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From ‘tota’ to ‘sofa’: An intervention study of six children with phonological disorder

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Sammanfattning. Syftet med denna studie var att undersöka en allmänt vedertagen behandlingsmodell av fonologiska språkstörningsprocesser hos svenska förskolebarn. Sex barn mellan 4;1 och 5;7 år med liknande fonologisk språkstörning fick en individuellt anpassad intervention innehållande, i varierande omfattning, artikulatoriska, fonologiska och meta-fonologiska metoder. Målet för interventionen var att etablera frikativor. En single-subject multiple baseline design med /f/ och /s/ som målfonem (beroendevariabler) och velara klusiler och /r/ som kontrollfonem (kontrollvariabler) användes. Generaliseringsdata visade förbättrad produktion av de behandlade fonemen hos fem av barnen medan en flicka etablerade /f/ men inte /s/. Kontrollfonemen förblev oförändrade hos alla barn. Barnen behövde mellan 6 och 18 terapisessioner för att nå interventionsmålet. Individuellt anpassad intervention visade sig vara en effektiv metod för att förbättra talproduktionen hos de flesta av barnen med fonologisk språkstörning. Studien belyser vikten av att beakta heterogeniteten hos barn med fonologisk språkstörning.

Sökord: fonologisk språkstörning, individuellt anpassad intervention, intervention, single-subject design

Abstract. The purpose of this study was to investigate a commonly applied intervention model for treating phonological processes in Swedish pre-school children. Six children between 4;1 and 5;7 years old with similar developmental phonological disorder (PD) received an individually adjusted intervention including, to a varying extent, articulatory, phonological and meta-phonological approaches. The goal of intervention was to establish fricatives. A single-subject multiple-baseline design with /f/ and /s/ as target phonemes (dependent variables) and velar plosives and /r/ as control phonemes (control variables) was used. Generalization probe data showed improved production of the treated phonemes in five of the children while one girl established /f/ but not /s/. The control phonemes remained unchanged for all children. The children needed between 6 and 18 therapy sessions to reach the intervention goal. An individually adjusted intervention proved to be an effective method for improving speech production in most of the children with PD. The study highlights the importance of considering heterogeneity in children with PD.

Keywords: developmental phonological disorder, individually adjusted therapy, intervention, single-subject design

Developmental phonological disorders (PD) are a common problem in children, affecting approximately 10% of the pre-school and school-age population (Gierut, 2001; Eikeseth and Nesset, 2003). What is impaired in these children is the acquisition and organization of the phoneme system needed for speech, reading and spelling (Bowen and Cupples, 2004). Children with PD are often hard to understand because they speak with a simplified phonological pattern; this often results in impaired speech interaction. A qualitative analysis of phonological processes in children with PD shows three main types of speech-error patterns (Dodd and Bradford, 2000): (1) delayed development, with phonological processes typical of younger children (e.g. velar fronting); (2) consistently used atypical phonological processes (e.g. initial-consonant deletion); (3) inconsistently used phonological processes (e.g. the child will variously produce 'sun' as tun and hun. According to Nettelbladt and Salameh (2007), stopping, fronting and weakening/gliding are the most common consonant processes in Swedish children with PD. In addition, stopping and fronting are the processes most commonly occurring in combination.

The prognosis for normal speech intelligibility in children with PD is good, provided that effective intervention is made (Gierut, 1998). Law and co-workers (2009) show, in their meta-analysis of randomized controlled trials of speech and language interventions for children, that there is a positive effect of intervention for children with expressive phonological and expressive vocabulary difficulties. Phonological intervention is not only important for the development towards the use of correct speech sounds, but also necessary to prevent later problems in the process of reading and writing acquisition (Dodd and Gillon, 2001).

Before the 1960s, both articulatory and phonological disorders were seen as having a motor-speech origin, meaning that an articulatory intervention approach was practised. Linguistic theories of child language development that emerged after 1960 gave new insights into pronunciation problems in early childhood, entailing that intervention approaches in speech and language pathology were instead oriented towards phonology (Nettelbladt and Salameh, 2007). Research in recent decades based on psycho-linguistically oriented theories has identified auditory perceptual processing and auditory-memory span as another core problem area for children with PD and other language disorders (e.g. Stackhouse and Wells, 1993; Bishop, 1997).

What children with PD find difficult, to a varying extent, is decoding the speech signal, encoding and articulating speech, and storing the phonological information relating to a word in memory. The knowledge we have today of heterogeneity in the group of children with PD (e.g. Bird and Bishop, 1992; Bird et al., 1995; Adams et al., 2000) has implications for our opportunities to adjust intervention programmes to suit individual children. The importance of considering individual differences was highlighted by Baker and McLeod (2004) in their study, where two children had completely different intervention outcomes in terms of the number of therapy sessions needed to achieve the same pre-determined goal of intervention. One explanation discussed by the authors is better expressive language skills and ability to focus in the child with faster progress. The need to make individually appropriate adjustments not only at the beginning of the intervention but also over the course of it was obvious.

In a study of five children using an articulatory approach, the production of /s/ was trained and changes in the production of that phoneme and in other properties of the phonological system were observed after the start of treatment (Powell et al., 1999). Differences in learning strategies were apparent among the children. There was also a

difference between the children in their generalization of changes to other phonemes in the phonetic inventory.

In their comparative case study of therapy methods for three children with different types of PD, Dodd and Bradford (2000) suggest that for some children, a mix of treatment approaches rather than any one approach is the most appropriate option. The authors point out that the management of children with PD involves selecting and sequencing a range of different treatment approaches, adding that within the same child, different parts of the phonological and phonetic inventory may respond to different types of approaches.

One advantage of single-subject designs over randomized controlled trials is that the former can provide information about what specific elements of treatment are effective in the individual child and what duration or intensity of intervention is needed to bring about change (Pascoe et al., 2005). Case studies enable in-depth assessments of the participant to be made, which may help increase our theoretical knowledge about the nature of phonological disorders (Baker et al., 2001). With single-subject designs, it is possible to measure several behaviours for each participant and to monitor how those behaviours change within the individual as a reaction to the treatment procedure. If the treated behaviours (dependent variables) change only when they come under the influence of the treatment (independent variable), then it is possible to control for extraneous variables (e.g. maturation, spontaneous development). Each time a behaviour is brought under control, the baselines of unchanged behaviours (control variables) help document the effects of treatment (Hegde, 1994). A multiple-baseline design demonstrates the effect of an intervention by showing that behaviour changes when and only when the intervention is applied (Kazdin, 1982). Multiple-baseline designs across behaviours have been used extensively in clinical research involving treatment evaluation. A large number of evidence-based intervention studies of children with speech and language disorders have been performed but such studies remain rare in Sweden (Nettelbladt, 1995; Nettelbladt and Salameh, 2007).

The first aim of this study was to investigate the effectiveness of an individually adjusted intervention targeting the phonological process of stopping of fricatives in Swedish pre-school children. The intervention model combined, to a varying extent, articulatory, phonological and meta-phonological approaches.

The second aim was to find out how many therapy sessions were needed to achieve generalization of /f/ and /s/ to untreated words.

Methods and Materials

Participants

Selection process. The participants were recruited from the Department of Pediatric Speech and Language Pathology at Queen Silvia Children's Hospital, Gothenburg, Sweden. The inclusion criteria were:

- a phonological pattern predominantly characterized by the following processes: stopping of /f/ and /s/ or other substitution of /f/ and /s/, fronting of velar plosives and weakening of /r/;
- age-appropriate language comprehension defined as a score of ≥ 25th percentile on the Test for Reception of Grammar (TROG) (Bishop, 1998);

- age 4;0–6;0 years;
- monolingual Swedish-speaker;
- no earlier phonological treatment or no observed effect of such treatment.

Two children were recruited directly from among incoming referrals and five children were already present at the clinic. Those five had previously been diagnosed as having PD with no other language problems. After being informed about the study, the parents gave written consent for their children to participate. One of the children had to be excluded during the baseline period because of spontaneous phonological development.

The children were examined using Fonemtest (Hellquist, 1995), a Swedish phonological test, and the TROG. Fonemtest is a picture-naming test eliciting 99 words where all Swedish consonants and consonant clusters are represented in varying positions. The TROG was used to define receptive language ability; a score of ≥ 25th percentile was considered to be within the normal range.

Description of participants. **Amanda** had been referred from the Child Health Services (CHS) because of difficulties with pronunciation. The consulting SLP had given her parents advice about general language stimulation. At reassessment six months later, Amanda had made no progress in her phonological development. Her phonological system matched the inclusion criteria but she also had some examples of deletion of final consonant and she simplified all consonant clusters. Amanda's early language development was reported as normal by her parents, who were, however, worried about her pronunciation difficulties and weak vocabulary.

Ben had been referred from the CHS and had attended seven therapy sessions focusing on /f/ and /v/. No change in phonology had been seen at reassessment three months later. Ben's phonology matched the inclusion criteria and he also had consistent deletion of final consonant (except nasals), assimilations, metathesis and consonant-cluster reductions. The parents had reported normal milestones for early language development but were worried about Ben's unintelligible speech.

Charles had been referred from the CHS because his parents were worried about his unintelligible speech. They had received instructions from the SLP about exercising /f/ and /v/. At reassessment three months later Charles had started to use /f/ in certain trained words. There were no signs of further phonological development. In addition to his phonological pattern matching the inclusion criteria, Charles used /d/ or /n/ in initial word position as a substitute for approximants and /v/, and he reduced consonant clusters. Normal milestones for early language development had been reported.

Diana had been referred by a paediatrician owing to delayed phonological development. She had established /f/ in medial and final position about half a year earlier but no further development had occurred. The family had received materials for home training, but at reassessment three months later Diana's phonological status was unchanged. Her early language milestones had been within the normal range but the parents thought that Diana's pronunciation was poor.

Edward had been referred from the CHS owing to unintelligible speech. His phonological production matched the inclusion criteria for velar fronting and weakening of /r/. /f/ and /s/ were stopped in medial and final word position, but were substituted with /h/ word-initially. The parents reported normal early language development.

Fiona had been referred from the CHS owing to pronunciation difficulties. Her phonological production matched the inclusion criteria perfectly. Her parents described her as a little clumsy, noting that she did not enjoy activities demanding fine motor skills; her early language development, however, was reported as normal.

Table 1. Description of the six participants at inclusion in the present study

	Age	Gender	Prior treatment	Hearing	Heredity	TROG percentile
Amanda	4;1	F	Indirect	Normal	No	25
Ben	4;9	M	7 sessions	Normal	Yes	50
Charles	4;2	M	2 sessions	Normal *	No	95
Diana	4;11	F	Indirect	Normal	No	90
Edward	5;7	M	None	Normal	No	75
Fiona	4;4	F	None	Normal	Yes	95

Note: * reported to be normal by parents.

Table 1 shows that the three girls and three boys in the study were between 4;1 and 5;7 years old at the start of the interventions. Ben and Charles had received direct treatment prior to the intervention. For Ben it seemed to have had no effect, while Charles had started to use fricatives in trained words. Ben's brother had a phonological disorder; Fiona's mother had had a language delay during childhood and her father reported reading difficulties. Several children had had otitis and otosalpingitis, but at the beginning of the interventions their hearing was normal. Their scores on the TROG showed a range between the 25th and 95th percentiles.

Design

This study has a single-subject multiple-baseline design across behaviours replicated across six participants. The baselines were established by measuring the dependent and control variables on three occasions (once a week) prior to the intervention. Treatment was given once a week during the intervention phase. The dependent and control variables were measured every third therapy session. All dependent and control variables were measured on three occasions (once a week) post-intervention and at a follow-up three months later. The dependent and control variables were measured using a researcher-made special test (see Appendix 1) to obtain generalization probe data.

Procedure

The dependent variables consisted of the treated target phonemes /f/ and /s/ while the control variables consisted of the untreated phonemes /k, g/ and /r/. The special test measured stability in the variables during the baseline period and possible change during the intervention period. The pre-intervention baseline period confirmed that no spontaneous development occurred. A stable baseline was a prerequisite for beginning the intervention period. When the first target phoneme /f/ was brought under the

influence of treatment, the second target phoneme /s/ was still held in baseline as untreated, until there was a well-defined change in /f/. The untreated control phonemes remained without treatment throughout the intervention period.

Measures

The special test. The special test consisted of 38 pictures, taken from different materials, that represented words with the treated target phonemes and untreated control phonemes in initial, medial and final word position (see Appendix 1). To make it possible to obtain generalization probe data and control data, those words were not used in treatment. The target phonemes occur more frequently in the test than the control phonemes because the number of measurements needed to be larger to enable detection of small signs of improvement in the children's phonological production as a response to intervention. Because of the focus on the word-initial position in treatment, this position is represented more frequently in the test than other word positions. On each occasion the test was presented by a trained layman, to avoid the influence of the treating SLP. Three elicitation strategies were used to make the children name the pictures: (1) Direct naming, sometimes with some semantic cuing; (2) 'Is this an x or a y?'; and (3) 'Can you say x?' All measurements were audio-recorded with a Marantz Professional CDR300 and video-recorded with a Sony Digital Handycam Video Recorder with a Shure 849 microphone.

PCC. Shriberg and Kwiatkowski (1982) established the concept of 'Percentage Consonants Correct' (PCC), which is now widely used in clinical settings as a severity metric for phonological disorder. In the present study, PCC was calculated for all consonants in the words of the special test. PCC was calculated on group level according to the Wilcoxon Signed Ranks Test using data from the first baseline measurement and from the follow-up measurement. Because Fiona did not participate in the follow-up measurement, PCC was instead calculated using her final special test during the intervention period.

Intervention

The children were treated by Authors 1 and 2, who each treated three children. Treatment was given once a week and treatment data were noted in medical records by the treating SLP. In the first phase of the intervention, the aim was to remedy the stopping of /f/ (Process 1). In typical phonological development, /f/ is the first-occurring fricative sound in Swedish children (Nettelbladt and Salameh, 2007). This is why it was chosen as the first target phoneme. When the treated Process 1 had decreased to a number of occurrences under 50% of the potential occurrences measured in the special test, the intervention proceeded to the second phase, aiming to remedy the stopping of /s/ (Process 2). This percentage of decrease in Process 1 is proposed by Dean and co-workers (1995) as being a point in therapy when it is appropriate to start treating Process 2. In the second phase, /s/ was introduced while /f/ was still maintained in treatment for reinforcement. When Process 2 had decreased to 50% or less of the potential occurrences, the treatment was ended.

The SLP used onomatopoetic pictures – commonly used in articulatory and phonological interventions by Swedish SLPs – to illustrate the sounds of /f/ and, later on, /s/ as well as their substitution phonemes. When the child could discriminate and produce on the phonemic level, the next step was to use pictures of words with /f/ and /s/ in initial position. Various simple games accompanied the picture materials. Treatment at this level began to differ across participants owing to the need for individual adjustments. Three different approaches were used to a varying extent:

1. The articulatory approach includes the SLP describing and showing the articulatory position and movements, giving visual guidance and feedback. Visual feedback is obtained by looking in a mirror and at the position of the SLP's mouth. Pictures and gestures symbolizing the phoneme (e.g. a snake for /s/) are examples of visuo-motoric cues. Simultaneous production; slow, smooth articulation; and segmented production (e.g. s-ofa) are used to elicit articulatory movements.
2. The phonological approach includes auditory discrimination of phoneme contrast in minimal pairs in different listening activities. For example, the child may be presented with the choice between 'tea' and 'sea', and asked to give the SLP the picture of 'sea'.
3. The meta-phonological approach includes exercises in identifying phoneme and phoneme positions in words as well as exercises focusing the child's auditory attention and encouraging reflection on his/her own production. Questions such as 'Can you hear /f/ at the beginning, in the middle or at the end of the word "brief"?' and 'Did you mean "fish" or "dish"?' are examples of this approach.

At the end of each therapy session the parent would be present in the therapy room to observe the treatment and obtain oral instructions and picture materials for exercises at home. The instructions given after a therapy session would build on the parts of the treatment to which the child had responded positively. The parents would be recommended to practise about 15 minutes daily with their children. Parent/caregiver involvement was an integral part of the therapeutic process, as suggested by Bowen and Cupples (2004).

Statistical methods

d-index. The calculation of the effect size of an intervention, or the d-index (Beeson and Robey, 2006), in single-subject designs can be done by subtracting the mean of the baseline phase from the mean of the intervention phase and dividing by the standard deviation of the baseline phase. The effect size as a comparison between the baseline and intervention phases gives a measure of the effectiveness of treatment. A d-index for each variable was calculated in this way from generalization probe data.

It is often impossible to calculate the d-index because the baseline is too stable, entailing a standard deviation of zero. On the other hand, a stable baseline is desirable in single-subject designs. In this study, positive values for the d-index are interpreted as improvement due to intervention while negative values are interpreted as the opposite.

Reliability. Generalization probe data from the special test were broadly transcribed on a continuous basis during the study phases by Authors 1 and 2 according to the conventions of the International Phonetic Association (IPA) (2005). The authors arrived at phonetic transcriptions by consensus in order to create a more solid basis for the decision on when the intervention should move from the first to the second phase.

After the study was finished, Authors 1 and 2 as well as an independent SLP re-transcribed 30% of the data to test intra- and inter-reliability. The samples were selected randomly and the raters were blind to whether a recording had been made before, during or after the intervention. Intra-reliability between the two consensus transcriptions and inter-reliability were calculated point-by-point. Intra-reliability was 96.5% and inter-reliability was 93.2%.

Results

The results are presented graphically below (Figures 1–6) together with statistical results (Tables 2–7) for each participant. Qualitative comments are given on the results. The values for the d-index, shown in Tables 2–7, will be commented on under Statistical results.

Amanda

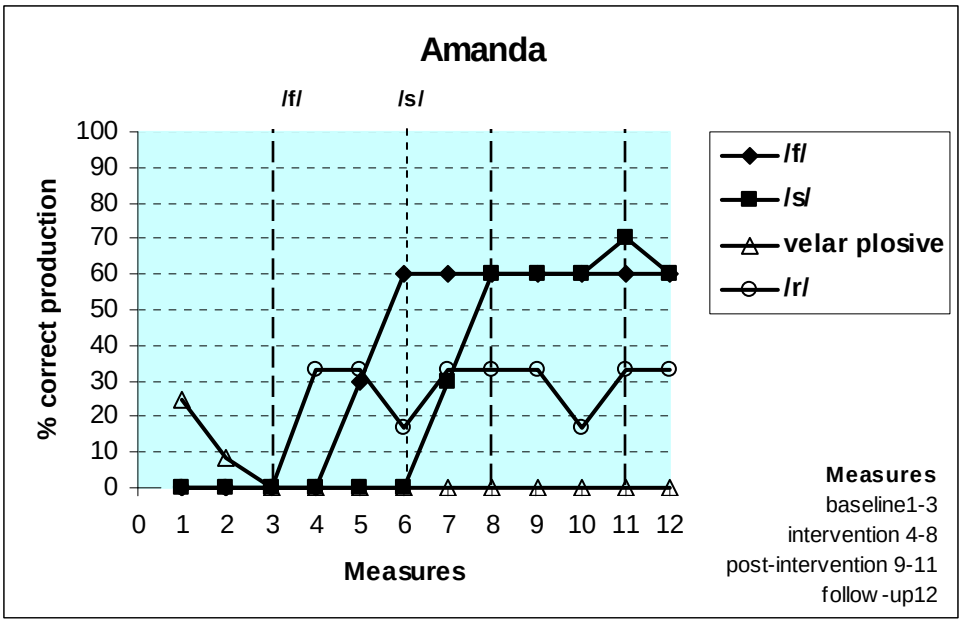

Figure 1. Baseline (/f/ 1–3, /s/ 1–6), intervention (/f/ 4–8, /s/ 7–8), post-intervention (9–11) and follow-up (12) performance for generalization probe words and control words for Amanda. During the intervention phase, measurements were made every third therapy session.

After nine therapy sessions, Amanda could produce /f/ initially in all words (Measurement 6 above). The second phase then began, and after another six therapy sessions she could produce /s/ initially in all words (Measurement 8). Post-intervention and follow-up generalization probe data showed that the treatment effect was maintained. There was no generalization of fricative phonemes to other word positions. The control data showed no developmental trend.

An articulatory approach was used throughout the intervention, including onomatopoetic pictures, simultaneous production, visual feedback and visuo-motoric cues. It became obvious during the study that Amanda had a slow lexical-acquisition rate: she had difficulty naming the words in the special test during the entire period.

Table 2. Amanda's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	0.0 (0.0)	0.0 (0.0)	11.1 (12.7)	0.0 (0.0)
Intervention	42.0 (26.8)	45.0 (21.2)	0.0 (0.0)	29.7 (7.3)
Post-intervention	60.0 (0.0)	63.3 (5.8)	0.0 (0.0)	27.5 (9.5)
Follow-up	60.0	60.0	0.0	33.3
d-index	-	-	-	-

Note: The effect sizes (*d*-index) could not be calculated as the standard deviation for the pre-intervention phase is zero for all variables.

Table 2 shows that the mean values for the dependent variables were higher than for the control variables during the intervention and post-intervention phases for Amanda. The value at follow-up showed the same pattern. There was a strong increase in the values of the dependent variables from mean values of 0% at baseline to more than 40% during intervention and 60% at follow-up.

Ben

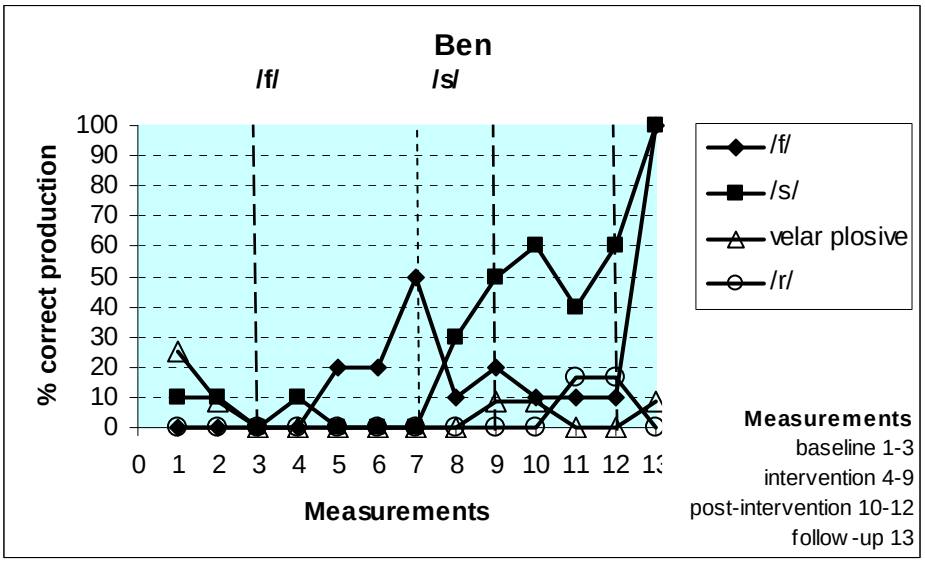

Figure 2. Baseline (/f/ 1–3, /s/ 1–7), intervention (/f/ 4–9, /s/ 8–9), post-intervention (10–12) and follow-up (13) performance for generalization probe words and control words for Ben. During the intervention phase, measurements were made every third therapy session.

Ben needed 12 therapy sessions to reach 50% correct production of /f/ words (Measurement 7 above). The second phase then started, where it took him six therapy sessions to reach 50% correct production of /s/ words (Measurement 9). During the intervention relating to /s/, Ben lost most of his ability to produce /f/ words in the generalization probe. In the post-intervention period, Ben maintained his /s/ word production and deteriorated further in his /f/ word production. At follow-up, Ben had

fully established /f/ and /s/ words and reached 100% correct production. The control data showed no developmental trend.

Ben benefited the most from an articulatory approach including simultaneous production and visual support from the SLP's mouth position. When he had achieved the ability to produce words with initial /f/, he started to overgeneralize in a mechanical manner. The intervention had to be supplemented with a more phonological approach in a second step.

Table 3. Ben's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	0.0 (0.0)	4.3 (5.4)	11.1 (12.7)	0.0 (0.0)
Intervention	20.0 (16.7)	40.0 (14.1)	1.4 (3.4)	0.0 (0.0)
Post-intervention	10.0 (0.0)	53.3 (11.6)	2.8 (4.8)	11.1 (9.6)
Follow-up	100.0	100.0	8.3	0.0
d-index	-	6.6	-0.8	-

Note: The effect sizes (*d*-index) could not be calculated for /f/ and /r/ as the standard deviation for the pre-intervention phase is zero.

Table 3 shows that the mean values for /f/ increased slightly during the intervention while a small decrease can be seen during the post-intervention phase. The mean value for /s/ increased during both the intervention and the post-intervention phases. An increase to 100% at follow-up can be seen for both /f/ and /s/, indicating generalization. The values for the control variables remained low at follow-up.

Charles

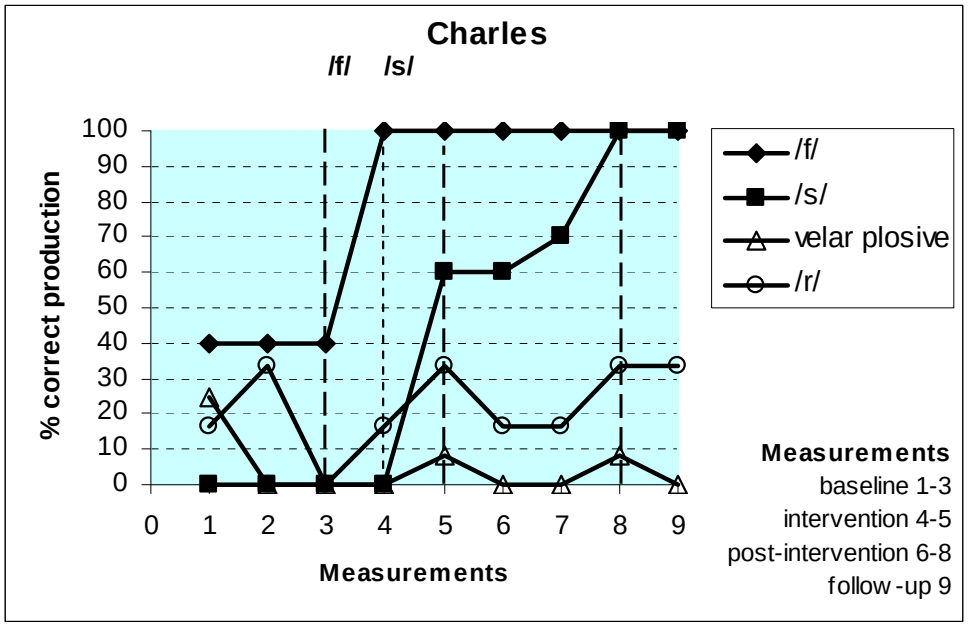

Figure 3. Baseline (/f/ 1–3, /s/ 1–4), intervention (/f/ 4–5, /s/ 5), post-intervention (6–8) and follow-up (9) performance for generalization probe words and control words for Charles. During the intervention phase, measurements were made every third therapy session.

Charles needed just three therapy sessions on /f/ (Measurement 4 above) to reach 100% correct production. After a further three therapy sessions, he could produce /s/ in all initial word positions. At the end of the post-intervention period he had reached the 100% correct level. The control data showed no developmental trend.

It was obvious at an early stage of the intervention period that Charles had a good meta-phonological ability. He was aware of his difficulties, but he did not want to work directly on his pronunciation and he would not participate in articulation exercises. He was helped by a phonological and meta-phonological approach, such as auditory discrimination and analysis of phonemic position in words chosen by himself.

Table 4. Charles's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	40.0 (0.0)	0.0 (0.0)	8.3 (14.4)	16.6 (16.6)
Intervention	100.0 (0.0)	60.0 (0.0)	4.2 (5.9)	25.0 (11.8)
Post-intervention	100.0 (0.0)	76.7 (20.8)	2.8 (4.8)	22.2 (9.6)
Follow-up	100.0	100.0	0.0	33.3
d-index	-	-	-0.4	0.5

Note: Effect sizes (*d*-index) could not be calculated for /f/ and /s/ as the standard deviation for the pre-intervention phase is zero.

Charles's results in Table 4 show that the mean values of the dependent variables were higher than those of the control variables during the intervention and post-intervention phases. The value at follow-up showed the same pattern. Table 4 shows a strong increase in the dependent variables: for /f/ from a mean value of 40% at baseline to 100% at follow-up and for /s/ from a mean value of 0% to 100% at follow-up.

Diana

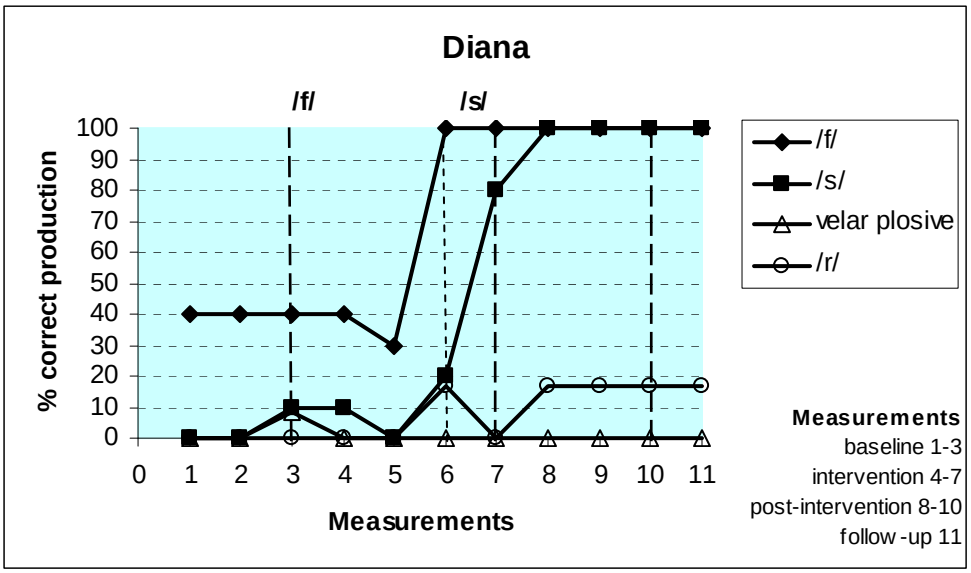

Figure 4. Baseline (/f/ 1–3, /s/ 1–6), intervention (/f/ 4–7, /s/ 7), post-intervention (8–10) and follow-up (11) performance for generalization probe words and control words for Diana. During the intervention phase, measurements were made every third therapy session.

After nine therapy sessions Diana reached 100% correct production of /f/ words (Measurement 6 above), subsequently maintaining this level throughout the study. She needed only three therapy sessions to reach 80% correct production of /s/ words (Measurement 7). Post-intervention and at follow-up, Diana achieved 100% correct production of /s/ words. The control data showed no developmental trend.

Diana was helped by an articulatory approach where the words were separated into initial phoneme + rest of the word (/s/+un for 'sun'), and she would take turns with the SLP in producing parts of the target word. Through simultaneous slow production accompanied by a hand gesture, Diana achieved the skill to use /f/ and /s/ co-articulated with the rest of a word. Diana's meta-phonological strength was used in reflecting verbally on her production difficulties.

Table 5. Diana's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	40.0 (0.0)	5.7 (7.9)	2.8 (4.8)	0.0 (0.0)
Intervention	67.5 (37.8)	80.0 (0.0)	0.0 (0.0)	4.2 (8.3)
Post-intervention	100.0 (0.0)	100.0 (0.0)	0.0 (0.0)	16.6 (0.0)
Follow-up	100.0	100.0	0.0	16.6
d-index	-	9.4	-0.6	-

Note: Effect sizes (*d*-index) could not be calculated for /f/ and /r/ as the standard deviation for the pre-intervention phase is zero.

Diana's results in Table 5 show that the mean values of the dependent variables were higher than those of the control variables during the intervention and post-intervention phases. The value at follow-up showed the same pattern. Table 5 shows a strong increase in the dependent variables: for /f/ from a mean value of 40% at baseline to 100% at follow-up and for /s/ from a mean value of 5.7 % to 100% at follow-up.

Edward

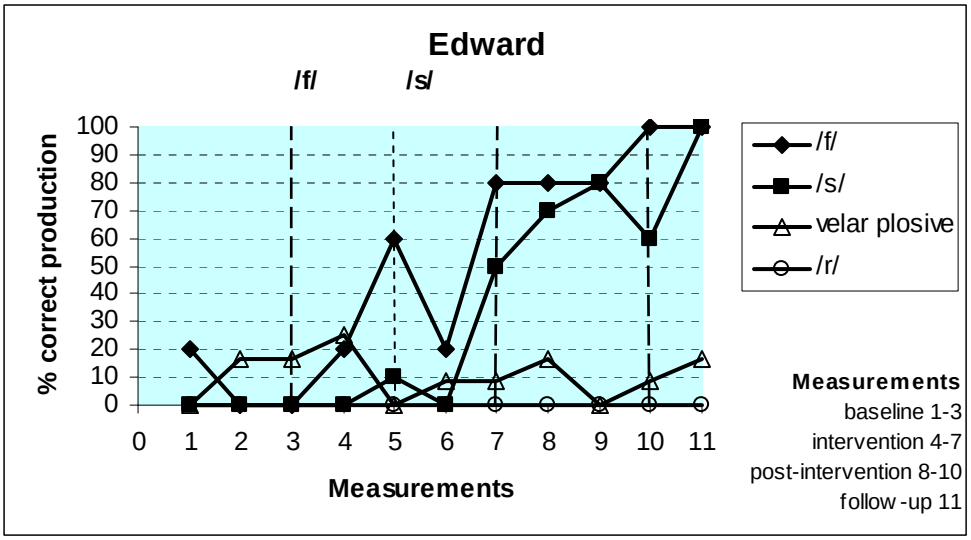

Figure 5. Baseline (/f/ 1–3, /s/ 1–5), intervention (/f/ 4–7, /s/ 6–7), post-intervention (8–10) and follow-up (11) performance for generalization probe words and control words for Edward. During the intervention phase, measurements were made every third therapy session.

After six therapy sessions, Edward correctly produced /f/ words in initial position and one word with /f/ in medial position (Measurement 5 above). After another six sessions he could produce /s/ correctly in at least 50% of the words (Measurement 7). This

development continued in the post-intervention period, and at follow-up he had 100% correct production of the fricative phonemes. The control data showed no developmental trend.

In Edward's intervention phase, the focus of treatment varied between an articulatory, a phonological and a meta-phonological approach. When /f/ and /s/ were trained in parallel in an articulatory way, Edward mixed them up in production. He was then helped by a phonological approach to master the difference between /f/ and /s/. His meta-phonological ability proved useful to help him identify phonemes and to make him aware of his own production and help him modify it.

Table 6. Edward's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	6.7 (11.6)	2.0 (4.5)	11.1 (9.56)	0.0 (0.0)
Intervention	45.0 (30.0)	25.0 (35.4)	10.4 (10.5)	0.0 (0.0)
Post-intervention	86.7 (11.6)	70.0 (10.0)	8.3 (8.3)	0.0 (0.0)
Follow-up	100.0	100.0	16.7	0.0
d-index	3.3	5.1	-0.1	-

Note: The effect size (*d*-index) could not be calculated for /r/ as the standard deviation for the pre-intervention phase is zero.

Edward's results in Table 6 show that the mean values of the dependent variables were higher than those of the control variables during the intervention and post-intervention phases. The value at follow-up showed the same pattern and a further increase in generalization to 100%.

Table 6 shows a strong increase in the values of the dependent variables: for /f/ from a mean value of 6.7% at baseline to 100% at follow-up and for /s/ from a mean value of 2% to 100% at follow-up.

Fiona

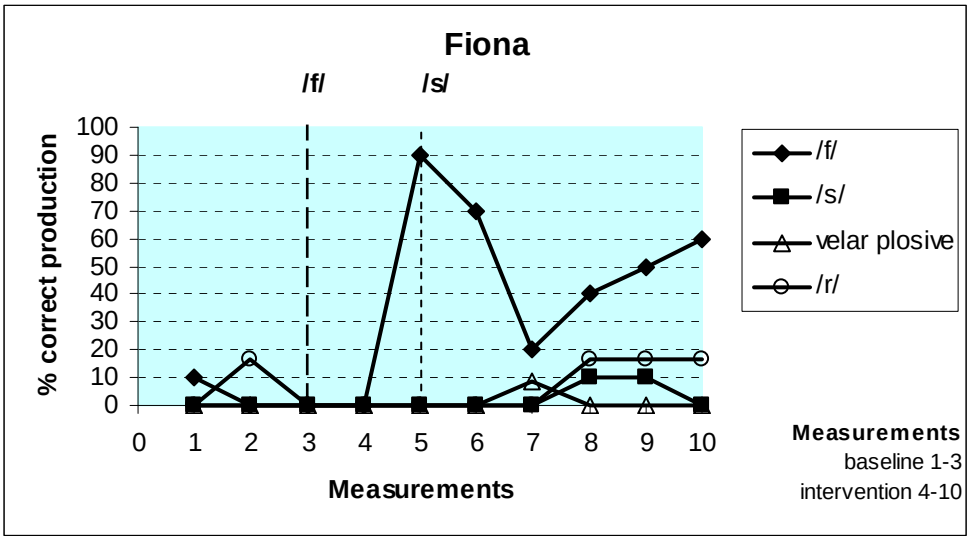

Figure 6. Baseline (/f/ 1–3, /s/ 1–5) and intervention (/f/ 4–10, /s/ 6–10) performance for generalization probe words and control words for Fiona. During the intervention phase, measurements were made every third therapy session.

Fiona was removed from the intervention study after 21 therapy sessions over a period of almost eight months (including a break for the summer holidays). She developed /f/ in words after six therapy sessions (Measurement 6 above) and produced 90% of the /f/ words correctly. The control data showed no developmental trend.

Fiona benefited from a mix of articulatory, phonological and meta-phonological approaches in exercising /f/. At the first therapy session when exercising /s/, Fiona could produce an interdental allophone. She was phonologically aware and was disturbed by the fact that she could not make /s/ distinct enough. Fiona never started producing /s/ in words in the generalization probe even though in therapy she could be made to pronounce /s/ in words. After 15 therapy sessions trying to develop /s/ in words, she left the study. After that she immediately continued treatment focusing on the development of velar consonants instead. For this reason, she could not take part in follow-up measurements.

Table 7. Fiona's percentages of correct production of target and control phonemes in the special test

Study phase	Dependent variables		Control variables	
	/f/	/s/	velar plosive	/r/
	M (SD)	M (SD)	M (SD)	M (SD)
Baseline	3.3 (5.8)	0.0 (0.0)	0.0 (0.0)	5.5 (9.6)
Intervention	47.1 (30.4)	3.3 (5.2)	1.2 (3.1)	7.1 (8.9)
d-index	7.6	-	-	0.2

Notes: Effect sizes (*d*-index) could not be calculated for /s/ and velar plosive as the standard deviation for the pre-intervention phase is zero.
Fiona did not participate in the post-intervention and follow-up sessions.

Fiona's results in Table 7 show that the mean value of /f/ was higher than those of the control variables and /s/ during the intervention phase. Table 7 shows a strong increase in /f/ from a mean value of 3.3% at baseline to 47.1% while for /s/ there is only a weak increase from a mean value of 0% to 3.3% during the intervention phase.

Number of therapy sessions. The number of therapy sessions needed to meet the criterion of at least 50% correct production of target phonemes in generalization probe words varied from 6 to 18. Amanda needed 15, Ben 18, Charles 6, and Diana and Edward 12 therapy sessions to conclude the intervention phase. For Fiona there was a need to change the focus of treatment to a non-fricative phoneme, and she ended her participation after 21 therapy sessions.

Statistical results

d-index. Tables 2–7 include information about effect sizes, or d-index, calculated for all variables in each child. The d-index could often not be calculated because the baseline was too stable, resulting in a standard deviation of zero, as was the case for Amanda and Charles. Nevertheless, the trend in results was clear. All d-indexes that could be calculated for target phonemes had positive values, reflecting improvement; and the d-indexes that could be calculated for control phonemes had negative or very small positive values. Edward was the only child who had a positive d-index for both /f/ and /s/. Ben and especially Diana had high positive d-index values for /s/. Fiona had a high positive value for /f/.

PCC. On group level, there was a significant difference between the first baseline and the follow-up in PCC at $p = .028$ calculated from all consonants in the words of the special test. This reflects an improvement in the generalization of the phonological production.

Discussion

Five children in the study responded positively to the overall intervention and achieved the treatment goals of producing /f/ and /s/ words correctly in more than 50% of the target words in the special test. Between 6 and 18 therapy sessions were needed to reach this goal. One girl, though she managed to learn /f/, had manifest problems with /s/ and her therapy needed to focus on other phonemes instead. For the other five children, generalization probe data showed that the intervention was highly effective and clinically significant: there was an important improvement in the production of the trained phonemes. As there was no change in the control variables, the intervention can be deemed to have caused that improvement.

Another outcome of the study is that it demonstrated the well-known heterogeneity of the group of children with PD (Fox and Dodd, 2001). Even though the children had largely the same phonological patterns when they were recruited to the intervention study, the content and the strategy of the therapy needed for each child to attain the desirable production differed.

The considerable inter-subject variability in phonological awareness that has been shown in several studies (Bird et al., 1995) was obvious among the children and

justified the choice to identify intervention approaches suitable for each individual child (Baker and McLeod, 2004). Meta-phonological ability, in combination with fine motor skills, appeared to be important for successful therapy outcome, as suggested by Adams and co-workers (2000). The better meta-phonological ability was, the faster progress in therapy would be; this was noticeable in Diana and Charles.

Charles's excellent meta-phonological ability could be used to make him aware of the difference between plosives and fricatives, and he spontaneously started to reflect on his own production and seemed to use his auditory attention exclusively to change his phonological processes. He clearly showed that he disliked direct articulatory cues and correction.

Amanda was Charles's total opposite in this respect. Her weak lexical ability went hand in hand with meta-phonological inability, but she immediately responded to gestural, pictorial and articulatory cues and to correction. She seemed to compensate with a stronger visual ability, often using spontaneous gestures when she had lexical problems in naming. The intervention period made it clear that Amanda had more general language problems with slow verbal learning in combination with her phonological difficulties. This may explain why she had difficulty starting to use the fricatives in other positions than word-initial and why no spontaneous development of fricatives was found at follow-up.

Diana, interestingly, benefited from a combination of using her meta-phonological ability and an articulatory approach. She was stuck in the pattern of adding a plosive between the fricative and vowel; even though she knew what she did wrong, she could not stop doing it. When the words were articulatorily separated into initial phoneme + rest of the word and followed by a gesture, she attained a satisfactory co-articulation of fricative phoneme and vowel.

Ben's intervention could be seen as a two-step process from an articulatory approach, with a great deal of simultaneous imitation, to a phonological approach aiming to inhibit his mechanical overgeneralization of /f/.

Edward also made progress with the help of a combination of articulatory and phonological strategies. He discriminated fricatives from plosives in his production at an early stage of the intervention, and he started to produce /s/ words with /f/ instead of a plosive. Like Ben, he needed to improve his auditory attention.

The choice of /f/ as the first target phoneme was justified by reference to the typical order of phonological development in Swedish children, where /f/ occurs before /s/. It might be expected that early phonemes are easier to learn and also facilitate the acquisition of later phonemes. /s/ is articulatorily more demanding than /f/ and should be harder to learn for children with PD. Our own clinical experience also supported the assumption that /f/ is easier to elicit than /s/. Gierut (2001) demonstrated that complexity of input triggers phonological learning in clinical treatment. That is, the more difficult the target of treatment is, the greater the phonological gains made will be. Later-acquired phonemes trigger greater learning, with generalization extending to treated and untreated phonemes from the same and different articulation-manner classes. Could the intervention period have been shortened if only /s/ had been treated? Or what if /s/ had been the first phoneme of intervention? Perhaps the intervention would have been shorter for some of the children, but probably not for Fiona, who had articulatory problems with /s/ even though she managed to produce /f/ easily. Rather, we believe that the fact that the production of /f/ is so visible and easy to explain in words may make this phoneme the easiest route into the world of fricative phonemes for

the child. Most of the children needed fewer therapy sessions to learn how to produce /s/. This is probably not because /s/ is easier to learn, but rather because the /f/ phase – the first step in learning about fricative phonemes – could be seen as a stepping-stone on the way to developing /s/. When they were introduced to the task of producing /s/, the children had already acquired the ability to produce a fricative phoneme. They had also indirectly learnt about the intervention process and techniques during the initial /f/ phase and could use this meta-knowledge when working on /s/.

Multiple-baseline designs must include at least two baselines (i.e. behaviours), but typically three or more are used (Kazdin, 1982; Hegde, 1994). The number of baselines contributes to the strength of the experiment. In the present study, four behaviours were base-rated. Two of them were brought under the influence of treatment while the other two were held in baseline as control variables. To strengthen the design, it would have been desirable to include those variables in the treatment procedure as well. On the other hand, the study is strengthened in that progress appears only in the dependent variables, with the control variables showing no developmental trend throughout the post-intervention period or even at follow-up.

All children had increasing PCC and there was a significant difference between baseline and follow-up values when they were considered as a group. PCC is most often calculated from a connected-speech sample. In the present study, however, data from the special test were used to calculate PCC. The words in the special test had been selected to elicit target and control phonemes and did not represent the complete phonemic inventory or all phonotactic possibilities of Swedish. A closer look at the words in the special test makes it obvious that phonological structures such as consonant clusters and polysyllabic words were not represented in the same degree as in typical Swedish; this could be considered a weakness.

Treatment effectiveness in terms of the effect size of intervention is a parameter that should preferably be presented in a study of this type. In single-subject designs, the d-index is a rather new statistical method. Beeson and Robey (2006) perform a meta-analysis and present guidelines for different levels of effect sizes in the research fields of acquired alexia and agraphia. There are no strict guidelines to be found for intervention studies relating to PD. Positive values of the d-index, as seen for the treated target phonemes in the present study, must be interpreted as improvements due to intervention. Negative values of the d-index must obviously be interpreted as the opposite; such values can be seen only for the untreated phonemes. Guideline values for effect size are needed for single-subject studies in the area of child speech and language pathology to give more solid statistical evidence (Dollaghan, 2008).

The criterion for moving the intervention from the first to the second phase was 50% correct production of /f/ in the special test. The same criterion was used for /s/ to decide when the intervention should be ended. This percentage of correct production is suggested by Dean and co-workers (1995) as a point in therapy when it is appropriate to introduce a new variable in treatment. When the child can suppress the phonological process and generalize this new phonological ability to untreated words in at least half of the possible target words, there is thought to be a process in development. The children could often produce the target phonemes in trained words in the therapy setting considerably earlier than they could do so in the target probe words. In the clinical reality, you are often satisfied when the child can produce the target phonemes in trained words. However, this does not guarantee that they can use their new phonological ability outside the therapy setting. The special test containing the target

phonemes in untrained words was a good instrument to reflect the actual generalized phonological change. The criterion of 50% correct use of target phonemes in the special test seemed to be an adequate way of showing that the child could take advantage of his or her new phonological ability outside the treatment situation. Even so, it would have been desirable to calculate PCC in connected-speech samples to obtain information about the children's phonological ability in a communicative context. Spontaneous comments by parents about increased intelligibility in everyday communication could also have been more systematically documented.

All children did a great deal of homework between therapy sessions. The aim was that their work at home should be very similar to ordinary work at the clinic. No detailed documentation of the homework was included in the study, which could be seen as a weakness. Instead the parents reported briefly on how the home exercises had worked out. The role of parents in the therapeutic process has grown more important in recent decades (Blosser, 1996). For example, Bowen and Cupples (1998; 2004) describe an eclectic phonological approach called Parents and Children Together (PACT), which builds on a model embracing family education, articulatory training and auditory, phonological and meta-linguistic exercises. In the present intervention study, the parents' engagement was very important.

Conclusions

The children in this study developed the fricatives /f/ and /s/ as a result of an individually adjusted phonological intervention. The expectation that the untreated phonological processes would remain unaffected was also affirmed. No general answer can be given about the number of therapy sessions needed to achieve measurable progress in generalization of the phonological ability acquired; this reflects the heterogeneity of the group of children with PD.

Clinical implications. The diagnostic instruments used in clinical assessment of phonology often include only a few representations of each phoneme in each word position, making them insufficient for decisions about when a phonological ability has reached a satisfactory level of generalization. It is therefore clinically relevant to design special probes with a large number of test words to capture small improvements in the specific phonological processes that interventions focus on.

Deciding in advance the number of therapy sessions needed for the individual child is not suitable because of the heterogeneity of the group of children with PD – even for children who exhibit the same phonological processes. Even if improvements in phonological production can be seen at an early stage in treatment probes, it is important to assess the child by means of generalization probes before decisions about therapeutic changes are taken. The intervention must be seen as a diagnostic and ongoing process giving the SLP knowledge about the amount and type of treatment that each child is responding to. Evidence-based intervention studies of children with speech and language disorders are rare in Sweden (Nettelbladt, 1995; Nettelbladt and Salameh, 2007). Children with PD constitute a large group among patients at SLP clinics and the effectiveness of intervention for this group needs to be proved in order to justify the allocation of SLP resources. Both the design of the study, the choice of participants and the programme of intervention had clinical relevance.

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Appendix 1. The special test

Words containing target phonemes:		Words containing control phonemes:	
/f/		velar plosives	
fyra (four)	/fy:ra/	**k**am (comb)	/kam/
fe (fairy)	/fe:/	kopp (cup)	/kɔp/
fel (fault)	/fe:l/	ja**ck**a (jacket)	/jaka/
fågel (bird)	/fo:gəl/	pa**ck**ar (pack)	/pakar/
finger (finger)	/fIŋər/	lo**ck** (lid)	/lɔk/
Findus (Findus)	/fIndʊs/	bo**k** (book)	/bu:k/
ga**ff**el (fork)	/gafəl/		
ka**ff**e (coffee)	/kafə/	**g**ammal (old)	/gamal/
giraff (giraffe)	/ʃIraf/	**g**am (vulture)	/ga:m/
nö**ff** (oink)	/nøf/	ö**g**a (eye)	/ø:ga/
		my**gg**a (mosquito)	/mYga/
/s/		ä**gg** (egg)	/ɛg/
sol (sun)	/su:l/	mu**gg** (mug)	/mʊg/
simmar (swim)	/sImar/		
säng (bed)	/sɛŋ/	/r/	
sår (wound)	/so:r/	**r**ing (ring)	/rIŋ/
soppa (soup)	/sɔpa/	**r**öd (red)	/rœ:d/
syr (sew)	/sy:r/	mo**r**ot (carrot)	/mu:ru:t/
läs**e**r (read)	/lɛ:sər/	pä**r**on (pear)	/pæ:rɔn/
mös**s**a (cap)	/møsa/	dö**rr** (door)	/dœr/
hu**s** (house)	/hɯ:s/	bu**r** (cage)	/bɯ:r/
bu**ss** (bus)	/bʊs/		