International Journal of Speech-Language Pathology

ISSN: 1754-9507 (Print) 1754-9515 (Online) Journal homepage: informahealthcare.com/journals/iasl20

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International Journal of Speech–Language Pathology, 2008; 10(5): 334–345

informa healthcare

The impact of selecting different contrasts in phonological therapy

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Abstract

Previous research indicates that the extent of progress made by children with phonological disorders depends upon the nature of the word pairs contrasted in therapy. For example, phonemes that differ maximally in terms of place, manner, voicing and sound class (e.g., *fan – man*) in comparison to therapy where the word pairs presented differ minimally (e.g., *fan – van*). To investigate the implications of target selection within a typical clinical context (as opposed to a rigorous research setting) eight speech-language pathologists implemented intervention with appropriate children from their caseloads. Nineteen children each received 6 hours of therapy over one school term. They were randomly allocated to two groups. One group (of nine children) received intervention based on a traditional minimal pair approach, targeting homonymy as well as distinctive feature contrast. The other group (ten children) received intervention targeting contrasts differing across a range of distinctive features. Children made considerable progress in therapy in terms of speech accuracy and number of error patterns suppressed. However, there was no difference between the progress of the two groups. Follow-up assessment of 14 of the 19 children indicated maintenance of progress by both groups. Reasons for the lack of difference between the groups in the current study are considered and clinical implications are drawn.

Keywords: *Minimal pairs, target selection, phonological therapy, intervention, speech.*

Introduction

The most common diagnosis made by clinicians working with paediatric caseloads is speech sound disorder. An incidence survey of a speech-language pathology service in England (Broomfield & Dodd, 2004), reported that 6.4% of children living within the service area were diagnosed as having a speech sound difficulty alone and 3.7% had both speech and expressive language difficulties. Children with speech sound disorders are at risk for academic, particularly literacy, failure (Gillon, 2004) and can have difficulties forming peer relationships (Fujiki, Brinton, Isaacson, & Summers, 2001). Their difficulties are likely to have long-term consequences and may lead to children not reaching their full potential (Felsenfeld, Broen, & McGue, 1994).

A number of different approaches have been advocated for cost-effective intervention of speech disorder, reflecting different theoretical accounts of phonological disorder (Baker & McLeod, 2004). One approach compares sets of word pairs differing by one phoneme (e.g., *tap – cap, tea – sea; toe – mow, wing – swing*). One phoneme is usually used accurately and the other is not part of the child's contrastive phonological system. Traditionally, clinicians have compared minimally paired words (or near-minimally paired words) that differ in one place, manner or voicing feature (e.g., *car – tar, sea – tea, pin – bin*) to address systemic simplification errors such as "fronting", "stopping" and "voicing" as well as homonymy (Grunwell, 1982). Minimal pairs are also commonly used to target structural simplifications such as "cluster reduction" and "final consonant deletion" (Dean & Howell, 1986; Lancaster & Pope, 1989).

Current research, however, claims that the phonemes contrasted should be known sounds that are maximally paired, differing across a number of features in manner, place, and voicing as well as sound class, such as sonorants vs. obstruents and marked vs. unmarked sounds (e.g., *toe – mow*) (e.g., Gierut, 2001). Advocates of a maximal contrast approach argue that the increased distinctive feature

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ISSN 1754-9507 print/ISSN 1754-9515 online © The Speech Pathology Association of Australia Limited
Published by Informa UK Ltd.
DOI: 10.1080/14417040701732590

distance between the phonemes compared increases learning and generalization (Bowen, 2005). The evidence directly comparing the efficacy of using minimal and maximal pair approaches, however, is limited to few children and appears to be constrained to systemic simplification error patterns.

The study reported here investigated the application of research on target selection to a typical paediatric speech-language therapy service context. It compared the effect of two different approaches to selection of contrasts in phonological therapy. One group of nine children were exposed to a traditional minimal pairs approach. The other group, of 10 children, were not only exposed to intervention for systemic error patterns where the word pairs differed in voice, manner and place of articulation, the approach was extended to structural error patterns like consonant cluster reduction. The two approaches to target selection differ on two parameters: the number of featural distinctions of the contrasts and homonymy.

The diagnostic category of phonological disorders

Intelligible speech is dependent upon a number of mental processes involving input (hearing and auditory processing), cognitive-linguistic phonological processing and output (phonological planning, motor planning and articulation). While specific intervention approaches are recommended for specific speech difficulties (e.g., PROMPT for children with childhood apraxia of speech, Square, 1994), most children referred with limited speech intelligibility of no known origin are diagnosed as having a phonological disorder. Phonology is a code (where words are sequences of sounds that represent objects and abstract concepts) that children must "crack" to both understand what others say and express their needs and thoughts. Different languages have different sets of phonemes and phonotactic constraints on how those phonemes may be combined into words. Children with phonological disorder may fail to acquire phonological knowledge that allows them to express meaning:

- by contrasting speech sounds (e.g., pronouncing *brush* as [bʌs], *scooter* as [skitə];
- by contrasting syllable structures (e.g., marking all word initial consonants as /h/, by only using a CV syllable structure);
- by using illegal consonants (e.g., bilabial fricative /β/, to mark consonant clusters in English);
- by placing consonants in illegal positions in word structure (e.g., *snake* as [ŋeɪk] or [kneɪk], *clangers as* [tlænɜz]); and
- by failing to develop a consistent phonological system.

Phonological disorders, then, reflect deficits in the cognitive-linguistic processes and the aim of phonological therapy is to re-organize a child's linguistic system. Most speech-language pathologists choose a traditional phonological contrast intervention programme (McLeod & Baker, 2004), comparing the target (correct phoneme) and the error sound usually produced, or another sound, to signal a difference in meaning. This confronts children with a communication breakdown due to their speech errors (e.g., "I don't know whether you mean *sun, fun* or *bun* because they all sound like *bun* to me"). This process requires recognition of similarities and differences between sounds and how these mark differences in meaning. It allows the child to actively organize sounds into classes and sequences into structures, leading to greater understanding of the phonological system and allowing generalization to non-treated phonological structures (Grunwell, 1997). It should be noted however that not all phonological contrast approaches confront the child with the homonymy resulting from their speech errors (e.g., maximal oppositions).

Intervention should aim to facilitate within- and across-class generalization, not just local generalization (Gierut, 2001). Local generalization affects a treated sound in untreated words (e.g., treating production of /s/ in word-initial position will generalize to all other untreated words with initial /s/ and possibly to /s/ in other word positions). Within-class generalization affects other sounds that share features with the treated sound or are the result of a common phonological error pattern such as stopping (e.g., treating /s/ may generalize to other fricatives such as /f/). Across-class generalization occurs when the targeted change stimulates changes in unrelated sounds or patterns (e.g., treating /s/ generalizes to /l/, or targeting stopping generalizes to gliding). The selection of intervention targets and their comparison sounds is one of the factors considered to be responsible for the degree of generalization evident following intervention.

Evidence for the effectiveness of minimal pair intervention

The minimal pair approach contrasts a child's error with the target sound using pairs of words containing a minimal contrast (e.g., Blache & Parsons, 1980; Ferrier & Davis, 1973; Gierut, 1991; Weiner, 1981). A minimal pair is formed by two words that differ by only one phoneme, usually by one feature (Bauman-Waengler, 2004). As examples, the words *tea* and *key* are similar because they are identical except for place of articulation of their initial sound; *spot* differs from *pot* only due to its initial cluster (near minimal contrast). The minimal contrast method is often implemented when clear error patterns are evident. It is considered a "conceptual form of sound teaching and is frequently used in the treatment of phonological disorders stemming from cognitive or linguistic difficulties" (Gierut, 1998, p. S89).

A number of experimental studies have evaluated the minimal pair approach to therapy. Some studies show very positive results with children receiving as little as 6 hours of therapy making major gains, not only in terms of accuracy but also for generalization. Weiner (1981) used minimal contrasts to suppress three error patterns (e.g., gliding of fricatives, stopping, final consonant deletion) in two preschool boys. Each error pattern was targeted with four sets of minimal pairs, one received 6 hours of therapy and the other 14 hours, scheduled thrice weekly for an hour. The results showed that the error patterns were suppressed in more than 90% of probes, and that there was local and within set generalization. Similar findings were made by Tyler, Edwards and Saxman (1987) who reported on two children receiving three 1-hour sessions per week. Three error patterns were suppressed using 5–10 minimal pairs per error pattern in a total of 8 and 9 hours of therapy. The outcomes included evidence of local and within class generalization. More recently, Crosbie, Holm and Dodd (2005) and Holm, Crosbie and Dodd (2005) showed that eight children responded well to 8 hours of minimal pair therapy, scheduled twice weekly for 30 minutes, leading to major gains in accuracy on a standardized assessment and within and across class generalization.

Two studies have provided limited evidence for change. A study by Saben and Ingham (1991) failed to provide evidence that a minimal pair approach resulted in progress for two preschool boys, even after providing a substantial amount of therapy (67 hours and 32 hours over 9 and 4 months). However, when therapy targeting oro-motor skills was included, gains were made.

Baker and McLeod's (2004) study showed dramatic differences in response to minimal pair therapy by two children reported to have similar phonological profiles receiving exactly the same intervention programme from the same therapist. One child, Cody, took 12 sessions (7 weeks) to generalize correct production of /s/ clusters to conversational speech whereas the other child, James, took 32 sessions (5 months). These two studies highlight the need to match detailed assessment procedures to specific intervention approaches. Studies by Crosbie et al. (2005) and Dodd and Bradford (2000) indicated that while children who make consistent errors responded well to minimal pair therapy, those who made inconsistent errors made little or no progress.

Evidence for the effectiveness of maximal pair intervention

A variation on the minimal pair method was described by Gierut (1990). Instead of contrasting the target sound with the child's error, an independent comparison sound is used. The contrast to the target needs to be one that is maximally different to the target sound. For example, a child stopping fricatives might be given pairs of words contrasting /s/ with /m/ (e.g., *sum – mum*, *sit – mitt*) because /m/ was maximally different (in place, voice and manner, obstruent-sonorant, marked-unmarked) and independent (i.e., not the child's error form). A child would produce the pairs without producing homonymy (e.g., *sum – mum* might be produced [dʌm – mʌm]). The method relies on meaning contrasts but not confusion. The maximal contrasts method is thought to create system-wide change on the basis of children filling in phonemic gaps.

Gierut argued that choosing and contrasting targets that are linguistically complex would enhance phonological learning during intervention. Specifically, generalization of learning would be enhanced when targets and their comparison were selected that differed most (e.g., in terms of distinctive features). Less change should be found for non-major linguistic differences. A series of efficacy case studies (Gierut, 1990, 1991, 1992; Gierut & Neumann, 1992) led Gierut (2004, p. B167) to conclude that "within and across children, greater generalization was observed for maximal relative to minimal contrasts".

This conclusion has important clinical implications. All novel intervention approaches, however, need to be evaluated from a clinical service perspective. Robey and Schultz's (1998) described a hierarchy for evidence based-practice that has six levels of increasing validity. Studies, like those reported by Gierut (2004) that define intervention, the population, exclusion criteria, outcome measures, amount of therapy, and type of service delivery, in optimal experimental conditions, need to be adapted for clinical service contexts. Evidence concerning the effectiveness (amount of change) and efficiency (change in relation to cost and therapy time) of phonological therapy is limited (Baker & McLeod, 2004; Gierut, 1998). One particular limitation in evidence is that research findings are not often evaluated at the service level by groups of practicing speech-language pathologists.

Few clinical trials have evaluated the outcome of maximal contrasts therapy. These studies focused on children who were often young (typically 3–4;6 years), many had above average intelligence, and information about the nature of their phonological systems was limited to phonetic repertoires. The lack of information about children's phonological systems is important since it does not allow discrimination between typical development, delayed and disordered phonological systems. Efficacy was limited to therapy targets, rather than spontaneous speech and long-term follow-up data were not available.

Several other difficulties for clinicians wishing to apply a maximal contrast approach are apparent. First, the approach often targets phonemes that are not typically part of a child's phonemic repertoire developmentally (e.g., targeting /θ/ in a child aged

3;8 years, Gierut, 1992). Although cogent theoretical reasons account for this choice, it may lead to confusion in intervention of articulatory and phonological goals. Further, only feature level contrasts of two singletons are included in the efficacy studies reported. The effect of intervention focusing on syllabic level contrasts, such as cluster versus singleton, has not been investigated despite cluster reduction being a salient feature of many children's phonological delay or disorder. Since previous research using maximal pairs had not targeted clusters, Gierut (personal communication, September 1, 2005) was asked to provide advice about how clusters should be targeted. She replied:

> When we have studied clusters, our focus has been on the linguistic structure of syllables. Given this we have manipulated aspects of sonority structure or branching, using traditional forms of treatment ... With clusters and minimal pairs, ambiguity is introduced because it is not clear what is being contrasted, e.g., is it sonority, onset structure, features, branching, phonemes and so on. This then introduces complications in interpretation of results because one single variable cannot be identified as causal to the pattern of learning.

Gierut's focus is in untangling the relative importance of very specific variables to unambiguously determine the effect of the contrast itself. Working with clusters introduces less clear-cut results, in terms of theory. Nevertheless, the clinical focus of this study necessitated the inclusion of clusters, since the clinicians involved considered clusters to have a high priority for intervention, due to their impact on intelligibility. Consequently, this study could not replicate previous research that has compared minimal and maximal contrasts in therapy. We used the term "non-minimal" to identify contrasts where the paired singleton sounds differ in place, manner and voice and where a cluster is compared to a singleton that is not part of the cluster targeted.

Finally, the intervention described was scheduled so that children received one hour of therapy, three times a week (see Gierut, 1989, 1992). Few children attending speech-language for as speech delay or disorder in Australia receive such extensive, intensive therapy. The study reported here, then, was unable to replicate the maximal contrast approach to phonological therapy. The literature reviewed, however, indicates the need to explore the effect of the type of contrast selected on intervention outcome within a typical clinical context (as opposed to a rigorous research setting) for children with phonological disorder.

Research questions and hypotheses

This study compared two different approaches to selection of contrasts in phonological therapy. Structural error patterns, like consonant cluster reduction, were included in both approaches. The two approaches were:

(i) a traditional minimal pairs approach; and
(ii) a non-minimal approach contrasting voice, manner and place of articulation.

Method

Participants

Speech-language pathologists from Education Queensland (Australian state government service provider) and the University of Queensland recruited children to the study who were on their caseload. Eight clinicians provided intervention to 19 children. Each clinician provided intervention for two to five children in the current study. The clinicians were all experienced (minimum of 12 years experience in paediatric speech pathology) and registered by the Speech Pathologists Board of Queensland. The children presented with moderate to severe phonological delay or disorder and had been identified as requiring phonological therapy. Children were recruited who met the following inclusion criteria:

- Severity: standard score of 3–5 on the percent consonants correct (PCC) measure of the *Phonology As*sessment (*Diagnostic Evaluation of Articulation and P*honology (DEAP) [standard score mean of 10, normal range of 7–13], Dodd, Crosbie, Zhu, Holm, & Ozanne, 2002).
- Consistency: consistent error patterns.
- Oromotor structure and skills: No structural problems apparent on oral examination.
- Receptive Language: Within the normal range on the *Peabody Picture Vocabulary* Test-III (Dunn & Dunn, 1997).
- Language background: Monolingual speaker of English.
- Consent: Consent to participate in an intervention study.
- The group of 19 children included 11 boys and 8 girls, ranging in age from 3;11 to 6;05 years, with a mean age of 5;04 years.

The children were a heterogeneous group with regard to their previous intervention: some of the children had received intervention previously but some had not. However, at the start of the intervention reported in this paper none of the children had received intervention for a period of at least four months. It is unlikely that there was any confounding treatment interference. Table I reports the details of the children participating in the study, including those sounds that were not stimulable (i.e., could not be elicited with cues). Appendix A provides details of the children's pre-treatment phoneme repertoire based on spontaneous speech, the phonological error patterns used and identifies their treating clinician.

Table I. Participant details and intervention assessment data.

Child	CA	Gender	Rec Lang SS	Pre PCC	Pre PVC	Pre PPC	Therapy group	Stimulability All sounds	Post PCC	Post PVC	Post PPC
1	71	M	81	35	89	54	Minimal	Except /θ/	55	98	70
2	60	M	91	49	95	65	Minimal	Except /dʒ/	64	97	76
3	70	M	102	63	99	76	Minimal		59	96	72
4	65	M	88	71	97	81	Minimal		85	99	90
5	51	M	107	38	97	59	Minimal		57	97	72
6	59	F	103	59	99	73	Minimal	Except /tʃ/	80	99	87
7	60	F	93	57	99	72	Minimal		88	100	92
8	73	F	85	66	99	78	Minimal		81	100	88
9	55	F	100	76	100	84	Minimal	Except /tʃ/	94	100	96
10	56	M	98	71	99	81	Non-min		77	98	84
11	77	M	85	38	94	58	Non-min	Except /tʃ, dʒ, θ, ð/	49	96	66
12	62	M	91	67	97	78	Non-min		76	99	84
13	65	M	93	76	99	84	Non-min		96	99	96
14	68	M	85	43	97	62	Non-min		58	97	72
15	58	M	96	62	97	75	Non-min		83	97	88
16	66	F	106	46	99	65	Non-min	Except /k, g, dʒ/	64	100	77
17	76	F	84	56	99	71	Non-min	Except /g, θ/	80	98	86
18	47	F	104	61	97	74	Non-min		73	97	82
19	64	F	117	70	100	81	Non-min		95	100	96

Pre-treatment assessment

An independent experienced paediatric speech-language pathologist (i.e., not involved in the child's speech therapy) assessed each child in a quiet room at their school or preschool. Parents were invited to be present at the assessment. Each child's speech, oro-motor and receptive language skills were assessed to allow for differential diagnosis of their speech disorder. The *Phonology Assessment* of the DEAP (Dodd et al., 2002) was used to measure speech skills. The DEAP provided standard scores with a mean of 10 and normal range of 7–13 for the percentage of consonants correct (PCC), percentage of vowels correct (PVC) and the percentage of phonemes correct (PPC). The assessing speech language pathologist made online transcriptions of the speech data. All productions were recorded using either a Marantz CP130 or videoed with a Sony Digicam. The online transcriptions were checked against the recording following the assessment to ensure accuracy.

The DEAP *Phonology Assessment* data were used to examine phonological ability by identifying and classifying error patterns in a child's speech. The assessment consisted of two parts: picture naming—eliciting 50 tokens covering all consonants in syllable-initial and final position; and picture description—eliciting 14 tokens from the naming task in a connected speech context. The speech measure (PCC, PVC, PPC) were calculated from the phonology data in accordance to the assessment manual instructions. Consistent speech error patterns (five examples of an error pattern) were identified and classified according to the assessment manual as typical or atypical of normal development.

The *Diagnostic Screener* was administered to check consistency of word production. Each child named a set of 10 pictures twice within the assessment session. The two productions of each item were compared to calculate an inconsistency score. Children who produced fewer than 50% of words variably were considered to have a consistent speech difficulty.

An informal stimulability assessment adapted from Carter and Buck (1958) was administered after the phonology assessment. Any singleton sound produced by the child in error was checked for stimulability in isolation, in consonant-vowel syllables (CV, VC) with the vowels /a/ and /i/. Modelling and cues were used to elicit sounds. Any sound that could be elicited in two conditions was considered to be stimulable.

Reliability

Inter-rater reliability measures were taken for the phonemic transcriptions. Broad transcriptions (phonemic) were made online during assessment sessions. The assessors checked their own online transcription with reference to the audio or video-recording following the assessment. To determine inter-judge reliability, an independent experienced speech-language pathologist re-transcribed 10% of the children's assessment transcriptions (phonology assessments) from the recordings. Point-to-point reliability was calculated based on each judge's transcription of each phoneme. Identical segmental transcriptions (excluding diacritics) were coded as agreements. The overall mean for broad transcription agreement was 90.24%, with a range of 84.44–95.79%. The original assessor's transcription was used for all analyses.

Project design

An independent group design was used. Once eligibility was confirmed children were randomly allocated to one of the groups. To ensure consistency of decision making, intervention planning and materials, the first four authors jointly selected the appropriate targets and prepared the materials for all of the clinicians. When therapy materials were handed over to each clinician by one of the first four authors, discussion included provision of detailed information regarding the intervention process (to ensure consistency of feedback given, activities used and session structure). To further ensure treatment fidelity, new target contrasts were discussed by telephone or e-mail, clinicians received new materials and two case discussion meetings involving all therapists were held during the course of the study. Clinicians could contact any of the first four authors at any time. No direct observation of therapy sessions was undertaken to check fidelity.

Targets were selected for each child based on clinical judgement of impact on intelligibility of successful remediation and sound-stimulability assessment. In the hierarchy of decision making concerning order of treatment, non-developmental error pattern (e.g., backing) were targeted before developmental error patterns (according to Dodd, Holm, Zhu & Crosbie, 2003). Developmental error patterns were generally addressed in the following order: stopping, cluster reduction (s + consonant clusters before plosive + glide clusters), fronting, gliding, voicing. Some variation occurred due to pervasiveness of an error pattern (e.g., all fricatives and affricatives stopped as opposed to only one fricative stopped), and frequency of the error pattern (e.g., consistency of application of error pattern); effect on intelligibility of successful remediation. All target sounds were stimulable. In the minimal contrasts group, contrasting singleton sounds belonged to the same major sound class (obstruents or sonorants). It was not possible to control for markedness since contrasting plosives and continuants and voicing disallows this contrast. In the 15 non-minimal pair targets all but one of the contrasts differed in terms of obstruent-sonorant (9) or marked-unmarked sound classes.

Inspection of the children's error patterns (see Appendix A) indicated that 18 of the 19 children were using the error pattern of cluster reduction. This error pattern affected the children's intelligibility. Not only were the majority of the children in this study reducing clusters but it is an error pattern often treated in clinical practice.

For each target, 10 pairs of words were created for treatment stimuli. Ten non-treated probe words were elicited every second session to monitor within-class generalization. All of the therapy materials were made using *Writing with Symbols* 2000 *Australian version* (Widgit Software, 2000). The laminated, colour pictures measured 6 × 6 centimetres.

Each child participated in 12 (30-minute) individual therapy sessions. There was one treatment session per week administered by the child's speech-language pathologist. An independent speech-language pathologist administered the DEAP *Phonology Assessment* at the end of the treatment block and again 8–10 weeks after the final assessment. The outcome measure for the study was the percentage of consonants correct (PCC) and the number of error patterns suppressed during treatment.

Phonological contrast intervention: Principles and structure

Error patterns were identified from analysis of the phonological assessment data. Each error pattern was targeted in four stages:

- auditory discrimination: the child was required to discriminate accurately and recognize each pair of words. This process was also important to ensure that the stimuli words were familiar and recognizable from the pictures being used;
- single words: the child was then required to start producing the word pairs, initially in imitation and then spontaneously;
- phrases (set and then spontaneous); and
- sentences within conversation.

Games were played where the child was required to produce the word pairs. Non-verbal and verbal feedback were given to the child. Non-verbal feedback was given by the selection of the correct picture by the therapist. Verbal feedback was provided to the child on the production of the words, with specific feedback about the target sound (e.g., "You said that really well because I heard a /k/ at the beginning of that word"). A 90% accuracy-training criterion was required to move from word to phrase to sentence stage. A new error pattern was introduced when an error pattern moved to phrase stage. There were two target conditions: minimal contrasts and non-minimal contrasts.

Minimal or near-minimal contrasts. The word pairs differed by one sound in either voice, place or manner. The word pairs typically contrasted the child's target and error sound. For example, if the target error pattern was velar fronting the minimal phoneme contrast pairs would include *car – tar*, *key – tea*. For clusters, the error form was always compared with the target. For example, contrasts for /s/ deletes in s+C clusters were: *top – stop*, *pin – spin*. A range of clusters could be targeted for any child within their phonological pattern (e.g., s + stop could include /sp, st, sk/ target words).

Non-minimal contrasts. The child's target sound was paired with a word that differed by one sound that was different to the target sound in terms of voice, place and manner. For example, if the target error pattern was velar fronting, the phoneme contrast pairs might include *key – me*, *can – man*. For clusters, the error form was never compared with the target. For example, contrasts for /s/ deletion in s+C clusters were: *mop – stop*, *heart – start*.

Nine children, four girls and five boys, received therapy with minimal contrast word pairs. Ten children, four girls and six boys, received therapy with word pairs containing a non-minimal contrast. There were no statistically significant differences between the groups in terms of chronological age ($F_{(1,18)} = .10$, $p = .75$), receptive vocabulary ($F_{(1,18)} = .10$, $p = .75$) or the number of error patterns evident in their speech ($F_{(1,18)} = .14$, $p = .72$). A multivariate analysis of variance comparing the two groups on the three speech accuracy measures indicated no significant differences ($F_{(3,15)} = .25$, $p = .86$). The groups did not differ on percent consonants correct (PCC) ($F_{(1,18)} = .09$, $p = .76$), percent vowels correct (PVC) $F_{(1,18)} = .32$, $p = .58$) or percent phonemes correct (PPC) $F_{(1,18)} = .13$, $p = .72$). Table II details individual error targets for therapy.

Results

Effect of therapy on speech accuracy

Paired samples t-tests examined the effect of speech therapy on children's speech accuracy scores. Therapy improved children's speech accuracy (see Table III). There was a significant difference in pre and post PCC (t (df 18) = 9.25, $p < .001$), PPC (t (df 18) = 8.89, $p < .001$), and the number of error patterns suppressed during therapy (t (df 18) = 8.23, $p < .001$). There was no significant difference between pre-and post PVC (t (df 18) = 1.47, $p = 1.60$). The majority of the children in the study had high vowel accuracy scores prior to therapy and vowels were not targeted in therapy.

Table II. Individuals' error targets during therapy.

Child	CA	Gender	Contrasts	Targets
1	71	M	Minimal	s + stop − stop, s + nasal − nasal, p-b
2	60	M	Minimal	s + stop − stop, s + nasal − nasal, n-l, p-b
3	70	M	Minimal	s + stop − stop, s + nasal − nasal, s-f
4	65	M	Minimal	s + stop − stop, s + nasal − nasal, w-l, dʒ-d, fr-f
5	51	M	Minimal	s + stop − stop, s + nasal − nasal, s-t
6	59	F	Minimal	s + stop − stop, s + nasal − nasal, t-k, d-g,
7	60	F	Minimal	s-t, dʒ-t, t-k, d-g, stop + r-r, fr-r, s-ʃ
8	73	F	Minimal	s + stop − stop, s + nasal − nasal
9	55	F	Minimal	tr-kr, dr-gr, s + stop − stop, s + nasal − nasal
10	56	M	Non-min	r-t, θw
11	77	M	Non-min	f-d, s-m, sn-b, s + stop-m
12	62	M	Non-min	tʃ-b, ʃ-n, t-m
13	65	M	Non-min	r-p, θ-m, s + stop-m
14	68	M	Non-min	s-g, f-m
15	58	M	Non-min	s-b, f-m
16	66	M	Non-min	ʃ-b, s-m, s + nasal-b, s + stop-m
17	76	F	Non-min	ʃ-b, k-l, s + nasal-b
18	47	F	Non-min	f-d, s-m, ʃ-b, s + nasal-b, s + stop-m
19	64	F	Non-min	ʃ-b, r-p

Effect of linguistic contrast on speech accuracy: Minimal versus non-minimal contrasts

A multivariate analysis of variance compared the effect of minimal versus non-minimal contrast therapy on speech accuracy. The groups did not differ overall across the three speech measures ($F_{(3,15)} = 9.23$, $p = .45$, partial $\eta^2 = .16$); nor on any of the individual measures: PCC ($F_{(1,18)} = .04$, $p = .84$, partial $\eta^2 = .003$), PVC $F_{(1,18)} = .27$, $p = .61$, partial $\eta^2 = .02$) or PPC $F_{(1,18)} = .04$, $p = .91$, partial $\eta^2 = .001$). A one-way ANOVA indicated no significant difference between the groups in terms of the number of error patterns suppressed during therapy ($F_{(1,18)} = 2.44$, $p = .14$, partial $\eta^2 = .13$). Table IV shows the mean (SD) speech accuracy measures and the number of error patterns suppressed by group (minimal versus non-minimal contrast therapy). There was no significant difference ($F_{(1,18)} = 2.366$, $p = .142$, partial $\eta^2 = .12$) in the number of contrasts targeted in the minimal contrast group (mean = 3.9, SD 1.5) as compared to the group exposed to non-minimal contrasts (mean = 3.0, SD 1.1).

Generalization

An analysis was undertaken to investigate whether the different types of linguistic contrasts (minimal vs. non-minimal) had a differential effect on generalization. The number of speech sounds added to each child's repertoire post therapy was calculated as a ratio of the number of speech sounds that were absent in their pre-therapy assessment. Clusters and singletons were analysed separately. For example, one 60-month-old girl did not have 8 speech sounds and 10 clusters prior to therapy. At the post-therapy assessment she had added six of the missing

Table III. Mean (SD) speech accuracy measures and the number of error patterns suppressed before and after therapy.

Measure	Pre therapy Mean (SD)	Post therapy Mean (SD)
PCC	58.11 (13.14)	74.42 (14.55)
PVC	97.47 (2.61)	98.26 (1.41)
PPC	72.16 (9.20)	82.84 (9.49)
Number of error patterns	4.42 (1.47)	2.37 (1.80)

Notes: PCC = percent consonants correct, PVC = percent vowels correct, PPC = percent phonemes correct.

Table IV. Mean (SD) speech accuracy measures and the number of error patterns suppressed by group (minimal versus non-minimal contrast therapy).

	Minimal contrast therapy		Non-minimal contrast therapy	
Measure	Pre therapy Mean (SD)	Post therapy Mean (SD)	Pre Therapy Mean (SD)	Post Therapy Mean (SD)
PCC	57.11 (14.08)	73.67 (14.90)	59.00 (12.94)	75.10 (15.00)
PVC	97.11 (3.41)	98.44 (1.51)	97.80 (1.75)	98.10 (1.37)
PPC	71.33 (10.10)	82.56 (9.99)	72.90 (8.77)	83.10 (9.55)
Number of error patterns	4.56 (1.67)	2.11 (1.70)	4.30 (1.33)	2.60 (1.90)

Notes: PCC = percent consonants correct, PVC = percent vowels correct, PPC = percent phonemes correct.

phonemes to her repertoire and eight of the clusters (ratio for singletons was .75, ratio for clusters was .80). Fifteen children were included in the analysis, eight children had received minimal contrast therapy and seven children had received non-minimal contrast therapy. A one-way analysis of variance indicated no significant difference between the groups in terms of increased speech repertoire of singletons ($F_{(1,13)} = .01$, $p = .91$, partial $\eta^2 = .001$) or clusters ($F_{(1,13)} = .37$, $p = .55$, partial $\eta^2 = .03$). Children receiving therapy with minimal contrasts had a mean increase of four consonants (SD 3.16) and seven clusters (SD 2.50). Children receiving non-minimal contrasts had a mean increase of four consonants (SD 1.81) and six clusters (SD 1.40).

Maintenance of progress

Fourteen children were assessed 8–10 weeks post-intervention to examine whether the gains made during therapy were maintained. Five children were unable to be re-assessed due to changes following the end of the school year (e.g., children changed schools, moved interstate, on holidays at time of reassessment). Paired-samples t-test indicated that children continued to improve between the end of therapy and the maintenance assessment (PCC: t (df13) = 3.29, $p < .01$; PPC: t (df13) = 3.53, $p < .01$). No difference was observed for PVC (t (df13) = 1.05, $p = .32$) but scores were already at ceiling at the end of therapy. A multivariate analysis of variance confirmed no significant differences at the maintenance assessment between the groups of children who received therapy with minimal versus non-minimal contrasts ($F(3,10) = .80$, $p = .52$, partial $\eta^2 = .19$). Individual measures revealed no differences: PCC ($F_{(1,13)} = 2.51$, $p = .14$, Partial $\eta^2 = .17$), PVC ($F_{(1,13)} = .00$, $p = 1.00$, partial $\eta^2 = .00$), PPC ($F_{(1,13)} = 2.37$, $p = .15$, partial $\eta^2 = .16$).

Comparison of singletons and clusters

Five children in the non-minimal paired group did not receive intervention for cluster reduction. A non-parametric Mann-Whitney test appropriate for analysing small clinical samples compared quantitative measures for these children with the other five children in the non-minimal pairs group who did receive intervention for cluster reduction. There was no significant difference on any of the measures (see Table V).

Discussion

Previous research has claimed that children with phonological disorder make more progress when they are presented with word pairs where the contrasted phonemes differ maximally in terms of place, manner voicing and sound class (e.g., *fan – man*) in comparison to therapy where the word pairs presented differ minimally (e.g., *fan – van*). The clinical trial reported compared non-minimal vs. minimal approaches to phonological contrast therapy in a speech-language therapy service context. It was not possible to implement therapy based on a strictly maximal contrast approach, due to the need to focus on cluster reduction in the children referred to the study. Eight speech-language pathologists implemented intervention with 19 children they selected from their caseloads. Each child was randomly allocated to work with minimally paired contrasts or non-minimally paired contrasts, receiving 6 hours of intervention.

Children made considerable progress in therapy in terms of speech accuracy and number of error patterns suppressed, but there was no difference between the progress made by children receiving minimally or non-minimally paired intervention stimuli. Investigation of patterns of generalization, using Gierut's (1992) outcome measure of number of speech sounds acquired during intervention, revealed no differences between children receiving minimal and non-minimal contrasts, although many singleton sounds and clusters were added to the children's phonetic repertoires. Follow-up assessment of 14 of the 19 children indicated maintenance of progress by both groups, although there was still no difference in the performance of the two intervention groups.

Progress in intervention

All children who participated in the study, except one, made considerable progress during the six hour

Table V. Mean (SD) speech accuracy measures for group receiving non-minimal contrast therapy targeting or not targeting clusters: Mann-Whitney U, p value.

	Clusters targeted				Clusters not targeted			
Measure	Pre therapy Mean (SD)	Post therapy Mean (SD)	U=	p =	Pre therapy Mean (SD)	Post therapy Mean (SD)	U=	p =
PCC	55.4 (14.55)	72.40 (17.56)	8	.421	62.60 (11.50)	77.80 (13.40)	10	.690
PVC	97.60 (2.19)	98.00 (1.58)	12	1.000	98.00 (1.41)	98.20 (1.30)	11.5	.841
PPC	70.40 (9.76)	81.40 (11.08)	8	.421	75.40 (7.89)	84.80 (8.67)	9.5	.548
Error p*	4.4 (.8)	3.0 (4.5)	12	.915	4.2 (1.7)	2.2 (1.7)	9	.443

*Number of error patterns.

	Pre-therapy				Post therapy			
Measure	Clusters targeted Mean (SD)	Clusters not targeted Mean (SD)	U=	p =	Clusters targeted Mean (SD)	Clusters not targeted Mean (SD)	U=	p =
PCC	55.4 (14.55)	62.60 (11.50)	8	.421	72.40 (17.56)	77.80 (13.40)	10	.690
PVC	97.60 (2.19)	98.00 (1.41)	13	1.000	98.00 (1.58)	98.20 (1.30)	11.5	.841
PPC	70.40 (9.76)	75.40 (7.89)	8	.421	81.40 (11.08)	84.80 (8.67)	9.5	.548
Error p*	4.4 (.8)	4.2 (1.7)	12	.915	0	2.2 (1.7)	9	.443

Notes: PCC = percent consonants correct, PVC = percent vowels correct, PPC = percent phonemes correct.

course of therapy that was delivered over one school term, irrespective of whether they were exposed to minimal or non-minimal contrasts. Children were usually seen once weekly for 30 minutes. The mean increase in PCC was over 16%; on average children suppressed two major error patters (e.g., stopping, cluster reduction) and added four singleton speech sounds and six clusters to their phonetic repertoires. The rate and extent of progress is similar to that reported for minimal contrasts by Crosbie, Holm, and Dodd (2005), Tyler, Edwards, and Saxman (1987) and Weiner (1981). These clinical research studies provided between 6 and 14 hours of intervention. It is more difficult to make comparisons with studies that report no data on general speech accuracy (Stoel-Gammon, Stone-Goldman & Glaspey, 2002). Other studies (e.g., Gierut, 1991) measure performance on probes (target sounds produced in learned non-words) that had a baseline of nil pre-therapy and had improved to scores of between 28–88% at end of therapy. While this improvement is large, it does not reflect performance on all sounds in a standardized assessment using real words. Another approach is to measure the number of speech sounds added to the child's phonetic repertoires during therapy. Despite a high number of intensive intervention hours, Gierut (1990) reported that the three children receiving maximal contrast intervention added either one or two sounds, which is considerably fewer than reported in the current study for either of the phonological contrast therapy approach used.

It might be argued that more contrasts were targeted in the minimal contrast therapy group (mean per child 3.9) than in the non-minimal pair therapy group (mean per child 3.0), and that if the same number of contrasts had been targeted in each group, then children exposed to non-minimal contrasts would have had a better outcome than children exposed to minimal contrasts. However, the difference between the two intervention groups' number of processes targeted was not statistically significant. In any case, cost-efficiency evaluation of intervention focuses on amount of positive change for hours of intervention expended. The reason why the non-minimal group were exposed to fewer targets was that they did not reach criterion performance for the introduction of a new target, as often as the group exposed to minimal contrasts, within the fixed "dosage" of 6 hours.

The fact that more targets were addressed in the group receiving minimal pairs does not allow the conclusion that the intervention approach was more efficient than non-minimal targets. The fact that there was no difference in progress between the groups indicates that such a conclusion would be wrong. Rather, the finding that addressing targets that differ non-minimally results in similar progress over the same amount of therapy, may indicate greater cost-efficiency in terms of therapy material preparation.

Another difference between the two intervention groups concerns the complexity of the contrasts targeted. For example, more consonant clusters (categorized as more complex than singletons, Gierut, 2004) were targets in the minimal contrast group than the non-minimal contrast group. Children whose targets included clusters should make greater progress given that greater complexity gives rise to better progress (Gierut, 2004). Comparison of the children in the non-minimal contrast group, however, showed no difference in outcome between the five children whose targets included clusters and the five children whose contrasts only involved singletons. Although the children whose intervention targeted clusters were exposed to 19 contrasts as compared to 11 for those exposed only to singleton contrasts, the total amount of therapy was the same.

According to linguistic theory, complexity can also be determined by sound class. One major difference is between sonorants (nasals and glides) as opposed to obstruents (plosives, fricatives and affricates). Another major sound class distinction is between marked and unmarked sounds. Marked sounds (voiced sounds, fricatives, affricates, clusters, and liquids) are considered more complex than unmarked sounds (voiceless sounds, stops, singletons, and nasals). Markedness theory is based on frequency of occurrence of sounds across languages as well as developmental patterns (Gierut, 1999, 2001). A contrast that includes sounds from two classes is considered more complex than one were both sounds belong to the same class, and likely to give rise to better outcome of therapy (Gierut, 1999, 2001).

In the study reported here, there were 14 different singleton non-minimal contrasts. Of these, nine (e.g., f – m, r – t, k – l) contrasted an obstruent and a sonorant. Of the remaining five contrasts, four differed in that one sound was marked and the other unmarked. Clusters versus singletons, of course are a complex contrast. In the minimal contrast groups, all 15 of the single sound contrasts targeted belonged to the same sonorant or obstruent sound class, although many differed in markedness (e.g., those targeting voicing and stopping). That is, the single-sound contrasts were more complex for the non-minimal group than the minimal pair group. More children in the minimal contrast group were exposed to singleton-cluster contrasts. However, whether clusters were, or were not targeted in the non-minimal group gave rise to no difference in outcome. It seems unlikely then, that the lack of difference between the groups can be attributed to the minimal contrast group being exposed to more complex targets than the non-minimal contrast group.

There are a number of factors that might explain differences in the extent of change: child-specific factors, clinician-specific factors and methodological differences in implementation of the phonological contrast approach and outcome measures. Inspection of the data describing participants in various studies indicates that severity level at baseline is unlikely to account for the difference. The mean age of children in the current study is older that those reported by Gierut, although that might be argued to disadvantage therapy (Gierut, 1998). The clinicians in the current study were experienced paediatric therapists who belonged to a Special Interest Group. The clinicians implementing therapy in most other studies are not identified.

Perhaps the most likely explanation for differences in the rate and extent of progress lies in the protocols used to deliver treatment. Gierut's (1990, 1991, 1992) therapy focuses on speech sounds rather than error patterns, employs non-words that children must lexicalize, and has two phases: up to 7 hours of non-word repetition followed by up to 12 hours of spontaneous production of the same non-words. Focusing on speech sounds rather than error patterns may be problematic. If a targeted speech sound is not stimulable (i.e., able to be imitated with cues) there is a danger that intervention may concentrate on teaching a motor pattern for articulation as opposed to linguistic knowledge about the contrasts and phonotactic constraints of the phonological system. Many of the targets selected in studies comparing minimal and maximal pair therapy are not, according to normative data for articulation, developmentally appropriate (e.g., targeting /f/ and /θ/ as a minimal pair in a child aged 4;2 years, Gierut, 1990).

The use of non-words may limit the extent and rate of progress in phonological contrast therapy. Children may have difficulty learning to lexicalize non-words (i.e., learn referents for the novel words) so that sessions come to focus on lexical representations rather than phonology. In addition, even when nonsense words are learned well, they are less likely to pose the difficulties of homonymy in so striking a way as real words in a child's vocabulary (e.g., [bʌs] for *brush*]. Gierut's treatment protocol also raises the issue of the usefulness of imitation in phonological therapy (see Bradford-Heit & Dodd, 1998). Imitation involves a limited number of mental processes (auditory and phonological analyses and phonological, motor planning and implementation of the motor plan, Ozanne, 2005) as opposed to the use of lexical representations to generate spontaneous spoken output.

The goal of the current study was to evaluate the cost-effectiveness of phonological contrast therapy using either minimal or non-minimal exemplars. The major finding, however, was that the small amount of intervention provided, irrespective of whether it used minimal or non-minimal contrasts, resulted in improvement that seems to exceed that usually reported for maximal contrasts therapy, particularly when number of therapy hours is considered (e.g., Gierut, 1989, 1990, 1991, 1992).

The literature on levels of evidence based practice in health care distinguishes between clinical research that defines the intervention in optimal experimental conditions and measures of effectiveness and efficiency at the service level by groups of practicing clinicians (Robey & Schultz, 1998). Clinicians often cannot replicate experimental conditions employed by researchers in universities and differences in findings may be attributed to the different contexts. Nevertheless, the results of the current study, in comparison to previously published reports of therapy, provide evidence that progress elicited by practicing clinicians might equal or exceed that research studies.

Indications for further research

Although the number of subjects who participated in the current study was large in comparison with previous studies, the results must be treated cautiously. Future studies might investigate child specific factors in more depth. It may be that the nature of a particular child's errors indicates that they will respond more positively to intervention focusing on either minimal or non-minimal contrasts.

Acknowledgements

The Royal Brisbane and Women's Hospital Research Foundation supported this research. We are grateful to the children, their parents and teachers who participated in the study. We would also like to thank Shannon Wandschneider for transcribing reliability data.

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Appendix A

Pre-therapy phonetic repertoire and error processes.

Child	C#	Phonemes Missing From Repertoire*	Error patterns: Delay	Error patterns: Disorder
1	B	/r, dʒ, θ, ð, tʃ, ʃ/	CR, V, G1	cluster → w or ϕ
2	F	/dʒ, ð, tʃ, ʃ, j/	CR, FCD, V, St, Fr	
3	D	/f, v, dʒ, θ, tʃ, ʃ/	CR, V, WSD, Gl	
4	C	/dʒ, θ, ð/	CR, St	
5	H	/l, f, s, z, k, g, r, j, dʒ, θ, ð, tʃ, ʃ/	CR, St, Fr	
6	F	/dʒ, θ, ð, tʃ, ʃ/	CR, V, Assim, Fr	
7	C	/k, g, j, dʒ, θ, ð, tʃ, ʃ/	CR, St, Fr	Atypical CR
8	E	/θ, ð/	CR, Gl, St, V	
9	C	/v/	CR, St,	Atypical CR, Bk
10	B	/r, ŋ, j, θ/	CR, Fr	
11	A	/f, v, s, r, dʒ, θ, ð, tʃ, ʃ, h/	CR, V, WSD, St, Fr	
12	C	/dʒ, θ, tʃ, j, v/	CR, V, Fr, De-aff	
13	C	/dʒ, θ, v/	CR, St	
14	E	/r, θ, ð/	CR, Gl, Fr, Assim, V	Bk
15	G	/r, θ, ð/	CR, Fr, St, Gl	
16	D	/k, dʒ, θ, ð, tʃ ʃ, ŋ, z/	CR, V, St, Fr	
17	B	/k, g, r, dʒ, θ, ð, tʃ, ʃ/	CR, St, Fr	Clusters → ϕ
18	A	/v, z, dʒ, θ, ð, tʃ, ʃ/	CR, FCD, St, Frr	
19	E	All present	St, Gl	

clinician; *Sounds not produced spontaneously; CR: cluster reduction; Fr: fronting; St: stopping; V: voicing; FCD: final consonant deletion; De-aff: deaffrication; WSD: weak syllable deletion; Gl: gliding; Bk: Backing, Assim: Assimilation.

Appendix B

Post-therapy phonetic repertoire and error processes.

Child	C#	Phonemes Missing From Repertoire*	Error patterns: Delay	Error patterns: Disorder
1	B	/dʒ, tʃ/	CR	
2	F	/dʒ, tʃ, ʃ, j/	CR, V, Fr	
3	D	/v, dʒ, θ, tʃ, ʃ/	CR, WSD, Gl	
4	C	/θ/	CR (3 members only)	
5	H	/j, dʒ, ð, tʃ/	CR, St, Fr	
6	F	/θ, tʃ/	CR	
7	C	/θ, ʃ/	Fr (/θ, ʃ → s/)	
8	E	/θ, ð/		
9	C	/v/		
10	B	/r, θ/		
11	A	/v, s, r, dʒ, θ, ð, tʃ, ʃ/	CR, V, St, Fr	
12	C	/dʒ, θ, j/	CR	
13	C	All present		
14	E	All present	CR, Gl, V, Assim	Bk
15	G	/θ, ð/		
16	D	/θ ŋ, z/	CR, V, St, Fr	
17	B	/θ, ð/	CR, St, Fr	
18	A	/r, dʒ, θ, tʃ/	St, Fr	
19	G	All present		

clinician; *Sounds not produced spontaneously; CR: cluster reduction; Fr: fronting; St: stopping; V: voicing; FCD: final consonant deletion; De-aff: deaffrication; WSD: weak syllable deletion; Gl: gliding; Bk: Backing, Assim: Assimilation.