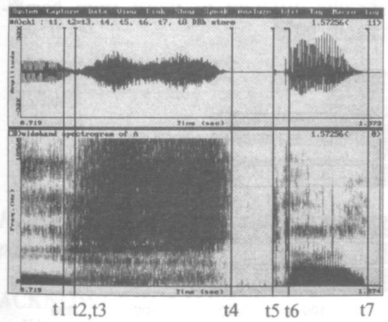

Figure 1. Annotated 'store' (DB).

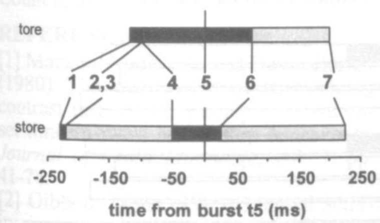

Figure 2. Key to graphs. 1-2 = carrier-final breathy vowel, 3-4 = [s], 4-5 = stop closure, 5-6 = VOT, 6-7 = target rime.

RESULTS

Mean durations of t1-t7 for each onset type are graphed in Figures 3-7 (*n*=18, 17 or 16 unless otherwise indicated). Figure 2, in conjunction with Figure 1, exemplifies the key to the graphs.

Figures 3a, 4a, 5a, 6a refer to each subject's first session, while Figures 3b, 4b, 5b, 6b refer to the second session, approximately four months later. In the text, DBa, for example, refers to DB's first session (Figure 5a).

DISCUSSION

In the cases with unreduced /st/ (Figures 5b, 6, 7), the mean stop closure duration (t4-t5) in [st] is less than in the independent stop phonemes /t/ and /d/. We might therefore have expected covert contrast to be signalled with a shortened closure in the stop realising reduced /st/. Alternatively, since unreduced [st] has greater duration as a whole than the closure phase of /t/ or /d/, then we might have expected, with Weismer [4], to find a *greater* stop closure in reduced /st/. In fact, in the sessions where subjects exhibit cluster reduction (Figures 3, 4, 5a), stop closure duration in reduced /st/ is similar to the independent stop phonemes.

The mean duration of [st] as a whole is greater than the singleton durations mainly because of the relatively long [s] (t3-t4). In DBb, where the cluster was only recently acquired, [s] was often extremely long, incorporating two or more separate energy peaks (Figure 1). KG's [s] sometimes exhibited near-complete cessation of frication medially.

Duration measures can hide the variability in the individual productions. In JS, the stop component of /st/ was typically spirantised, and effaced completely 50% of the time. (Nevertheless, most of these spirantised tokens contained bursts.) If the mean duration is calculated for just those closure durations which are not 0ms, her closure durations for /st/ are roughly commensurate with the independent stops. Such a revised mean would hide JS's typically weak stop closure, however, so all her tokens are used. This spirantisation could be due to her fast speaking rate or young age. A different type of variability was shown by SR, who typically reduced /st/ to [t]. In session 2, all six tokens of 'store' exhibited cluster reduction to [sː]. These strategies are graphed separately.

Voicing during the stop closure was open to great intersubject variability. Most closures were largely voiceless, but at the other extreme, IB's were often fully voiced during the stop closure, followed by voiceless aspiration (i.e. [d] for /d/ and /st/, [dʰ] for /t/).

The rime duration (t6-t7) is useful in relativising the duration of closure or VOT to that of the whole word. Rime duration is influenced heavily by speaking rate and phrasal position. The carrier phrase incorporated a final 'please', but this was only employed by JS, IB, DBb, and KGb. In addition, individual differences are a strong determinant of this measure.

Carrier-final breathy vowel offset (t1-t2) was generally greater for /t/ than /d/, and was a very consistent factor for KG. Given the immature nature of [s] in the children's /st/, a high value for this duration is to be expected for [st]. A similar increase might have been expected to appear in *reduced* /st/, as a covert contrast with /d/. Slowed closure or devoicing of [ɪ] might have boosted this duration, but no consistent increase was observed. The audible character of t1-t2 varied from [h] to [i̥] to [ç].

VOT (t5-t6) was similar for /d/ and reduced /st/. VOT was calculated from the release of closure to the detectable presence of periodic phonation. (F2 was detectable a cycle or two after t6.) An accurate measure of IB's VOT in /d/ and /st/ is made difficult by noise immediately after the burst obscuring any low amplitude phonation that might be present. (For IB's /t/, however, there is a clear long lag before voice onset.) In general, long-lag VOT for /t/ was often in excess of our Scottish English estimate of 55-75ms. The short lag values may also be rather high. This suggests a maturation model for the subjects with over-long VOT in the early stages, approximating later to adult values.

Given the excessive length of [s] in DBb, presumably the same pattern of hyper-duration followed by progressive approximation to the adult mean will be observed in his later maturation of /st/. As with all the measures, further sessions with these subjects will chart such development.

Finally, note that the use of different articulators, e.g. in [sp], might lead to results different to those from homorganic [st].

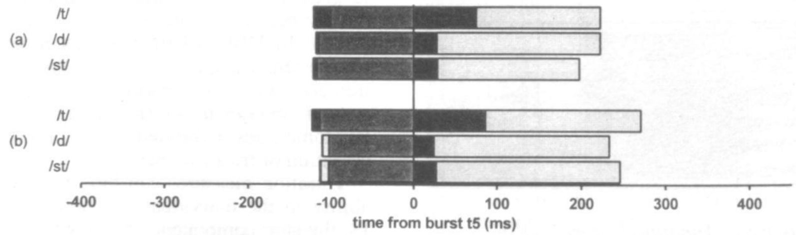

Figure 3. IB 4;3 (a) and 4;7 (b). Target phrase-medial, nonrandom order.

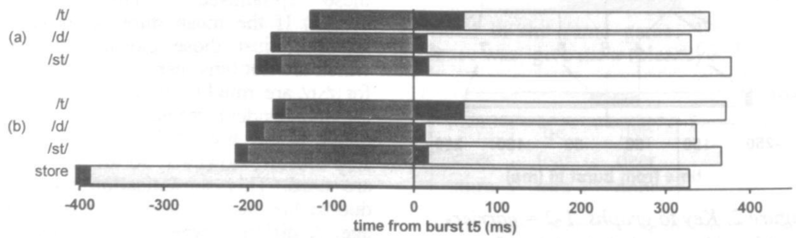

Figure 4. SR 5;7 (a) and 5;11 (n=12 for /st/) (b). Target phrase-final.

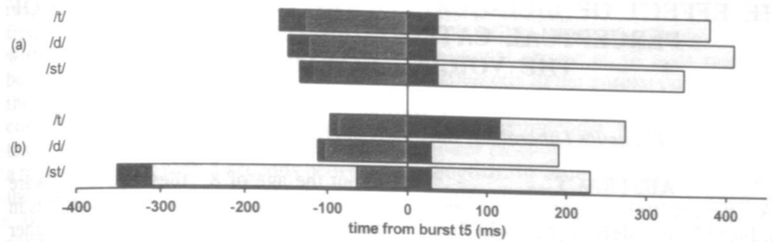

Figure 5. DB 4;1 phrase-final (a) and 4;5 phrase-medial (b).

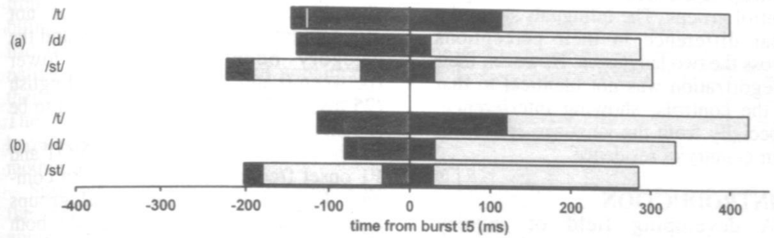

Figure 6. KG at 4;1 phrase-final (a) and 4;5 phrase-medial (b).

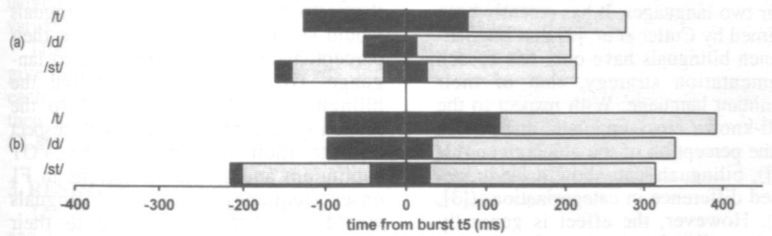

Figure 7. Control JS at 3;3 phrase-medial (n=8 for /t/) (a) and control RM at 4;0 phrase-final (b).

ACKNOWLEDGEMENTS

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