Remediating Speech Production Errors with Sound Identification Training

Remédier aux erreurs de production verbale par l'éducation à l'identification des sons

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Key words: articulation disorder, speech disorder, speech assessment, perceptual training, perceptual disorder, acquisition

Abstract

This study examined the possibility that speech perception training would be effective in remediating speech production errors for a subgroup of children with functional articulation disorders. Following a pre-treatment assessment of each child's speech perception abilities, a modified fading technique was used to teach each child to identify two synthetically produced fricatives, one corresponding to the target and the other to the substitution error observed in the child's speech. Each child's response to the treatment program was examined using a randomization test, within a single-subject design. Three children with both production and perception difficulties showed significant gains in production following perception training. As expected, perception training did not improve speech production in two other cases: one in which the child showed normal perception ability during pretesting and one where the child showed abnormal perception during the pretest, but failed to learn the perceptual distinction. These results suggest that, for children who have both abnormal perception and production, an appropriately-designed program of perception training can quickly improve speech production.

Résumé

L'étude examine la possibilité que l'éducation de la perception du langage permette de remédier efficacement aux erreurs de production verbale d'un sous-groupe d'enfants ayant des troubles d'articulation fonctionnels. Après une évaluation avant traitement de la capacité de perception du langage de chaque enfant, une technique modifiée de diminution a été utilisée pour enseigner à l'enfant à identifier deux fricatives produites synthétiquement, dont une correspond à la fricative cible et l'autre à la fricative erronée observée dans le langage de l'enfant. La réponse de chaque enfant au test a été étudiée en utilisant un test hasard, à l'aide d'un modèle pour sujet unique. Trois enfants ayant des troubles de production et de perception ont montré une augmentation significative de la production verbale à la suite de l'éducation de la perception. Tel que prévu, l'éducation de la perception n'a pas amélioré la production verbale dans deux cas: un de ces cas était un enfant qui a montré des aptitudes de perception normales durant les tests préliminaires, mais qui n'a pas réussi à apprendre la distinction de perception. Ces résultats suggèrent que, pour les enfants qui ont une perception et une production anormales, un programme personnalisé sur l'éducation de la perception peut améliorer rapidement la production verbale.

Remediating Speech Production Errors with Sound Identification Training*

Converging evidence from several laboratories indicates that a subgroup of children who are diagnosed as having functional articulation disorders[1] are likely to have related perceptual difficulties (Broen, Strange, Doyle, & Heller, 1983; Hoffman, Daniloff, Bengoa, & Schuckers, 1985; Morgan, 1984; Raaymakers & Crul, 1988; Rvachew & Jamieson, 1989; Winitz, 1969). While a cause and effect relationship between production and perception difficulties remains an open topic, it is of practical significance to know the possible benefits of perceptual training for children who present with both perception and production errors. Unfortunately, despite the past popularity of ear training procedures (eg., Van Riper, 1963), surprisingly few studies have investigated the effectiveness of speech perception training in remediating production errors (eg., Shelton, Johnson, Ruscello, & Arndt, 1978; Williams & McReynolds, 1975; Winitz & Bellerose, 1967). Moreover, because of certain failures to demonstrate that speech perception training helps to remediate production errors, speech-language pathologists have been advised against the use of auditory training procedures in the treatment of functional articulation disorders (eg., Seymour, Baran, & Peaper, 1981; Shelton & McReynolds, 1979).

Several methodological concerns surround the reports of negative findings (for reviews, see Locke, 1980; and Rvachew & Jamieson, 1989). One concern is that the initial assessment of speech perception abilities in subjects may have been unsuitable and/or incomplete, precluding an effect of perception training on speech perception abilities. A second concern is that, in some studies, speech perception training has been directed toward a phoneme contrast that was not relevant to the child's articulation errors. Because children's speech perception errors may be specific to their sound production errors (Monnin & Huntington, 1974; Rvachew & Jamieson, 1989), speech perception training should teach the child specifically about the differences between the target phoneme and the substituted sound. Third, in the studies published to date, the training stimuli have consisted of live voice or recorded natural speech, with no apparent effort to control the acoustic details of the stimuli. Because such acoustic factors have not been controlled, children's responses during training may be based on factors other than those intended to signal the critical differences between the contrasting phonemes. For example, the children in the Shelton, Johnson, Ruscello & Arndt (1978) study may have learned to differentiate /s/ and /θ/ on the basis of non-acoustic (eg., visual) cues provided by their parents during training, rather than on the basis of acoustic cues which would generalize to later auditory testing.

Despite these methodological difficulties, the several failures to demonstrate the effectiveness of speech perception training in remediating production errors may have prematurely halted efforts to develop systematic procedures for teaching children to discriminate and identify phonemes. At the same time, however, a number of researchers have demonstrated effective perception training procedures in the related area of training new (foreign-language) speech contrasts. For example, Jamieson and Morosan (1986) demonstrated that a carefully designed and systematic sound identification procedure can be used to teach unilingual French speaking adults to perceive the English /θ/ - /ð/ contrast. This program was designed to promote both errorless learning and the generalization of performance from synthetic training stimuli to untrained natural speech stimuli. The program emphasizes several factors: (1) Training stimuli are carefully structured to contrast the acoustic cues critical to the identification of the target phonemes, within a speech context, to increase the similarity between the synthetically produced training stimuli and natural speech; (2) An identification task (rather than a discrimination task) is used because identification training is better suited to the goal of teaching the listener about the phonologically relevant contrasts between stimuli rather than about the within-category, allophonic differences; (3) Listeners are presented with multiple tokens of each phoneme, differing in a systematic manner, to teach the listener to ignore subphonemic acoustic variability while attending to those acoustic cues that are critical to the phoneme contrast; (4) The training stimuli are ordered so that at the beginning of training the subject identifies stimuli that are highly distinct in terms of their acoustic characteristics; as training progresses, the stimuli to be identified become increasingly similar. The effectiveness of these procedures has been confirmed in a series of further studies (Jamieson & Morosan, 1989; Morosan & Jamieson, 1989; Jamieson & Moore, 1991).

The purpose of the present study was to determine whether this sound identification training procedure would facilitate sound production learning for children with functional articulation disorders. It was expected that this training procedure would improve the production abilities of children who demonstrate difficulties with both the production and the identification of fricatives but that it would not influence the production abilities of children who have no problem identifying these sounds. A single-subject design that permits the use of randomization tests (Edgington, 1984, 1987; Rvachew, 1988) was used so that individual differences in response to this training program could be examined.

Method

Subjects

School speech-language pathologists referred four children whose records indicated the following: (1) mild or moderate functional articulation disorder, (2) normal hearing, (3) normal language skills, and (4) English as the native language. Each child received the *Goldman-Fristoe Test of Articulation* (GF; Goldman & Fristoe, 1972), a sound production task (SPT) for the target phoneme and the substituted phoneme, and a word identification test (WIT). The SPT (Elbert, Shelton, & Arndt, 1967) required the child to imitate 30 items (syllables, words, and sentences) which contained the test phoneme in a variety of phonetic contexts. In the WIT (Rvachew & Jamieson, 1989), each child was required to identify each sound in a continuum of seven synthetic speech stimuli relevant to the child's substitution. For one continuum, the parameters of the synthesis created stimuli which varied between /s/ and /ʃ/, while for the other, the stimuli varied between /s/ and /θ/. The WIT involved a two-alternative, forced choice procedure in which the children were required to identify each stimulus by selecting the appropriate picture from a pair placed in front of them. Prior to administering the formal WIT, the children received practice with a pair of words which contrasted the target phoneme with /p/ (eg., *seat* and *Pete*, or *sick* and *pick*). After obtaining a score of at least 80% correct on a block of ten practice trials, the child was required to respond to the formal test stimuli. All responses to the test stimuli were acknowledged, but feedback about correctness of response was not provided.

These tests were administered in a quiet room, in one 45-60 minute session. All children also received a hearing screening at the frequencies of 0.5, 1, 2, 4, and 8 kHz presented at 25 dB SPL. All these tests were administered by the second author, a certified speech-language pathologist with five years of clinical experience.

C.S., age 6 years - 0 months, misarticulated /ʃ/, /tʃ/, and /θ/ on the GF. Her SPT scores were 83% correct for /s/ and 0% correct for /ʃ/. She consistently substituted /s/ for /ʃ/, and consequently received sound identification training for the /s/ - /ʃ/ contrast. She had received previous speech therapy for remediation of /s/ errors and one therapy session for stimulation of the /ʃ/ sound.

P.R., age 5 years - 0 months, misarticulated /f/, /ŋ/, /ʃ/, /tʃ/, /l/, /r/, /v/, /s/, /z/, and /θ/ on the GF. His SPT scores were 100% correct for /s/ and 0% correct for /ʃ/ and consequently received sound identification training for the /s/ - /ʃ/ contrast. He had not received speech therapy previously.

A.M., age 7 years - 9 months, misarticulated /r/, /s/, /z/, and /θ/ on the GF. He obtained SPT scores of 0% correct for both the /s/ and the /θ/ phonemes. His /s/ error involved a variety of substitutions including /θ/, a mildly lateralized /s/, and a bladed /s/. He received sound identification training for the /s/ - /θ/ contrast. He had received several months of therapy for remediation of the frontal lisp. This therapy program did not include any speech perception training.

E.L., age 7 years - 9 months, misarticulated /l/, /ʃ/, /tʃ/, /d/, /s/, and /dʒ/ on the GF. His SPT scores were 0% correct for /s/, 0% correct for /ʃ/, and 93% correct for /θ/. He consistently substituted /θ/ for /s/ and lateralized /ʃ/. He had received several months of speech therapy for remediation of the frontal lisp, but this therapy program did not include any speech perception training. E.L. received sound identification training for both the /s/ - /θ/ contrast (where he is denoted E.L. - /s/ - /θ/) and for the /s/ - /ʃ/ contrast (where he is denoted E.L. - /s/ - /ʃ/). Because E.L. demonstrated perceptual difficulties with /s/ vs /θ/, it was anticipated that such training might prove beneficial; E.L. was also trained using the /s/ - /ʃ/ distinction which he did not misperceive and from which he was not therefore expected to benefit.

Stimuli

To train the /s/ - /ʃ/ contrast, four stimuli were synthesized using an implementation of Klatt's (1980) parametric synthesizer, running at 10 kHz on a Vax 11/730 computer. These 300 ms stimuli began with 110 ms of fricative noise followed by initial formant transitions and a steady state portion. These signals were based closely on stimuli 1, 2, 6 and 7 in the continuum described by Rvachew and Jamieson (1989). The acoustic consequences of this synthesis were that the amplitude and duration of the fricative portions of the stimuli were held constant, while the major spectral amplitude peak of the noise portion decreased from 4875 Hz for stimulus 1 of the present study (seat) to 2833 Hz for stimulus 4 of the present study (sheet). The steady state vowel was /a/, synthesized using the formant parameters recommended by Klatt (1980). Complete details of the stimulus parameters for these signals are available in Rvachew and Jamieson (1989).

To train the /s/ - /θ/ contrast, four stimuli were synthesized using an implementation of Klatt's (1980) synthesizer, running at 16kHz on a Vax 11/730 computer. These 317 ms stimuli began with 137 ms of fricative noise followed by an appropriate vowel. The signals were based closely on stimuli 1, 2, 6 and 7 of the continuum described by Rvachew and Jamieson (1989). The acoustic consequences of this synthesis were that the amplitude and duration of the fricative portions of the stimuli were held constant, while the major spectral amplitude peak of the noise portion increased from 5433 Hz for stimulus 1 (sick) to 7800 Hz for stimulus 4 (thick). Additional details of the stimulus parameters for these signals are available in Rvachew and Jamieson (1989).

The stimuli were output using a 12 bit D/A converter on a PDP 11/23+ computer and recorded on audio tape (Maxell XLII) using a Revox BV710 MkII recorder. The /sa/ - /ʃa/ stimuli were synthesized and output at a 10 kHz sample rate and low-pass filtered at 4.8 kHz, while the /sa/ - /θa/ stimuli were synthesized and output at a 16 kHz sample rate and low-pass filtered at 8 kHz. The tapes used during phases 1, 2, and 3 of treatment contained 240 stimuli with an interstimulus interval of 4 seconds. These stimuli were organized into 5 blocks, each containing 48 trials in a randomized order. The tapes used during the fourth phase of training contained 100 trials, organized into 5 blocks of 20 trials each. The frequency with which each of the four types of training stimuli appeared within each block of trials varied as training progressed (cf., Table 1).

Table 1. Number of times each stimulus was presented within a block of trials during each of the four treatment phases.

	Stimulus Number			
Treatment Phase	1	2	3	4
I	24	0	0	24
II	12	12	0	24
III	12	12	12	12
IV	5	5	5	5

Procedure

Training was divided into 20 short treatment sessions lasting approximately 6 minutes each. These sessions were scheduled consecutively, approximately half during a one-hour period on one day, and the remainder during a one-hour period on the next day. Sound identification training began on a session chosen at random between sessions 6 through 15, inclusive. This procedure was used to permit the use of the randomization statistical test. The training procedure, which is described below, was administered at the beginning of the chosen session and was readministered at the beginning of every subsequent session (including sessions 16 through 20). Prior to the first treatment session, all sessions were control sessions; at the beginning of each of these control sessions, five control trials were administered as described below.

A ten-item imitative production probe was administered at the end of each session. The probe items consisted of syllables, words, and sentences randomly selected from the appropriate SPT. The child's responses to each probe were recorded on audio tape with a Sony WM-D6C recorder and a Revox M-3-500 microphone. The WIT was readministered after completion of the last treatment session.

Sound Identification Training

During sound identification training, the child listened to the training stimuli and pointed to a "happy face" when the target was heard and to an "x" when a nontarget stimulus was heard. To establish the link between the target and the happy faces, the children received a few minutes of practice with live-voice presentations accompanied by exaggerated visual cues. Each child quickly demonstrated an understanding of the task and all further training and control trials involved tape-recorded stimuli. Training stimuli were played using a Sony WM-D6C playback system for monaural presentation to subjects at 85 dB SPL over AKG 240 headphones.

Training progressed through four phases. During the first phase, the most extreme versions of the training stimuli were presented (i.e., stimulus 1, /sa/, and stimulus 4, /ʃ a/ or /θa/). During the second phase, a less extreme version of the /sa/ was added to the stimulus set (i.e., stimulus 1, stimulus 2, and stimulus 4 were presented). During the third phase, a less extreme version of the contrasting phoneme, /ʃ a/ or /θa/, was added to the training set (i.e., stimulus 1, stimulus 2, stimulus 3, and stimulus 4 were presented). The pass criterion for each phase was 80% correct identification. After the child had reached criterion in phase 3, it was assumed that the child had learned the training task and that further training with these particular stimuli was clinically unnecessary. However, in order to apply the randomization test, each child was required to repeat the training task until 20 sessions were completed. Therefore, during the fourth phase, the number of trials was reduced from 48 to 20 in an effort to maintain the children's attention on the task for the remaining sessions. The child was given feedback regarding the correctness of each response and received a sticker at the end of each session.

Control Trials

To control for the effect of simply drawing the child's attention to the target phoneme, a second treatment task was administered during control sessions. The control task was the same as the sound identification training task, except that the control stimuli were natural speech syllables which contrasted the target phoneme with non-fricative phonemes. Five syllables were presented during these control sessions, one of which contained the target phoneme. These stimuli were recorded and replayed to the children under the conditions described for the Identification Training Procedure. All children performed with 90 to 100% accuracy during control sessions.

Results and Discussion

Each response to each production probe item was scored as correct or incorrect with respect to the production of the target phoneme. Two control probes and two treatment probes were chosen randomly for each child for reliability testing. These probes were scored by one of the authors (SR, a speech-language pathologist) and by a second speech-language pathologist. Agreement between the two scores ranged from 78 to 83 percent and averaged 80 percent across all subjects. The difference between the mean treatment probe score and the mean control probe score was calculated for each subject, and the probability (p) value associated with this difference score was determined by randomization test[2].

The upper half of Figure 1 shows the pre-treatment and post-treatment identification functions for the /s/ - /θ/ WIT for subject E.L. - /s/-/θ/. Identification training began during session 8. The lower half of the figure also illustrates his performance on the identification training trials and with the production test probes for the 20 treatment sessions. E.L. maintained a high level of performance on the identification task with scores ranging from 69 to 100% correct, and completed all three treatment phases. This child's ability to classify the "sick" and "thick" stimuli improved markedly over the course of the treatment program. He obtained a mean production probe score of 39% for control sessions compared to a mean score of 59% for treatment sessions (difference = 1.99, $p = 0.1$)[3].

The upper half of Figure 2 shows the pre-treatment and post-treatment identification functions for the /s/ - /ʃ / WIT for subject C.S. This child's ability to classify stimulus 1 and stimulus 7 of the "seat-sheet" continuum improved markedly

Figure 1. The upper panel displays pre-treatment (open symbols) and post-treatment (closed symbols) identification functions for subject E.L. - /s/ - /θ/ with sounds from the /s/ - /θ/ continuum. The lower panel shows identification performance (closed symbols) and /s/-production probe performance (open symbols) for the same subject on a session by session basis. Identification training was initiated during session 8.

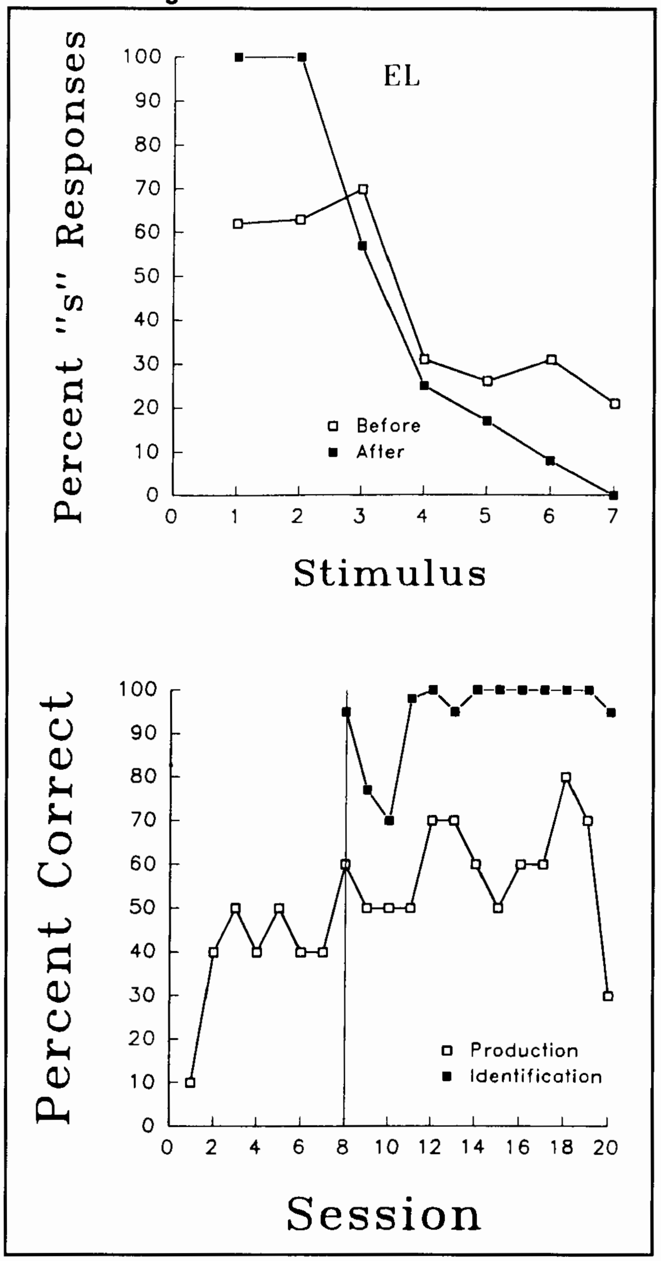
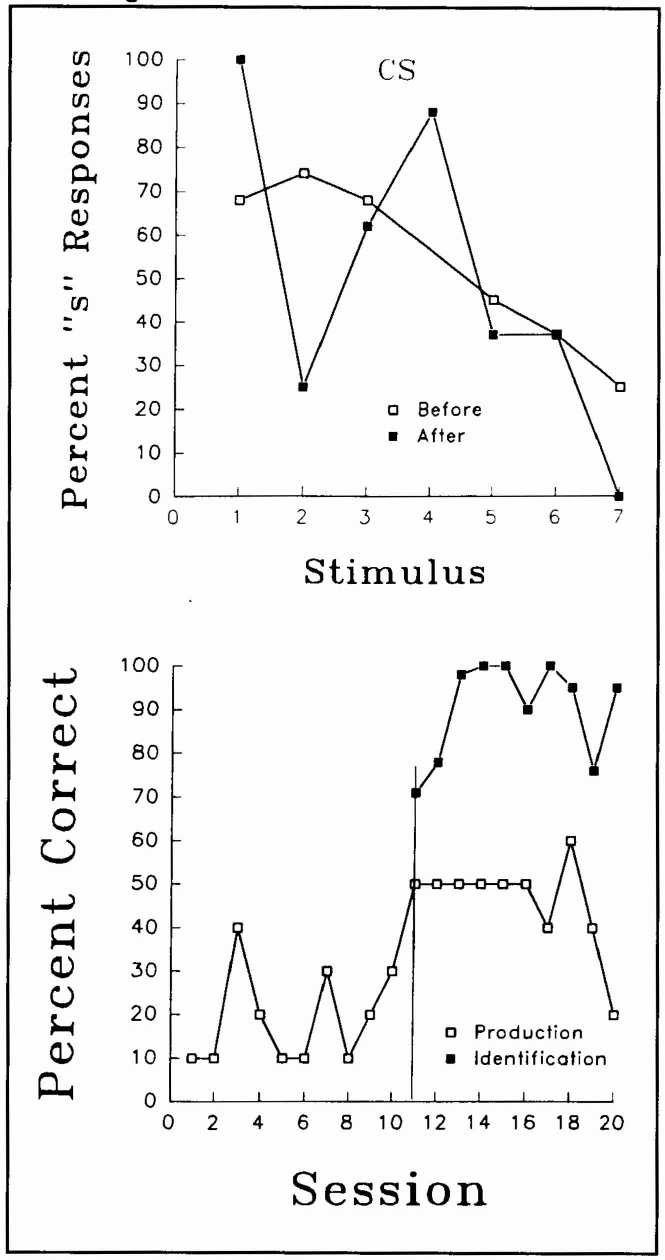


Figure 2. The upper panel displays pre-treatment (open symbols) and post-treatment (closed symbols) identification functions for subject C.S. with sounds from the /s/ - /ʃ/ continuum. The lower panel shows identification performance (closed symbols) and /ʃ/-production probe performance (open symbols) for the same subject on a session by session basis. Identification training was initiated during session 11.



over the course of the treatment program, although her post-treatment identification function is not normal with respect to the other stimuli. As shown in the lower half of Figure 2, identification training began during session 11. C.S maintained a high level of performance on the identification task, with scores ranging from 71 to 100% correct and completed all three treatment phases. She obtained a mean production probe score of 19% for control sessions compared to a mean

Figure 3. The upper panel displays pre-treatment (open symbols) and post-treatment (closed symbols) identification functions for subject P.R. with sounds from the /s/ - /ʃ / continuum. The lower panel shows identification performance (closed symbols) and /ʃ /-production probe performance (open symbols) for the same subject on a session by session basis. Identification training was initiated during session 10.

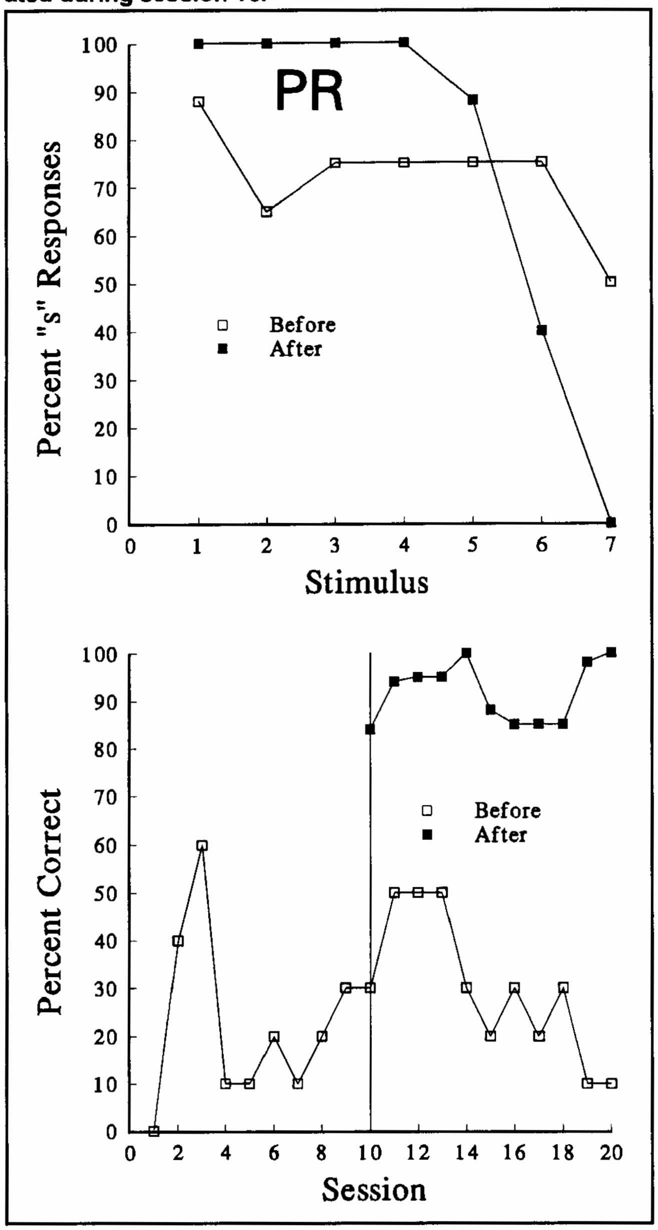
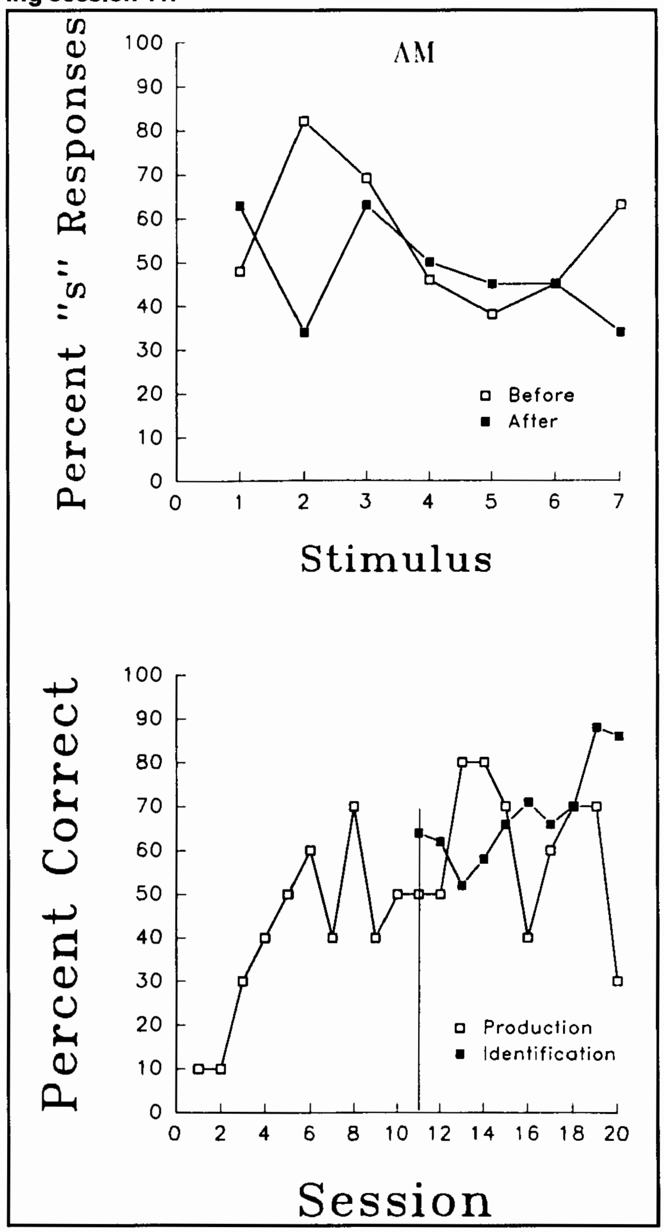


Figure 4. The upper panel displays pre-treatment (open symbols) and post-treatment (closed symbols) identification functions for subject A.M. with sounds from the /s/ - /θ/ continuum. The lower panel shows identification performance (closed symbols) and /s/-production probe performance (open symbols) for the same subject on a session by session basis. Identification training was initiated during session 11.



score of 46% for treatment sessions (difference = 2.7, p = 0.1)[3].

The upper half of Figure 3 shows the pre-treatment and post-treatment identification functions for the /s/ - /ʃ / WIT for subject P.R. As shown in the lower half of Figure 3, identification training began during session 10. He maintained a very high level of identification task performance with scores ranging from 81 to 100% correct and completed all three treatment phases. This subject also showed marked improvements in his ability to identify the test stimuli. Unfortunately, this child was recovering from a recent illness and became tired and uncooperative towards the end of the treatment period, which may explain the progressive decline in /ʃ/ production performance which begins during session 14. He obtained a mean production probe score of 22% for control sessions compared to a mean score of 30% for treatment sessions (difference = 0.8, $p = 0.3$)[3].

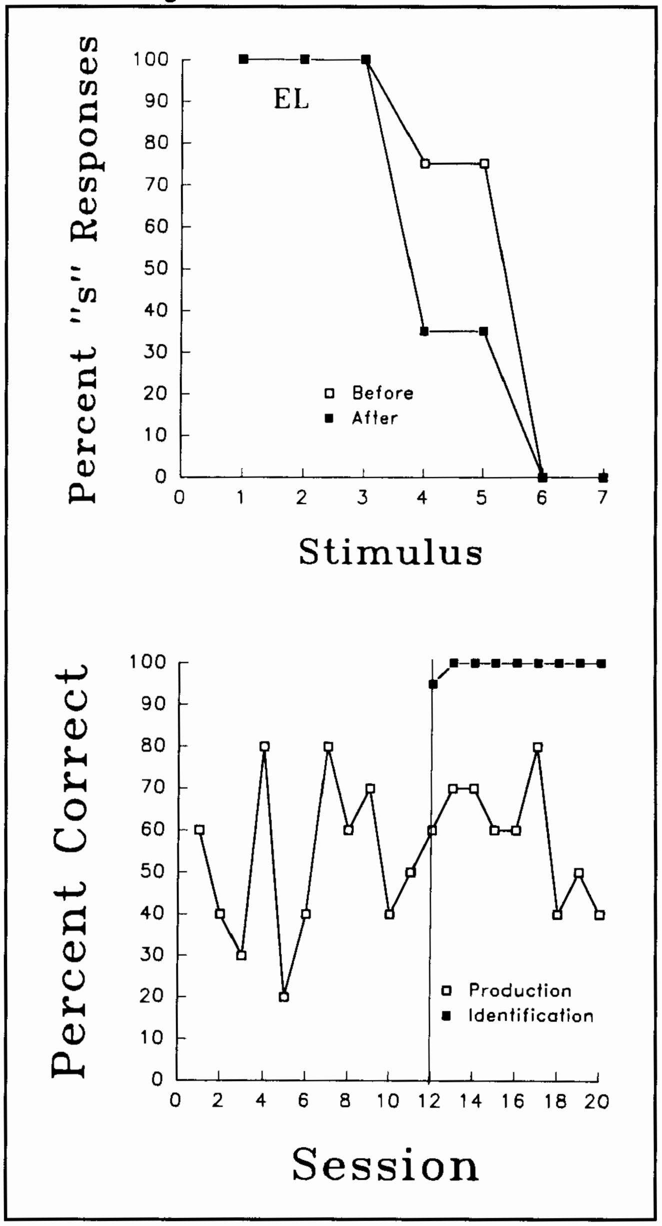
The upper half of Figure 4 shows the pre-treatment and post-treatment identification functions for the /s/ - /θ/ WIT for subject A.M. As shown in the lower half of Figure 4, identification training began during session 11, but this subject *did not* learn to identify the test stimuli appropriately. He initially had great difficulty with the task, obtaining scores ranging from 52 to 88% correct, and completed only the first treatment phase. He obtained a mean /s/ production probe score of 40% for control sessions compared to a mean score of 60% for treatment sessions (difference = 2, $p = 0.7$)[3].

The upper half of Figure 5 shows the pre-treatment and post-treatment identification functions for the /s/ - /ʃ/ WIT for subject E.L. - /s/-/ʃ/. This child lateralized the /ʃ/ rather than substituting /s/ for /ʃ/ and clearly had no difficulty identifying the "seat" and "sheet" stimuli. As shown in the lower half of Figure 5, identification training began during session 12. As noted, the child was not expected to benefit from perception training. He maintained an almost perfect level of performance on the identification task with scores ranging from 94 to 100% correct, and he passed quickly through all three treatment phases. He obtained a mean production probe score of 52% for the control sessions compared to a mean score of 59% for the treatment sessions (difference = 0.7, $p = 0.4$)[3].

Overall, these children give evidence of three distinct groups of functional articulation disorder: (1) those who demonstrate pre-treatment difficulties with both the perception and the production of a given contrast and who successfully learn to identify the training stimuli (eg., C.S., P.R., and E.L. - /s/ - /θ/,); (2) those who demonstrate pre-treatment difficulties with both perception and production but who fail to learn to identify the training stimuli (eg., A.M.); and, (3) those who demonstrate pre-treatment difficulties with the production but not the perception of a given speech contrast (eg., E.L. - /s/ - /ʃ/).

Children in the first group can be expected to demonstrate improved production as a result of the sound identification training procedure, while children in the latter groups can be expected not to show such improvement. In fact, when the p values for the first group (i.e., C.S., P.R., and E.L. - /s/ - /θ/) are pooled using the additive method for pooling discrete probability values (Edgington & Haller, 1984), the resulting

Figure 5. The upper panel displays pre-treatment (open symbols) and post-treatment (closed symbols) identification functions for subject E.L. - /s/ - /ʃ/ with sounds from the /s/ - /ʃ/ continuum. The lower panel shows identification performance (closed symbols) and /ʃ/-production probe performance (open symbols) for the same subject on a session by session basis. Identification training was initiated during session 12.



combined p value is $p = 0.01$. When the p values for children in the latter two groups (A.M. and E.L. - /s/ - /ʃ/) are pooled in this way, the resulting combined p value is 0.55.

General Discussion

The results of this study show that a short period of speech perception training can facilitate sound production learning for some children, provided that the child initially demonstrates both speech production and speech perception difficulties for the target stimuli. All of the subjects demonstrated considerable variability in production performance over the course of the experiment. This variability is superimposed on a generally improving trend for most of the subjects which is likely due to practice effects, given the repeated administration of the imitative production probes, as well as the effect of simply drawing the child's attention to the "sh" sound by asking the child to identify this sound during both control and treatment sessions. However, visual inspection of the figures and the statistical analysis suggests an additional effect of the treatment for three of the experiments (C.S., P.R., and E.L. - /s/ - /θ/). A positive relationship between production performance and the introduction of the sound identification training was observed in cases where the child demonstrated difficulty with the identification task before treatment, maintained high levels of correct responding to the perceptual task during treatment, and generalized this newly learned identification ability to at least some of the words used in the post-test.

The training procedure was designed to promote: (1) errorless learning, (2) increased sensitivity to between-category differences, (3) reduced sensitivity to within-category differences, and (4) the transfer of training from trained to untrained stimulus items. These objectives were achieved with three children. In addition, these children showed significant and almost immediate improvements in their productions of the target phoneme even though no direct production training was provided.

These results suggest that speech production difficulties in some children are related to an incomplete knowledge of the critical acoustic cues that differentiate the relevant phoneme categories. For these children, learning to identify the target and substituted sound appropriately permits the production of the target phoneme to be adjusted so that it more closely approximates the standard articulation.

One child (E.L.) presented with a misarticulation of the /ʃ/ sound but showed normal speech perception ability on the /s/ - /ʃ/ Word Identification Test. As predicted, this child's production of /ʃ/ did not improve as a consequence of speech perception training. This finding supports the hypothesis that past failures to demonstrate an effect of ear training on production ability may stem from an inappropriate application of speech perception training to contrasts that the child perceives correctly or to speech contrasts that are not relevant in terms of the child's speech production errors. It seems clear that speech perception training can be expected to contribute to the remediation of production errors only for children who demonstrate both abnormal speech perception and speech production difficulties. Unfortunately, speech clinicians may have difficulty identifying those children who are most likely to benefit from this training program because many of the standardized speech perception tests currently available to speech-language pathologists have questionable sensitivity, reliability and validity (cf., Locke, 1980; Rvachew & Jamieson, 1989).

As an alternative, tests such as the WIT used in this study offer several advantages in assessment: (1) they target a phoneme contrast which is directly relevant to the child's substitution error; (2) they use synthetically produced speech stimuli which contrast the acoustic features that are critical to the identification of the test phonemes; (3) they include several different tokens of each test phoneme; and (4) they present multiple trials for each test stimulus.

The effectiveness of the sound identification training program may also be attributed to the systematic training procedures employed in this study. These procedures include: (1) the use of synthetically produced stimuli designed to direct the child's attention to the critical acoustic differences between the target phoneme and the child's substitution; (2) the use of an identification procedure which promotes between-category sensitivity and reduces within-category sensitivity; (3) the use of multiple tokens of each phoneme in order to facilitate generalization from trained to untrained exemplars of each phoneme; and (4) a careful ordering of the stimuli designed to promote errorless learning on the part of the child.

While the present study did not involve a systematic manipulation of these training variables in order to determine the relative contribution of each component to the program's success, previous research has demonstrated the importance of using an identification procedure (Carney, Widen & Viemeister, 1977; Jamieson & Morosan, 1986) and a careful ordering of stimuli from least to most difficult (Jamieson & Morosan, 1986; 1989; Winitz & Priesler, 1967). However, the importance of using synthetic stimuli has not been determined.

Although the improvements in production ability that were observed for three of the subjects were statistically significant, it is likely that these children would have benefitted from additional program steps designed to promote generalization of their sound identification abilities to new vowel contexts and to other words and sentences. Further research is required to determine how much and what kind of speech perception training is required to facilitate correct production of the target sound in spontaneous conversation.

In fact, the randomization testing measure used here is sensitive only to relatively rapid changes in production ability. Using this criterion, three children were found to benefit from the training procedure. However, many other important questions could only be addressed with a modified procedure. For example, what are the long-term effects of such training; to what extent do the observed effects transfer to other listening and speaking situations; do children like A.M. differ in kind or in severity from those children who did learn to identify the training stimuli? Larger gains in speech production ability would be expected if the speech perception training were combined with traditional sound production training procedures. Further research is required to determine whether speech perception training should be administered prior to or concurrently with production training. Further research is also required to determine how to integrate interpersonal speech perception training with intrapersonal speech perception training because self-monitoring has been shown to be important to attaining generalization of correct articulation to conversational speech (Seymour, Baran & Peaper, 1981).

In summary, further refinements of this training procedure are required in order to determine when and under what conditions children with concurrent speech perception and speech production difficulties can obtain the most benefit from this procedure and to facilitate the application of this training procedure to the clinical setting. However, it is clear that a systematic speech perception training procedure can facilitate sound production learning when it is directed at the subgroup of speech disordered children who display both speech perception and production problems.

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Author's Notes

* This paper is based on M.Sc. thesis research undertaken by S. Rvachew supervised by D.G. Jamieson. The research was supported by grants awarded to D.G. Jamieson by the Natural Sciences and Engineering Research Council of Canada, the Ontario Ministry of Health and the University Research Incentive Fund, and by a University of Calgary Thesis Research Grant to S. Rvachew. We are grateful to E.S. Edgington for his advice regarding statistical analyses using randomization testing and to Laurie Williams for her assistance with the scoring of production probes. Correspondence should be addressed to Dr. Donald G. Jamieson, Hearing Health Care Research Unit, Department of Communicative Disorders, Elborn College, University of Western Ontario, London, Ontario, Canada N6G 1H1.

[1] Current terminology would characterize these children as "phonologically impaired". We use this term descriptively, however, and have not attempted analyses of the type required to describe the phonological system of any of our children.

[2] Edgington (1987) provides a detailed discussion of the application of the randomization test to single subject designs. Briefly, this test entails deriving a reference set from the data by calculating the difference scores associated with all possible assignments of control and treatment sessions (eg., the mean score for sessions 6 through 20 minus the mean score for sessions 1 through 5; the mean score for sessions 7 through 20 minus the mean score for sessions 1 through 6, and so forth). The ten difference scores that result from the randomization procedure are then rank ordered, and the difference score corresponding to the actual time at which treatment began is located within this rank order; for example, if treatment began on session 6, this is the difference score for sessions 7 through 20 minus that for sessions 1 through 6. The p (probability) value is the proportion of difference scores that are equal to or greater than the child's actual difference score. Single-subject and repeated measures designs are subject to a number of temporal trends, including practice and fatigue effects. The randomization procedure and test described here controls for these effects in a manner analogous to the control provided by random assignment of subjects to treatments in a multisubject design. However, in this case, the procedure involves random assignment of sessions to treatments (see Rvachew, 1988, for a more complete discussion of internal validity and single-subject designs).

[3] Because the smallest p value for any one subject is 0.1 (i.e., when the actual score is the smallest of the ten scores in the comparison set), p values are pooled across subjects in order to obtain an estimate of the overall p value for the treatment procedure. Here, we report both individual p values for each subject (minimum attainable value = 0.1) and the appropriate pooled values.