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Treatment Efficacy: Functional Phonological Disorders in Children

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This report addresses the efficacy of treatment for functional phonological disorders in children. The definition of phonological disorders and their incidence and prevalence are first presented. The impact of this disorder on the lives of children and the role that speech-language pathologists play in treating this disorder are then discussed. Evidence of the positive outcome of phonological treatment is reviewed, with particular emphasis on treatment procedures that have been deemed effective, the specific effects of these treatments on improving intelligibility, and comparisons between treatments in facilitating improved sound production.

KEY WORDS: phonological disorders, phonological treatment, treatment efficacy, speech-language pathology

There is both scientific and clinical evidence that children with functional phonological disorders benefit from the services of speech-language pathologists. This evidence is documented in experimental research and clinical case studies that trace and monitor treatment efficacy. *Treatment efficacy* is a broad term that addresses several questions related to treatment effectiveness (Does treatment work?), treatment effects (In what ways does treatment alter behavior?), and treatment efficiency (Does one treatment work better than another?) (Olswang, 1990). In general, treatment efficacy studies have used either group or single-subject experimental designs to answer these questions. Both methodologies are included in this review of phonological treatment, but single-subject experimentation is predominant in the published literature on functional phonological disorders. Other sources of information, including case studies, lend descriptive support to experimental findings of treatment efficacy. Case studies can offer a more individualized account of treatment benefits, and they serve to illustrate the range of variability among children with phonological disorders. For this reason, an illustrative case describing the treatment outcome for a child presenting a phonological disorder is also included.

Definition of Phonological Disorders

A *phonological disorder* affects a speaker's production and/or mental representation of speech sounds of the target language (Bernthal & Bankson, 1993; Edwards & Shriberg, 1983; Ferguson, Menn, & Stoel-Gammon, 1992; Fey, 1992; Folkins & Bleile, 1990; Grunwell, 1981, 1982; Harris & Cottam, 1985; Hoffman & Daniloff, 1990; Ingram, 1989b; Leonard, 1973; Locke, 1983a; Shriberg & Kwiatkowski, 1982a). Specifically, a phonological disorder may reflect an inability to articulate speech sounds, with the communication difficulty involving a motoric component. Disorders of this type have been described as *phonetic* in nature; that is, the difficulty lies in how sounds are produced (Dinnsen, 1984; Elbert, 1992; Hoffman, Schuckers, & Daniloff, 1989; Stoel-Gammon, 1985). A phonological disorder may also affect the way in which speech sound information is stored and represented in the mental lexicon or is accessed and retrieved cognitively (Bernhardt, 1992a, 1992b; Chiat, 1994; Dean, Howell, Waters, &

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Reid, 1995; Dinnsen, 1984; Dodd, Leahy, & Hambly, 1989; LaRiviere, Winitz, Reeds, & Herriman, 1974; Leonard, Schwartz, Swanson, & Loeb, 1987; McGregor & Schwartz, 1992; Schwartz, 1992; Stackhouse & Wells, 1993). In this case, the communication difficulty may have a linguistic or cognitive basis. Disorders of this type may be termed *phonemic* because the difficulties can involve the way in which sounds are used to signal meaning differences among words (Dinnsen, 1984; Elbert, 1992). It is significant that these types of phonological disorders are not mutually exclusive. Phonological disorders thus may have a broad impact on both a child's articulation (i.e., performance) and internalized knowledge (i.e., competence) of the sound system of the target language (Gierut, 1990b; Kamhi, 1992).

In a majority of cases, phonological disorders in children are functional, with no known cause for the communication breakdown (Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber, 1986). These children generally present normal hearing; intelligence; and social, emotional, and behavioral skills. Yet, for many children with functional phonological disorders, receptive and expressive language abilities are not age-appropriate (Hoffman, 1992). Semantic, syntactic, and pragmatic disorders of language have frequently been observed in association with functional phonological disorders (Camarata & Schwartz, 1985; Campbell & Shriberg, 1982; Fey, Cleave, Ravida, Long, Dejmal, & Easton, 1994; Himmelwright-Gross, St. Louis, Ruscello, & Hull, 1985; Panagos & Prelock, 1982; Paul & Jennings, 1992; Paul & Shriberg, 1982; Ruscello, St. Louis, & Mason, 1991; Schwartz, Leonard, Folger, & Wilcox, 1980; Tyler, 1992; Tyler & Sandoval, 1994; Tyler & Watterson, 1991). In these cases, there appears to be more global involvement of multiple aspects of the linguistic system. Other co-occurring conditions have been reported in conjunction with functional phonological disorders, including, for example, early otitis media (Churchill, Hodson, Jones, & Novak, 1988; Paden, Matthies, & Novak, 1989; Paden, Novak, & Beiter, 1987; Roberts, Burchinal, Koch, Footo, & Henderson, 1988; Shriberg & Kwiatkowski, 1982a; Shriberg & Smith, 1983), perceptual deficits (Broen, Strange, Doyle, & Heller, 1983; Locke, 1980a, 1980b; Ohde & Sharf, 1988; Rvachew & Jamieson, 1989; Smit & Bernthal, 1983; Winitz, 1975), and disfluency (Conture, Louko, & Edwards, 1993; Luoko, Edwards, & Conture, 1990; Throneburg, Yairi, & Paden, 1994; Wolk, Edwards, & Conture, 1993). To date, however, the causal and precedence relationships among these co-occurring conditions remain unknown and the focus of continuing research (Johnson, Shelton, & Arndt, 1982; Lewis & Freebairn, 1993; Shriberg, 1993).

There are also subsets of children who may exhibit phonological difficulties that are associated with their multicultural origins. These can include bilingualism, dialect differences, or native language differences. As an example, children acquiring English as a second language may exhibit differences in the production and use of sounds of the target language. These children do not necessarily have a phonological "disorder" in the sense described above; rather, the source of target sound production errors may be traceable to phonological differences between the child's native language and the target language being learned (Iglesias & Anderson, 1993; Lahey, 1992; Seymour, 1992; Taylor, Payne, & Anderson, 1987). Differences between a native and target language can affect, for example, the inventory of sounds a child may produce, perception of these sounds, rules of the language, or lexical stress (Eckman, 1993; So & Dodd, 1994; Yavas, 1994). The order of acquisition of sounds has also been shown to differ across languages (Anderson & Smith, 1987; Eblen, 1982; Ingram, 1988; Jimenez, 1987; Locke, 1983b; Pye, Ingram, & List, 1987), influencing expected developmental sequences. The most appropriate diagnostic and treatment procedures for children with phonological differences due to native language differences, dialect differences, or bilingualism are concerns receiving increased research attention (Gandour, 1980; Kiernan & Swisher, 1990; Morosan & Jamieson, 1989; Perozzi, 1985; Roseberry-McKibbin & Eicholtz, 1994; Schmidt & Meyers, 1995).

Finally, certain phonological disorders may have an organic basis (Cermak, Ward, & Ward, 1986; Christensen & Hanson, 1981; Dworkin & Culatta, 1985; Hall 1989; Hardcastle, Morgan-Barry, & Clark, 1987), and these most directly affect the articulatory or motor aspects of speech sound production. Children who have been diagnosed, for example, with craniofacial anomalies (Blakeley & Brockman, 1995; Estrem & Broen, 1989; Hodson, Chin, Redmond, & Simpson, 1983; Lynch, Fox, & Brookshire, 1983), mental retardation (Smith & Stoel-Gammon, 1983; see also Shriberg & Widder, 1990), or developmental apraxia (Hall, 1989; Thoonen, Maassen, Gabreëls, & Schreuder, 1994; Williams, Ingham, & Rosenthal, 1981; Yoss & Darley, 1974) may exhibit such organically based phonological disorders. Diagnostic and treatment procedures are being evaluated to determine if the same methods that are successful in improving functional phonological disorders are also appropriate in the remediation of organic phonological disorders (Dyson & Lombardino, 1989).

Incidence and Prevalence of the Disorder

Phonological disorders are among the most prevalent communicative disabilities diagnosed in preschool and school-age children. Phonological disorders affect approximately 10% of this population (National Institute on Deafness and Other Communication Disorders [NIDCD], 1994). For 80% of these children, the disorder is sufficiently severe to require clinical treatment (NIDCD, 1994). For speech-language pathologists employed in schools, children with phonological disorders constitute approximately 99% of average caseloads (NIDCD, 1994). Oftentimes, children with phonological disorders require other types of remedial services, with 50% to 70% exhibiting general academic difficulty through grade 12 (Aram, Ekelman, & Nation, 1984; Aram & Hall, 1989; Felsenfeld, Broen, & McGue, 1994; King, Jones, & Lasky, 1982; Shriberg & Kwiatkowski, 1988). There is also an observed relationship between early phonological disorders and subsequent reading, writing, spelling, and mathematic abilities (Bird, Bishop, & Freeman, 1995; Catts, 1993; Catts & Kamhi, 1986; Clarke-Klein & Hodson, 1995; Hoffman, 1990; Hoffman & Norris, 1989; King et al., 1982; Lewis & Freebairn, 1992; Shriberg, Kwiatkowski, Best, et al., 1986; Webster & Plante, 1992).

Effects on Daily Life Activities

Of greater significance is the fact that phonological disorders may have long-

term consequences that can potentially affect an individual throughout the lifespan (Bebout & Arthur, 1992; Felsenfeld, Broen, & McGue, 1992, 1994; Freeby & Madison, 1989; Lewis, 1990; Shriberg & Kwiatkowski, 1988). In particular, retrospective studies have shown that adults who were diagnosed and treated for phonological disorders in childhood continued to have global difficulties in the retrieval, manipulation, and comprehension of linguistic information (Felsenfeld et al., 1992; Felsenfeld, McGue, & Broen, 1995; Lewis, Ekelman, & Aram, 1989; Lewis & Freebairn, 1992). On the surface, these adults did not have trouble producing speech sounds, but they had extreme difficulty processing information that pertained to language generally and to the sound system in particular. These adults consistently made more errors and were slower to interpret language than other adults with no prior history of phonological disorders (i.e., controls).

Adults with a history of a phonological disorder also may complete fewer years of formal education and hold jobs that involve unskilled labor. In one retrospective study (Felsenfeld et al., 1994), 70% of adults with a history of a phonological disorder finished high school, but none went on to earn a college degree. This was in contrast to controls with no history of the disorder who typically completed at least one year of college. Similarly, for adults who completed high school, 70% of those with a history of a phonological disorder held an unskilled job, whereas none of the controls with a terminal high school degree held an unskilled position.

Together, these reports suggest that individuals with phonological disorders may be disadvantaged in situations that require the comprehension and production of language (Crowe Hall, 1991; Henry, Reed, & McAllister, 1995; Madison, 1992; Silverman & Paulus, 1989). They may not attain the same level of education as others and may select jobs that require minimal communication skills. This does not mean, however, that educational or occupational achievement is "caused" by childhood phonological disorders. Rather, the disorder may be one of many interrelated factors that shape an individual's life goals and accomplishments (Felsenfeld et al., 1994). This notwithstanding, those who do receive some form of clinical treatment for their phonological disorder have better long-term social, academic, and communication prognoses than those who do not (King et al., 1982; Kwiatkowski & Shriberg, 1993; Shriberg, Gruber, & Kwiatkowski, 1994; Shriberg, Kwiatkowski, & Gruber, 1994). In light of this, research calls for both retrospective and prospective studies of the etiology of phonological disorders and the identification of integrated causal relationships and their outcome on a speaker's daily life activities (Felsenfeld et al., 1995; Shriberg & Kwiatkowski, 1994).

Role of the Speech-Language Pathologist

In the clinical treatment of phonological disorders, the speech-language pathologist has the primary goal of improving a child's speech intelligibility to facilitate effective communication (Kent, Miolo, & Bloedel, 1994; Kwiatkowski & Shriberg, 1992; Weston & Shriberg, 1992). This is a two-pronged task involving (a) teaching the accurate articulation of speech sounds, and (b) facilitating the conceptual organization, lexical representation, and memorial storage of speech sound information (Bernhardt, 1992a; Catts, 1991; Dean et al., 1995; Gierut, 1990b; Hoffman, 1990; Kent, 1983). Because it would be an impossible task to teach a child every target sound in every relevant word and word position, the speech-language pathologist plans treatment with the minimal amount of teaching in mind—this in exchange for the greatest structural change, generalization, and improvement in the sound system (Campbell & Bain, 1991; Edwards, 1983; Powell, 1991; Shriberg & Kwiatkowski, 1987). An ultimate goal of phonological treatment is to induce the greatest, most widespread change in a child's sound system in an effort to bring that system more into accord with the phonology of the target language (Bain & Dollaghan, 1991; Olswang & Bain, 1991).

In addition to planning and providing clinical treatment for phonological disorders, the speech-language pathologist is responsible for the initial diagnosis of the communication problem and for continued assessment throughout the course of treatment in an effort to monitor systematic improvements in sound production (Olswang & Bain, 1994; Winner & Elbert, 1988). Oftentimes, the speech-language pathologist is a member of an interdisciplinary service delivery team that may include audiologists, nurses and physicians, occupational and physical therapists, parents, psychologists, social workers, special educators, and teachers. The composition of this team is dependent on the child's needs not only in the area of communication but in development generally. The team initiates and coordinates the optimal intervention program for the child and facilitates the program's transfer and utility in daily settings.

Evidence of the Benefits of Phonological Treatment

Overview

The positive benefits of phonological treatment have been widely documented in descriptive, clinical, and experimental studies dating back to the 1960s (Sommers, 1992). Three primary questions have been addressed in examinations of the functional outcome of phonological treatment. First, does treatment work? Here, the concern is in establishing the success of particular clinical teaching methods and procedures in changing children's sound systems. As defined previously, this question deals specifically with *treatment effectiveness*. A second question relates to *treatment effects*. For phonological disorders, treatment effects are revealed in the different changes that take place in a child's sound system. The central issue involves identifying the type and extent of sound change induced in treatment. A third question is comparative: Does one treatment work better than another? This bears upon relative *treatment efficiency*. Toward this end, attention has primarily been given to comparative evaluations of different treatment paradigms, targeted sounds for treatment, and modes of presenting sounds in treatment.

A majority of efficacy studies for functional phonological disorders have relied on well-established and accepted research methodologies of the social and behavioral sciences focusing exclusively on relatively few participants, with less emphasis on studies that involve large groups of children (Connell & Thompson, 1986; Kearns, 1986; McReynolds & Kearns, 1983). The aim of such *small n* studies is to capture common patterns

of phonological learning across a group of participants and, at the same time, to examine in detail the individual variability in sound learning. Thus, both homogeneity and heterogeneity among children with phonological disorders can be addressed. The generalizability of small *n* studies to the population-at-large comes in the form of direct and systematic replications of treatment effects (Attanasio, 1994; McReynolds & Thompson, 1986). Direct replications provide a demonstration that a given treatment is effective for children with similar presenting conditions. Systematic replications demonstrate that this same treatment is also effective for different children displaying different phonological characteristics and problems.

Most treatment efficacy studies have also focused exclusively on the consonantal system. Less attention has been given to errors in production of vowels. This may be due to several observations: vowels are earliest acquired, the accurate production of consonants has been thought to influence intelligibility to a greater degree than vowels, and variations in the production of vowels are often linked to differences between dialects. Recently, however, errors in the production of vowels and reduced inventories of vowels have been described for children with phonological disorders (Clement & Wijnen, 1994; Davis & MacNeilage, 1990; Hargrove, 1982; Pollock, 1991; Pollock & Keiser, 1990; Reynolds, 1990; Stoel-Gammon & Herrington, 1990). The diagnosis of vowel errors has motivated treatment programs aimed at expanding the vowel repertoire, but this is an area that warrants continued research.

The present review summarizes the general and uniform findings of treatment efficacy for functional phonological disorders by focusing on the three main research questions cited above. The review concentrates on small *n* studies designed to improve production of errored consonants. Efficacy studies published between 1980 and 1995 are reviewed, with the primary reference source being scientific journals published by the American Speech-Language-Hearing Association (ASHA). During the noted time frame, 64 publications in ASHA journals dealt specifically with the direct treatment of phonological disorders or the evaluation of relative treatment efficacy for phonological disorders. In addition to contemporary citations, select reference is given to seminal work on treatment methods and their efficacy published before 1980. Numerous other reports have addressed the diagnosis and classification of phonological disorders, treatment of nonfunctional phonological disorders, treatment of adults with speech sound disorders, and treatment of mixed disorders involving breakdowns in multiple components of speech or language. These important research issues are complementary to treatment efficacy but beyond the scope of the present review.

Treatment Effectiveness: Methods of Phonological Treatment

The method of treatment that a speech-language pathologist selects for a given child is a direct derivative of the diagnostic and classification framework that forms the initial phonological evaluation. There are a number of reliable and valid diagnostic frameworks available (e.g., Bernhardt & Stoel-Gammon, 1994; Dinnsen, Chin, Elbert, & Powell, 1990; Elbert, Dinnsen, & Weismer, 1984; Elbert & Gierut, 1986; Fey, 1986; Folkins & Bleile, 1990; Grunwell, 1985; Hodson, 1986; Ingram, 1981; Klein, 1984; Kwiatkowski & Shriberg, 1992; Lowe, 1994; MacNeilage & Davis, 1990; McReynolds & Elbert, 1981; Schwartz, 1992; Shriberg, 1993; Shriberg & Kwiatkowski, 1982a, 1982c, 1994). Similarly, a host of treatments has been introduced that vary in structure, implementation, and focus (Bedore, Leonard, & Gandour, 1994; Bountress, Bountress, & Nusbaum, 1985; Chaney, 1990; Christensen & Hanson, 1981; Clark, Schwarz, & Blakeley, 1993; Dagenais, Critz-Crosby, & Adams, 1994; Dunn & Barron, 1982; Dunn & Till, 1982; Fey & Stalker, 1986; Johnson & Hood, 1988; Kelman & Edwards, 1994; Kent, 1982; Khan & Lewis, 1990; Kupperman, Bligh, & Goodban, 1980; Leonard & Brown, 1984; Leonard & Leonard, 1985; Leonard & Webb, 1971; Lundberg, Frost, & Peterson, 1988; McGregor, 1994; Monahan, 1986; Morosan & Jamieson, 1989; Ruder & Bunce, 1981; Schilp, 1986; Shriberg, 1980; Shuey, 1992; Shuster, Ruscello, & Smith, 1992; Shuster, Ruscello, & Toth, 1995; Stringfellow & McLeod, 1994; Weaver-Spurlock & Brasseur, 1988; Williams, 1993; Wolfe, Blocker, & Prater, 1988; Wood, 1988; Young, 1987). The broad range of available treatment methods can be classified generally as those that adopt a sensory-motor approach as opposed to a cognitive-linguistic approach to clinical intervention (Bernthal & Bankson, 1993). Despite apparent differences, all are within an acceptable range of clinical practice.

For issues of treatment efficacy, the teaching methods used in treatment provide precisely the means for facilitating positive improvements in the sound systems of children with functional phonological disorders. Four established approaches to phonological treatment are briefly summarized to illustrate some of the available treatment methods. The examples include both sensory-motor and cognitive-linguistic treatment methods. The specific treatments were selected for description because they have been widely documented in the clinical research literature to positively affect a child's sound system, resulting in more accurate production and use of speech sounds and improved intelligibility.

A *traditional approach* to sound teaching considers both the perception and production of speech sounds and introduces linguistic complexity with successive improvements in sound learning (Van Riper & Emerick, 1984; Winitz, 1969, 1975). Treatment typically starts with what has been called ear training or auditory bombardment. A child listens to and may judge the accuracy of a target sound in an attempt to improve speech sound awareness and the self-monitoring of speech. Treatment then progresses to sound production, with the child producing the target sound in units of increasing linguistic complexity. That is, sound production may begin in isolation (e.g., [s]), advancing to syllables (e.g., [sa] [as] [asa]), then words, phrases, sentences, and finally, conversational speech. In each case, sound production is likely to be supported at first by imitation of the speech-language pathologist's verbal model. Over time and with improvement, this model may be phased out, so the child is producing the target sound spontaneously. In addition, the target sound may be first introduced in a limited context, typically the word-initial position, followed by word-final and then word-medial positions. The traditional approach is considered a sensory-motor

method of sound teaching (Bernthal & Bankson, 1993). Although it specifically provides a means of improving articulation skills associated with motor difficulties in sound production, the traditional approach is often widely used in the treatment of a broad range of phonological disorders.

A second example of a method of phonological treatment is *cycles* (Hodson & Paden, 1991). Like a traditional approach, this method involves auditory bombardment in conjunction with sound production. The full range of target sounds a child produces in error, and the patterns relating sound errors, are first identified. These sounds are then introduced in turn in successive treatment sessions. Complete mastery of a given sound is not required before the introduction of a subsequent sound in the cycle; rather, a child samples target sounds auditorily and productively across the treatment sequence. If a child continues to produce a target sound in error even after intensive exposure to that sound, then that target may be "recycled" until more accurate discrimination and production result. This approach to treatment exposes a child to a wide range of sound contrasts in the language. The emphasis is on language input in an effort to parallel the process of normal sound development (Elbert, 1984; Ingram, 1989a; Locke 1983b, 1993; Moskowitz, 1980; Stoel-Gammon & Cooper, 1984).

A third example is a method of *minimal pair treatment* (Blache & Parsons, 1980; Blache, Parsons, & Humphreys, 1981; Elbert, Rockman, & Saltzman, 1980; Ferrier & Davis, 1973; Gierut, 1989, 1990a, 1991, 1992; Gierut & Neumann, 1991; Saben & Ingham, 1991; Tyler, Edwards, & Saxman, 1987; Weiner, 1981b). Minimal pairs are two words that differ by one sound, as in rhyming words like *sun–fun*. In its conventional application, minimal pair treatment associates the target sound with its corresponding error substitute. That is, if a child produces [f] as the substitute for target /s/, then the two sounds [f] and [s] would be introduced together and contrasted during treatment. The sounds are presented in rhyming words like *sun–fun* or *sit–fit*. The goal of teaching is to instruct the child that it is necessary to use two different sounds to signal differences in meaning between words. If a distinction is not made between the target and substitute sound, then there will be a breakdown in communication, with both words being produced identically (Gierut, 1991; Ingram, 1989b; Leonard, Camarata, Schwartz, Chapman, & Messick, 1985; Leonard, Schwartz, Allen, Swanson, & Loeb, 1989; Locke, 1979). This potentially results in confusion because a listener may not know the child's intent. The minimal pair approach has been deemed a conceptual form of sound teaching and is frequently used in the treatment of phonological disorders stemming from cognitive or linguistic difficulties.

A final illustration is *metaphon*, a method of phonological treatment that has most recently been introduced in the clinical efficacy literature (Dean et al., 1995; see also Klein, Lederer, & Cortese, 1991; Tomes & Shelton, 1989). This cognitive-linguistic treatment aims to increase metalinguistic awareness as a means of facilitating phonological change and improved sound production. Like minimal pair treatment, metaphon emphasizes contrasts among speech sounds and sound properties. The first phase of treatment involves the conceptualization of opposites, as in *long* versus *short*, *front* versus *back*, or *noisy* versus *quiet*. These concepts are introduced generally and independently of their role in phonology or speech. The second phase of treatment is designed to transfer these general concepts to the speech domain by contrasting sounds that differ—for example, in duration (e.g., long–short), place of articulation (e.g., front–back), or manner of production (e.g., noisy–quiet). Minimal pairs are used to illustrate these conceptual differences and sound contrasts. Metaphon is similar to minimal pair treatment because it provides opportunities for a child to explore phonemic contrasts. It makes a child aware of failed communication attempts that result from a collapse of contrasts (i.e., homophonous productions). Metaphon is unique, however, because it includes a teaching component that employs the recognition, matching, and categorization of sounds—abilities that are associated with metalinguistic and early reading skills (Bleile & Hand, 1995; Goswami & Bryant, 1990; Swank & Catts, 1994).

It is noteworthy that methods of phonological treatment have been administered in different ways—also contributing to treatment effectiveness. For the most part, effective treatment relies on interpersonal interactions between a speech-language pathologist and a child (Elbert & Gierut, 1986; Fey, 1986). Yet, other service delivery models that actively involve parents as facilitators in the teaching process have been shown to produce positive results (Broen & Westman, 1990; Fey et al., 1994; Hodson & Paden, 1991; Kupperman et al., 1980; Shelton, Johnson, & Arndt, 1972; Shelton, Johnson, Willis, & Arndt, 1975). Recent advances in computer technology have also influenced the delivery of speech sound treatment. Computerized speech instruction has been implemented, evaluated, and continues to be developed (Kewley-Port, Watson, Elbert, Maki, & Reed, 1991; Masterson, 1995a, 1995b; Ruscello, Yanero, & Ghalichebaf, 1995; Shriberg, Kwiatkowski, & Snyder, 1986, 1989, 1990). For the most part, computerized treatment has been successful with school-age children as a supplement to clinical treatment provided by a speech-language pathologist. Children who participate are typically mildly to moderately impaired and produce a few target sounds in error; and these may be persistent errors, resistant to change through conventional teaching methods. During computerized instruction, a child is involved in an interactive program that involves drill in the production and/or perception of target sounds. The child receives visual and auditory feedback about the accuracy of responding in a computer game format. Computer-assisted instruction has been reported to be highly effective because it is structured, supplemental, entertaining, and can be completed independently by the child.

In summary, treatment effectiveness for functional phonological disorders has been demonstrated through the success of teaching methods and procedures in improving speech intelligibility and in bridging the gap between the sound system of the child and that of the target phonology. The available treatment methods are oftentimes based on different theoretical frameworks, emphasize different treatment goals, and rely on different teaching strategies. Despite differences, the most appropriate treatment method for a given child emerges directly from the results of the diagnostic assessment of the phonological disorder (Dyson & Robinson, 1987). For the most part, treatment delivery follows a direct service model whereby the speech-language

pathologist provides the treatment; however, other models that utilize parents or computers in treatment have also produced positive results.

Treatment Effects: Types of Phonological Change

The effects of phonological treatment are reflected in the positive changes that such treatment induces in a child's sound system. Phonological change (i.e., generalization) can occur to different extents (Gierut, Morrisette, Hughes, & Rowland, 1996). The most local change involves generalization in production and use of the sound that is being directly taught. In comparison, the most global change involves generalization in production of sounds that are not directly taught, thereby prompting widespread gains that can affect the entire sound system. These changes are not accidental, but rather are planned for and routinely expected following phonological treatment (Irwin, West, & Trombetta, 1966; Powell, 1991). Improvements in a child's sound system are generally monitored during treatment but also may be traced longitudinally to several months posttreatment, during which time continued treatment would not necessarily be provided. Thus, change in both treated and untreated (errored) sounds are important indicators of treatment efficacy, with generalization being reported both during and following treatment (Bain & Dollaghan, 1991; Olswang & Bain, 1994; Winner & Elbert, 1988). The strongest evidence of treatment efficacy comes in the form of global and longitudinal system-wide change in a child's sound system, resulting in improved intelligibility.

Changes in treated sounds. A number of positive improvements in production of treated sounds have been documented following clinical treatment (Elbert & McReynolds, 1979). Specifically, it has been demonstrated that if a sound is taught in a limited number of words, change extends more broadly to other words that also contain that target sound (Elbert & McReynolds, 1978; Hoffman, 1983). In fact, it may only be necessary to teach a sound in three to five different words in order to get widespread lexical change (Elbert, Powell, & Swartzlander, 1991). This is extremely economical in that mastery of only a few exemplars facilitates generalization in sound production across the child's vocabulary.

Similar changes have been reported across phonetic contexts (Elbert & McReynolds, 1975; Hoffman, 1983; Hoffman, Schuckers, & Daniloff, 1980; Kent, 1982; Weston & Irwin, 1971). For instance, treatment may emphasize production of a target sound in a given word position, but accurate sound production is observed in other word positions as well. As with lexical change, production of the target sound in these alternate contexts need not be directly taught; these gains may be obtained for "free."

Another type of change is extension of a treated sound to more complex linguistic units (Bernhardt, 1992a). Here, treatment of a sound may focus on production at the syllable level, but this training in turn stimulates increased sound accuracy at the word level (McReynolds, 1972; Powell & McReynolds, 1969). Similarly, treatment at the word level promotes improvements in sound accuracy in spontaneous connected speech (Elbert, Dinnsen, Swartzlander, & Chin, 1990; Shriberg & Kwiatkowski, 1987).

One other kind of generalization with treatment involves the use of a treated sound in different settings (Bankson & Byrne, 1972; Costello & Bosler, 1976; Olswang & Bain, 1985). Treatment is likely to be provided in a carefully controlled environment such as a clinic, hospital, or school. But, for treatment to be truly successful, it is necessary that accurate sound production be maintained in less structured and nonteaching situations. Transfer across settings has been documented both with and without additional (temporary) treatment in those settings (Gray & Shelton, 1992; Koegel, Koegel, & Ingham, 1986; Koegel, Koegel, Van Voy, & Ingham, 1988; Shriberg & Kwiatkowski, 1990).

Changes in untreated sounds. Phonological treatment has also been effective in promoting generalization to other errored sounds that are not directly treated (Rockman & Elbert, 1984). Widespread improvements in untreated sounds are largely traceable to certain relationships that exist among sounds in a language. More generally, sounds of a language can be described in terms of where they are articulated in the vocal tract (i.e., place of articulation) and how they are articulated (i.e., manner of articulation). Within these categories, sounds may also be produced with or without vocal fold vibration (i.e., voicing). To illustrate, some target English sounds produced in the same place of articulation are called the alveolars. These sounds involve raising the tongue tip in production, as with the sounds [n t d l]. An example of some target English sounds produced with the same manner of articulation are the fricatives—these having noisy continuant air flow, as with the sounds [s z ʃ]. Voicing differences are illustrated in pairs of sounds sharing the same place and manner of articulation, as in the pair [p] (voiceless with no vocal fold vibration)–[b] (voiced with vocal fold vibration) or [f] (voiceless)–[v] (voiced).

These general relationships among sounds are significant because prominent changes associated with these categories have been reported in the treatment literature. In particular, treatment of one representative aspect of a sound category has been shown to facilitate improvements across that category of similarly articulated sounds. This is termed *within-class generalization*. It has been widely cited for all places, manners, and voicing of production. To provide some examples, for place of production, treatment of the alveolar sound [s] prompted change in untreated alveolar [n], also produced in error by the child (Gierut, 1989). For manner, treatment aimed at production of the fricates [s θ] enhanced change in other untreated errored fricatives [z ð ʃ] (Costello & Onstine, 1976). Finally, treatment of one member of a voiced–voiceless pair facilitated mastery of its untreated counterpart (Elbert, Shelton, & Arndt, 1967; McReynolds & Bennett, 1972).

General relationships among sounds can also be described in terms of the kinds of error patterns a child exhibits (Camarata & Gandour, 1984; Edwards, 1992; Hodson, 1992; Leonard, 1985, 1992; Weiner, 1981a). Two common error patterns often seen in children's speech are the omission of final consonants (e.g., *boat* produced [bo]) and the simplification of consonant clusters or blends (e.g., *stone* produced [ton]) (Hodson & Paden, 1981; Ingram, 1989b; Stoel-Gammon & Dunn, 1985). Treatment studies have focused on eliminating such error patterns by teaching a few sounds affected by the pattern and watching for broad changes across the pattern. The primary intent of this treatment is to interrupt the pattern through illustration of a few sounds. Results support the effectiveness of this

approach because treatment of representative exemplars of the error pattern has indeed facilitated improvements in other sounds disrupted by that same pattern (Elbert & McReynolds, 1985; Powell & Elbert, 1984; Weiner, 1981b). This too reflects another kind of within-class generalization.

In addition to cases of within-class generalization, the treatment literature has also documented *across-class generalization*. Here, improvements not only extend to untreated sounds of the same category as the treated sound, but also to untreated sounds from different categories. When across-class generalization occurs, the result is broad and system-wide change in a child's sound system. One kind of across-class generalization has been directly associated with a linguistic phenomenon known as *markedness*. Markedness describes the implicational relationships among sounds and sound categories. The implication is stated as follows: If a language has property X (i.e., marked), it will also have property Y (i.e., unmarked) but not vice versa. Implicational relationships have been tested in phonological treatment because one prediction is that treatment of a marked sound X will prompt changes in the unmarked sound Y without direct instruction of Y. This prediction has in fact been shown to hold for children with phonological disorders in the acquisition of a wide range of known implicational relationships of language. These include the acquisition of (a) voiced as opposed to voiceless obstruents (McReynolds & Jetzke, 1986), (b) voicing of stops in word-final as opposed to word-initial position (Rockman, 1983), (c) fricatives as opposed to stops (Dinnsen & Elbert, 1984), (d) clusters as opposed to singletons (Elbert & McReynolds, 1978; Gallagher & Shriner, 1975), and (e) marked clusters as opposed to unmarked clusters (Elbert, Dinnsen, & Powell, 1984; Powell & Elbert, 1984). In these reported cases, both within- and across-class generalization was typically observed, resulting in overall improvements in the child's sound system.

In summary, the effects of phonological treatment have been documented for treated and untreated errored sounds. Treatment is effective in improving treated sounds, as demonstrated by generalization across lexical items, phonetic contexts, units of increasing linguistic complexity, and settings. Treatment promoting changes in untreated sounds is in part associated with category relationships among sounds, such that treatment of one member of a sound category (or one aspect of an error pattern) triggers change in other members of the same category. In some instances, change can be even broader, affecting untreated sounds from other categories as well. This latter case may be related to the implicational relationships among sounds in language. It is important to note that individual differences exist among children in terms of the nature and extent of generalization observed with treatment. Two children exhibiting similar phonological systems being taught the same target sound might evidence different degrees of change in the treated sound, the number of untreated sounds that improve, the categories that change, or the accuracy of change. Although change in a child's sound system may be expected with treatment, the specifics of such change are not yet predictable in a direct or absolute way. Variability in learning across children is a central research question that deserves continued attention.

Treatment Efficiency: Comparisons of Phonological Treatments

The efficiency of phonological treatment has not been examined as extensively as other issues of treatment efficacy. There are relatively few published studies that have established that one treatment results in greater changes in a child's sound system than another. Even scarcer are comparisons of the time it takes to complete treatment using different methods or procedures (Campbell & Bain, 1991). Of the available treatment comparisons, research has emphasized three lines of study: comparisons of treatment methods, sounds targeted for treatment, and modes of presentation of sounds in treatment. It should be emphasized that, although few in number, these comparisons are based on carefully controlled replicable experimental studies. Moreover, the outcome of these studies lends additional support to the effectiveness of phonological treatment because improvements in sound production were always observed. This was true despite relative differences in treatment effects across the experimental conditions.

Treatment methods. One line of efficiency research has examined specific methods of treatment in facilitating phonological change. A series of studies focused exclusively on the minimal pair method of treatment, comparing the efficiency of alternate forms of this approach to teaching (Gierut, 1990a, 1991, 1992; Gierut & Neumann, 1991). The collective findings from this line of investigation identified greater change when minimal pair treatment introduced the child to two new (previously errored) sounds in comparison to each other. (For comparable findings in the semantic domain, see Au & Laframboise, 1990.) Moreover, if the treated sound pair also differed along multiple and higher-order category dimensions, then greater phonological change occurred. In other words, widespread phonological improvements were facilitated when treated sounds differed by a number of distinctive features including major class features. To illustrate, if the sounds / k l / were in error, then these sounds would be paired for treatment as in the rhyming words *cap–lap*. This pair would be especially conducive to promoting system-wide change because the sounds / k l / differ in terms of place, manner, and voicing of production, and they represent different major classes of phonological organization (i.e., obstruent vs. sonorant, respectively).

The method of minimal pair treatment has also been compared to cycles treatment and to treatment that emphasizes sound production in the more generalized context of language intervention (i.e., *whole language treatment*; Chaney, 1990; Norris & Damico, 1990). In the comparison of minimal pair and cycles treatments (Tyler et al., 1987), results indicated that the two were essentially equivalent in effecting phonological change. Although both treatments resulted in significant quantitative improvements in sound production, there was the suggestion that children with focused error patterns might be better candidates for minimal pair treatment, whereas those with broad-based phonological problems might benefit from cycles treatment. These recommendations, however, have not been experimentally evaluated. It should also be mentioned that these two methods of treatment—minimal pair and cycles—may be associated with different goal attack strategies (Fey, 1986). For example, minimal pair treatment was

implemented in this study as a vertically structured program, where two target sounds were treated to pre-established criteria before a child's advancement through the treatment sequence. By comparison, cycles treatment combined both vertical and horizontal instructional strategies because several goals were identified, and treatment was implemented for specific lengths of time independent of a child's performance. Thus, from the available results, both minimal pair and cycles treatments (or by extension, vertical and/or horizontal goal attack strategies) may be equally effective and efficient.

Mixed results have been reported in comparing minimal pair treatment to whole language intervention. The conflicting results are likely associated with general differences in methodology, participant selection, and treatment administration across the available studies. In a preliminary study of two children (Hoffman, Norris, & Monjure, 1990), both minimal pair treatment and whole language intervention resulted in comparable phonological gains. The treatments differed, however, in their impact on the semantic and syntactic use of language, with whole language treatment facilitating a child's expressive construction of stories. In other more comprehensive studies, however, this general finding was not supported (Fey et al., 1994; Tyler & Watterson, 1991). Whole language treatment did not facilitate phonological gains; improvements were noted only in children's expressive use of language. A general conclusion from these latter investigations is that treatment for phonological disorders must be specifically directed at phonology if significant improvements in the productive sound system are to be observed.

Treated sounds. Efficiency studies have also focused on comparisons of the kinds of sounds that are taught and the relative improvements that follow. One consideration in the selection of target sounds for treatment relates to ease of production and its impact on learning. Several studies have addressed this issue from varying perspectives. In one report, treatment of sounds following a developmental sequence was examined (Gierut et al., 1996). An assumption is that sounds acquired first by children who are normally developing are easier to learn than sounds acquired later. As applied to children with phonological disorders, there is a further assumption that children with disorders follow the same path in treatment as in normal acquisition. In related experiments, children were taught developmentally early versus later acquired sounds. Those taught early-acquired sounds showed improvements in the treated sound, and within-class generalization was observed. In contrast, children taught developmentally later-acquired sounds evidenced change in the treated sound, and both within- and across-class generalization occurred. These results indicate that treatment of both early- and later-acquired sounds promotes phonological gains, but that treatment of later-acquired sounds may be more efficient because improvements were more broadly observed across children's sound systems.

Another study bearing on ease of production compared treatment of sounds that are phonetically more complex to those that are phonetically less complex (Dinnsen et al., 1990; Tyler & Figurski, 1994). Extensive change was observed when treatment focused on the more complex phonetic distinctions, rather than the simpler distinctions. Related findings have also emerged from examinations of the role of acoustic phonetic distinctions in phonological learning (Catts & Jensen, 1983; Forrest & Rockman, 1988; Forrest, Weismer, Elbert, & Dinnsen, 1994; McLeod & Isaac, 1995; Smit & Bernthal, 1983; Tyler & Saxman, 1991; Weismer, 1984; Weismer, Dinnsen, & Elbert, 1981). Research has shown that some children may produce subtle acoustic phonetic differences among sounds, but that these differences are not auditorily perceptible to listeners. If a child maintains an acoustic (but not auditorily perceptible) distinction, then treatment may be unnecessary (Forrest, Weismer, Hodge, Dinnsen, & Elbert, 1990), or mastery in conjunction with treatment may be quite rapid (Tyler, 1995; Tyler, Edwards, & Saxman, 1990; Tyler, Figurski, & Langsdale, 1993). A suggestion is that acoustic distinctions appear to be predictors of imminent change and may require no or minimal treatment. Instead, sounds that are not acoustically differentiated warrant direct clinical attention.

Treatment of stimulable as opposed to nonstimulable sounds has also been examined in regard to ease of production (Powell, Elbert, & Dinnsen, 1991). *Stimulability* refers to a child's ability to accurately produce a target sound (otherwise produced in error) when provided with an auditory-visual model (Klein et al., 1991). The outcome was that treatment of a nonstimulable sound prompted change in that and other untreated (previously errored) stimulable sounds. In comparison, treatment of a stimulable sound did not necessarily lead to changes in untreated stimulable or nonstimulable sounds. The implication of these findings is that treatment of nonstimulable sounds may be more efficient than treatment of stimulable sounds because more widespread change occurred.

In other, related research, a child's linguistic competence, or internalized knowledge of the productive sound system, was examined relative to phonological change (Dinnsen & Elbert, 1984; Gierut, Elbert, & Dinnsen, 1987; Tyler et al., 1990; Williams, 1991). Comparisons were between treatment of target sounds of which a child had "least" versus "most" knowledge, as based on standard generative linguistic analyses. Operationally, *least phonological knowledge* translated to treatment of target sounds that were excluded from the phonetic and phonemic inventories of the child (i.e., phonotactic constraints); *most phonological knowledge* referred to target sounds that patterned variably by phonetic context (i.e., allophonic or neutralization rules). The general outcome was that treatment aimed at least knowledge resulted in extensive system-wide phonological change, whereas treatment of most knowledge contributed to focused but limited changes in a child's overall sound system. This suggests that more efficient treatment may involve teaching target sounds that are excluded from a child's repertoire.

Mode of presentation. The mode of presentation of a sound during treatment is another factor that has been examined with regard to relative efficiency. In particular, treatment of sound production as opposed to sound perception has been evaluated, yielding conflicting results. One initial study determined that treatment aimed at sound production was more effective than treatment aimed at sound perception (Williams & McReynolds, 1975). Treatment of sound production facilitated changes in both sound production and perception, whereas treatment of sound perception only enhanced perception but not production. However, a more recent set of studies has shown that children do evidence improvements in

sound production following perception training (Rvachew, 1994; Rvachew & Jamieson, 1989). These opposing results are likely attributable to broad differences in methodologies and technologies being used in perceptual treatment.

In another study, the effectiveness of teaching sounds through formal drill, through drill combined with play, and through play alone were compared (Shriberg & Kwiatkowski, 1982b). The result showed that children and speech-language pathologists alike preferred the drill-play combination of teaching to enhance phonological improvements.

Computer-assisted instruction has also been compared to treatment administered by speech-language pathologists. In a series of studies, both modes of treatment presentation were demonstrated to be comparable in effectiveness and efficiency (Shriberg et al., 1986, 1989, 1990). Several suggestions to guide selection of the most appropriate mode of presentation were offered. In particular, the speech-language pathologist may best facilitate accurate sound production during the earliest phases of treatment when the target sound is not yet stabilized. Children who are very young, distractible, or require feedback in the form of eye contact may also benefit most from services delivered by the speech-language pathologist. Computerized instruction may facilitate sound production in the later phases of treatment because it is flexible and readily captures the attention of children.

In summary, efficiency of phonological treatment has been demonstrated by converging lines of investigation that compare treatment methods, treatment targets, and treatment presentation. From the literature to date, the most efficient treatment appears to involve teaching sounds or sound pairs that are not in a child's pretreatment repertoire. Of these, selecting developmentally later-acquired sounds that are also phonetically more complex, acoustically undifferentiated, and nonstimulable may enhance greater phonological change. Although there may be no difference between treatments that use vertical and/or horizontal goal-attack strategies, treated sounds should be presented using drill combined with play for efficient teaching. Treatment may be administered using microcomputers, but consideration should be given to the child's age,

Case Study

Background Information

This clinical case, reported by Gierut (1989), is intended as an illustration of the nature of a disordered sound system, possible types of change that may occur in the system, and treatment methods that may facilitate such change. It should be recognized that children with phonological disorders are not a homogenous group and that individual differences in learning are one hallmark of this population.

This particular treatment study involved a young boy J, age 4 years, 7 months. J displayed an error pattern that involved the omission of all word-initial consonants except for the sounds [m b w y]. He was highly unintelligible because nearly all of the words he produced began with a vowel. J was normally developing in all respects except for sound production. His history did reveal a secondary cleft of the hard and soft palates that was surgically repaired and required no further medical or dental procedures. There was no necessary connection between the child's word-initial omissions and his history of secondary cleft palate because children with a history of cleft palate typically exhibit more errors in medial than initial position and more errors of substitutions than omissions (Philips & Harrison, 1969).

Treatment Goals

The goal of treatment was to interrupt this error pattern of word-initial consonant omission, which affected 16 target sounds. The teaching method involved a version of minimal pair treatment. In this case, an errored sound that J omitted in the word-initial position was paired with target sounds that he produced correctly in this same position. Thus, the pairing was between unknown and known sounds. Treatment focused directly on the production of these sound pairs.

Treatment Progress

Treatment began with production of [s] in comparison with other known (correct) word-initial sounds [m b w]. [y] was set aside in treatment because [m b w] are all produced in the same place of articulation (i.e., labials), whereas [y] is not. Following the first phase of teaching, J acquired three word-initial sounds: the treated sound [s] and untreated sounds [n h]. All were produced with 100% accuracy. Treatment then shifted to production of word-initial [tʃ] in contrast to the known sounds [m b s]. Following this phase of treatment, J mastered seven additional word-initial sounds: the treated sound [tʃ] and untreated sounds [t d z l ʃ dʒ]. Given this, there were only six remaining word-initial sounds for J to learn: [p k g f v θ]. Treatment next focused on production of word-initial [f] in comparison to the known sounds [m b s tʃ]. Upon completion of this phase of treatment, J had learned all word-initial target sounds except [k g]. Consequently, he was dismissed from treatment. One week later, J returned for posttesting, and at this time, both [k g] were being produced with 100% accuracy.

In summary, phonological treatment for this child facilitated improvements in the production and use of 16 word-initial sounds. Positive changes occurred following treatment of only three sets of sound pairs. For this child, both within- and across-class generalization were observed following a relatively short period of treatment. The entire treatment period spanned 3 months and involved 23 direct treatment sessions. No subsequent phonological treatment was needed, and intelligibility was greatly improved in time for the child's entry into kindergarten.

behavior, and linguistic ability. Treatment of perception versus production of sounds remains to be evaluated differentially, but the available evidence suggests that both may lead to improved phonological skills. Treatment that focuses on improving expressive language skills does not seem to lead to phonological gains, although this requires further validation. Taken together, it appears that greater phonological change occurs when more complex or linguistically challenging information is presented in treatment that utilizes drill-play. This is not to say that change is necessarily precluded if other sounds are treated using different methods of instruction. Simply, when evaluated relative to each other, the greatest change occurred in these conditions, resulting in the more efficient treatment.

Concluding Remarks

Treatment of functional phonological disorders in children is an established, well-documented form of clinical intervention. To date, the available research has clearly demonstrated the positive effects of such treatment. Children who receive phonological treatment exhibit both narrow and broad changes in their sound systems that enhance their overall intelligibility and general communicative functioning. A wide variety of effective treatment methods are available for facilitating such change in children's sound systems, with some procedures being more efficient than others. There are no known risks involved in the treatment, and the long-term benefits for continued communicative, educational, and social success are beginning to be documented (Shriberg & Kwiatkowski, 1994).

In accord with the aims of "Healthy People 2000," the National Institute on Deafness and Other Communication Disorders (1994) has established phonological treatment efficacy as one research priority. The direction of future research on the efficacy of phonological treatment will no doubt emphasize the development of novel and improved teaching methods. Greater consideration may be given to treatment of the production of vowels, nonsegmental errors involving stress or intonation, or multifaceted speech errors, as in disorders of phonology combined with disfluency. The broad applicability of such treatments to other nonfunctional disorders, to children who are bilingual or bidialectal, or to learners of English as a second language is a related concern.

The identification of the sources of individual differences in phonological learning is another fundamental research need. From this, it may be possible to establish the minimal and defining conditions of phonological change for all children, with potential precedence relationships among the contributing factors. These facilitating conditions could then be applied systematically in phonological treatment to potentially guarantee specific improvements in sound production and generalization.

Continued evaluation of relative treatment efficiency is also an important research goal. The direct comparison of treatment methods and the time it takes to successfully complete different treatment programs are topics to be addressed. Most important, research that systematically examines the etiology, course, and remediation of functional phonological disorders will ultimately bring us closer to the prevention, diagnosis, and treatment of this communication disorder that affects so many of our nation's children.

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