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Special Issue: Facilitating Speech Production

CASLPA-ACOA

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The Canadian Association of Speech-Language Pathologists and Audiologists (CASLPA) is the only national body that supports and represents the professional needs of speech-language pathologists, audiologists and supportive personnel inclusively within one organization. Through this support, CASLPA champions the needs of people with communications disorders. The association was founded in 1964 and incorporated under federal charter in 1975. CASLPA's periodical publications program began in 1973.

The purpose of the *Canadian Journal of Speech-Language Pathology and Audiology* (CJSLPA) is to disseminate contemporary knowledge pertaining to normal human communication and related disorders of communication that influence speech, language, and hearing processes. The scope of the Journal is broadly defined so as to provide the most inclusive venue for work in human communication and its disorders. CJSLPA publishes both applied and basic research, reports of clinical and laboratory inquiry, as well as educational articles related to normal and disordered speech, language, and hearing in all age groups. Classes of manuscripts suitable for publication consideration in CJSLPA include tutorials; traditional research or review articles; clinical, field, and brief reports; research notes; and letters to the editor (see Information to Contributors). CJSLPA seeks to publish articles that reflect the broad range of interests in speech-language pathology and audiology, speech sciences, hearing science, and that of related professions. The Journal also publishes book reviews, as well as independent reviews of commercially available clinical materials and resources.

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The Canadian Association of Speech-Language Pathologists and Audiologists ...the national voice and recognized resource for speech-language pathology and audiology.

Mission

The Canadian Association of Speech-Language Pathologists and Audiologists ...supporting and empowering our members to maximize the communication and hearing potential of the people of Canada

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L'Association canadienne des orthophonistes et audiologistes (ACOA) est l'association professionnelle nationale reconnue des orthophonistes et des audiologistes du Canada. L'Association a été fondée en 1964 et incorporée en vertu de la charte fédérale en 1975. L'Association s'engage à favoriser la meilleure qualité de services aux personnes atteintes de troubles de la communication et à leurs familles. Dans ce but, l'Association entend, entre autres, contribuer au corpus de connaissances dans le domaine des communications humaines et des troubles qui s'y rapportent. L'Association a mis sur pied son programme de publications en 1973.

L'objet de la *Revue canadienne d'orthophonie et d'audiologie* (RCOA) est de diffuser des connaissances relatives à la communication humaine et aux troubles de la communication qui influencent la parole, le langage et l'audition. La portée de la Revue est plutôt générale de manière à offrir un véhicule des plus compréhensifs pour la recherche effectuée sur la communication humaine et les troubles qui s'y rapportent. La RCOA publie à la fois les ouvrages de recherche appliquée et fondamentale, les comptes rendus de recherche clinique et en laboratoire, ainsi que des articles éducatifs portant sur la parole, le langage et l'audition normaux ou désordonnés pour tous les groupes d'âge. Les catégories de manuscrits susceptibles d'être publiés dans la RCOA comprennent les tutoriels, les articles de recherche conventionnelle ou de synthèse, les comptes rendus cliniques, pratiques et sommaires, les notes de recherche, et les courriers des lecteurs (voir Renseignements à l'intention des collaborateurs). La RCOA cherche à publier des articles qui reflètent une vaste gamme d'intérêts en orthophonie et en audiologie, en sciences de la parole, en science de l'audition et en diverses professions connexes. La Revue publie également des critiques de livres ainsi que des critiques indépendantes de matériel et de ressources cliniques offerts commercialement

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ACOA : Vision et Mission

Vision

L'Association canadienne des orthophonistes et audiologistes : porte-parole national et ressource reconnue dans le domaine de l'orthophonie et de l'audiologie.

Mission

L'Association canadienne des orthophonistes et audiologistes appuie et habilite ses membres en vue de maximiser le potentiel en communication et en audition de la population canadienne.

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Erratum

The english masthead in the Summer 2010 edition of CJSLPA should have read that associate editor Vincent Gracco is affiliated with McGill University.

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Special Issue: Facilitating Speech Production

Fall Issue

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Intervention for speech production in children and adolescents: overview

Children with protracted phonological development (PPD, often called speech sound disorders) comprise the largest group in speech-language pathologists' paediatric caseloads (ASHA, 2003). Intervention for speech production can be relatively effective in the short-term (Baker, 2010; Law, Garrett & Nye, 2009). However, the rate of change during intervention may be less efficient than clients and clinicians would like (Gierut, 1998). In fact, the word 'adolescent' in the title of the issue indicates that speech difficulties can persist for years after early intervention (Shriberg, Kwiatkowski & Gruber, 1994; Rvachew, Chang & Evans, 2007; Modha, Bernhardt, Church, & Bacsfalvi, 2008). Furthermore, even if speech normalizes through intervention early on, children with a history of protracted phonological development are at greater risk for difficulties with the acquisition of literacy skills (e.g. Leitão & Fletcher, 2004; Rvachew, Chang & Evans, 2007). Thus, there is a continuing need to innovate methods in assessment and treatment in order to maximize success potential, both for speech production and its related skills (literacy).

The current issue takes an inclusive approach to the area of speech difficulties in children and adolescents. That is, any person whose speech development appears to be taking longer than what speakers in the region consider average is considered to have *protracted phonological development* (without indication of etiology or attribution of 'disorder' or 'impairment', terms which have a negative connotation). The "phonological system" is assumed to include representation of phonetic form (both perceptual and productive), processing of form (input and output) and actual articulation (low-level articulatory phonetics).

Reflecting that all-encompassing point of view, the issue includes five papers addressing habilitation of speech production from various perspectives. The introductory paper on models of speech production (Bernhardt, Stemberger & Charest, this issue) provides a framework for the papers that follow, showing the many possible avenues into the speech production system, and consequently the alternative possibilities for assessment and treatment. Two papers focus primarily on the speech production system (Bacsfalvi; Bernhardt & Zhao) and two on related areas in the language system (Baker & McCabe; Shiller, Rvachew & Brosseau-Lapré). Bernhardt and Zhao show an adapation of a nonlinear scan analysis and goal selection (Bernhardt & Stemberger, 2000) for Mandarin (a clinical by-product of the first author's study of protracted phonological development in 12 languages). Bacsfalvi describes the use of ultrasound in evaluation and treatment of /r/ for three adolescents with cochlear implants and provides a basic introduction to ultrasound therapy for speech production. Visual feedback for tongue movements translates into later speech production improvements. Shiller, Rvachew and Brosseau describe the close links between speech perception and production and the relevance of systematic speech perception training in phonological intervention for a child learning French. Baker and McCabe outline an approach to intervention focusing on conversational repair strategies (clarification requests). As noted, two papers address languages other than English: Canadian French and Mandarin.

We invite the readers to contact the authors for further clarification of the methods and to develop their own innovations based on the papers in this issue and other possibilities brought to light through the study of speech production models.

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Rvachew, S., Chiang, P. & Evans, N. (2007). Characteristics of speech errors produced by children with and without delayed phonological awareness skills. *Language, Speech, and Hearing Services in Schools*, *38,* 60-71.

Shriberg, L.D., Kwiatkowski, J. & Gruber, F.A. (1994). Developmental phonological disorders II: Short-term speech-sound normalization. *Journal of Speech and Hearing Research*, *37,* 1127-1150.

May Bernhardt
Guest editor
bernharb@interchange.ubc.ca

Édition spéciale : Faciliter la production de la parole

Numéro d'automne

■ ■ ■

Interventions en production de la parole chez les enfants et les adolescents : un aperçu

Les enfants avec un retard du développement phonologique (souvent appelé trouble des sons de la parole) constituent la plus grande proportion des cas des orthophonistes travaillant auprès des enfants (ASHA, 2003). L'intervention en production de la parole peut être relativement efficace à court terme (Baker, 2010; Law, Garrett & Nye, 2009), mais les progrès pendant l'intervention peuvent être moins rapides que les clients et les cliniciens ne le préféreraient (Gierut, 1998). En effet, le mot « adolescents » dans le titre de ce numéro indique que les difficultés de parole peuvent persister bien des années après l'intervention précoce (Shriberg, Kwiatkowski & Gruber, 1994; Rvachew, Chang & Evans, 2007; Modha et al, 2008). De plus, même si la parole devient normale grâce à l'intervention, les enfants avec des antécédents de retard du développement phonologique sont à plus grand risque d'éprouver des difficultés dans l'apprentissage de la lecture et de l'écriture (p. ex., Leitão & Fletcher, 2004; Rvachew, Chang & Evans, 2007). Par conséquent, il existe un besoin continu d'établir de nouvelles méthodes d'évaluation et d'intervention pour maximiser le potentiel de réussite, tant pour la production de la parole que pour les habiletés connexes (l'apprentissage de la lecture et de l'écriture).

Le présent numéro examine de façon inclusive les difficultés de parole chez les enfants et les adolescents. On estime que toute personne dont le développement de la parole semble être plus lent que ce qui est considéré la moyenne chez les locuteurs de la région aurait un *retard du développement phonologique* (sans indication de l'étiologie ou l'attribution des termes « trouble » ou « déficience », qui ont une connotation négative). Aux fins de ces articles, le « système phonologique » comprend la représentation de la forme phonétique (tant perceptuelle que productive), le traitement de la forme (entrante et sortante) et l'articulation comme telle (phonétique articulatoire de bas niveau).

Afin de présenter un point de vue global de cette question, ce numéro comprend cinq articles examinant le traitement de la production de la parole de différents points de vue. L'article d'introduction sur les modèles de la production de la parole (Bernhardt, Stemberger & Charest, ce numéro) établit un cadre pour les articles qui suivent. Il illustre les nombreuses façons dont on peut analyser le système de production de la parole, et par le fait même, les méthodes possibles d'évaluation et de traitement. Deux articles sont principalement axés sur le système de production de la parole (Bacsfalvi; Bernhardt & Zhao), et les deux autres sur des domaines connexes dans le système langagier (Baker & McCabe; Shiller, Rvachew & Brosseau-Lapré). Bernhardt et Zhao démontrent une adaptation en mandarin (conséquence clinique de l'étude, par le premier auteur, du développement phonologique dans 12 langues) d'une analyse non linéaire et de la sélection des buts (Bernhardt & Stemberger, 2000). Bacsfalvi décrit l'utilisation d'ultrasons dans l'évaluation et le traitement du son /r/ chez trois adolescents avec un implant cochléaire et présente une introduction à la thérapie par ultrasons dans le domaine de la production de la parole. La rétroaction visuelle des mouvements linguaux donne lieu à des améliorations dans la production de la parole. Shiller, Rvachew et Brosseau décrivent les liens étroits entre la perception et la production de la parole, ainsi que la pertinence d'une formation systématique en perception de la parole dans le cadre de l'intervention phonologique chez un enfant apprenant le français. Baker et McCabe examinent une méthode d'intervention axée sur les stratégies de réparation de la conversation (demandes de clarification). Vous aurez noté que deux articles ciblent des langues autres que l'anglais, soit le français canadien et le mandarin.

Nous invitons les lecteurs à communiquer avec les auteurs pour obtenir de plus amples renseignements sur les méthodes présentées, ainsi qu'à établir leurs propres innovations fondées sur les articles dans ce numéro et les possibilités mises en valeur par l'étude des modèles de production de la parole.

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May Bernhardt
Rédactrice invitée
bernharb@interchange.ubc.ca

Intervention for speech production in children and adolescents: Models of speech production and therapy approaches. Introduction to the issue.

Interventions en production de la parole chez les enfants et les adolescents : modèles de production de la parole et méthodes d'intervention. Une introduction.

May Bernhardt
Joseph Stemberger
Monique Charest

Editorial process overseen by
Tim Bressmann

May Bernhardt, PhD
School of Audiology and Speech Sciences, University of British Columbia
Vancouver, British Columbia
Canada

Joseph Stemberger, PhD
Department of Linguistics, University of British Columbia
Vancouver, British Columbia
Canada

Monique Charest, MS
School of Audiology and Speech Sciences, University of British Columbia
Vancouver, British Columbia
Canada

Abstract

Although phonological intervention can be effective in the short-term (Law, Garrett & Nye, 2009), long-term normalization has been reported for only 20-50% of children (e.g., Rvachew, Chang & Evans, 2007). Furthermore, even in the short-term, not all children progress as quickly as might be hoped. Thus, it is important to continue to develop alternative approaches to intervention. The current issue describes recent studies concerning speech habilitation in children and adolescents, including an adaptation of nonlinear phonological assessment to Mandarin (Bernhardt & Zhao) and intervention approaches focusing on perception (Shiller, Rvachew & Brosseau-Lapré), discourse (Baker & McCabe) and visual feedback of tongue movements with ultrasound (Bacsfalvi). The range of approaches reflects the complexity of the speech production system. This introductory article discusses models of speech production processing as a foundation for the approaches presented.

Abrégé

Les interventions phonologiques peuvent être efficaces à court terme (Law, Garrett & Nye, 2009), mais la normalisation à long terme ne se produit que chez 20 à 50 % des enfants, selon la recherche (p. ex., Rvachew, Chang & Evans, 2007). De plus, même à court terme, les enfants ne progressent pas tous aussi vite qu'on ne l'espèrerait. C'est pourquoi il est important de continuer à établir de nouvelles méthodes d'intervention. Le présent numéro compte des études récentes sur la thérapie de la parole auprès des enfants et des adolescents, y compris l'adaptation d'une évaluation phonologique non linéaire en mandarin (Bernhardt & Zhao) et des méthodes d'intervention axées sur la perception (Shiller, Rvachew & Brosseau-Lapré), le discours (Baker & McCabe) et la rétroaction visuelle des mouvements linguaux à l'aide d'ultrasons (Bacsfalvi). La diversité des axes d'intervention de ces méthodes reflète la complexité du système de production de la parole. Cet article d'introduction examine des modèles de traitement de la production de la parole en tant que fondements des méthodes présentées.

Key words: Models of speech production, interactive activation models, phonological intervention, articulation and phonology

Children with protracted phonological development (PPD, sometimes called speech sound disorders of unknown origin) comprise the largest group in paediatric caseloads (ASHA, 2003). Although phonological intervention can be relatively effective in the short-term (Almost & Rosenbaum, 1998; Law, Garrett & Nye, 2009), studies report long-term normalization for only 20-50% of children (Shriberg, Kwiatkowski & Gruber, 1994; Bernhardt & Major, 2005; Rvachew, Chang & Evans, 2007). Even in the short-term, not all children progress quickly, especially if there are associated factors such as hearing impairment, orofacial anomalies, language or other cognitive processing difficulties. Thus, it is important for clinicians and researchers to continue to develop and evaluate approaches to speech habilitation.

The current issue describes recent research concerning speech habilitation in children and adolescents. Methods address both assessment and intervention: nonlinear phonological assessment adapted for Mandarin (Bernhardt & Zhao, this volume) and intervention focusing on perception (Shiller, Rvachew & Brosseau-Lapré, this volume), discourse (Baker & McCabe, this volume) and visual feedback of tongue movements with ultrasound (Bacsfalvi, this volume).

The range of approaches described reflects the complexity of speech production, which minimally requires integration of information from (a) perception; (b) representation (semantic, morphosyntactic and phonological); (c) articulatory parameters including speech timing and aerodynamics; and (d) discourse parameters. In the last few decades, psychologists, speech scientists and linguists have proposed a variety of models of speech production processing (see e.g., the issue of *Language and Cognitive Processes*, 2009, 24(5)). Models are abstractions of a dynamic process and thus underdetermine what actually occurs. However, reflection on the various aspects of speech production processing has the potential to stimulate new approaches to intervention. This introductory article thus discusses models of speech production processing as a foundation for the approaches presented in the issue. (See also Baker, Croot, McLeod, & Paul, 2001, for an earlier, still useful tutorial on the use of psycholinguistic processing models in speech therapy.)

Models of Language Production

Language production is a process that recodes a meaningful message into an output form that can be decoded by others to recreate the original message. While the creation of this message (i.e., what the speaker decides to say) is important, models of language production focus on what happens after that. Figure 1 indicates the various components involved in language production. Within the circle are the main linguistic levels for the processing of words and their pronunciations (ordered from early in processing at the top to later in processing at the bottom). Syntax is in a box at the right, showing interactions with multiple levels; the network of elements within the circle will be discussed in more detail below. Outside the circle are other aspects of cognition that influence language as well as cognition more broadly.

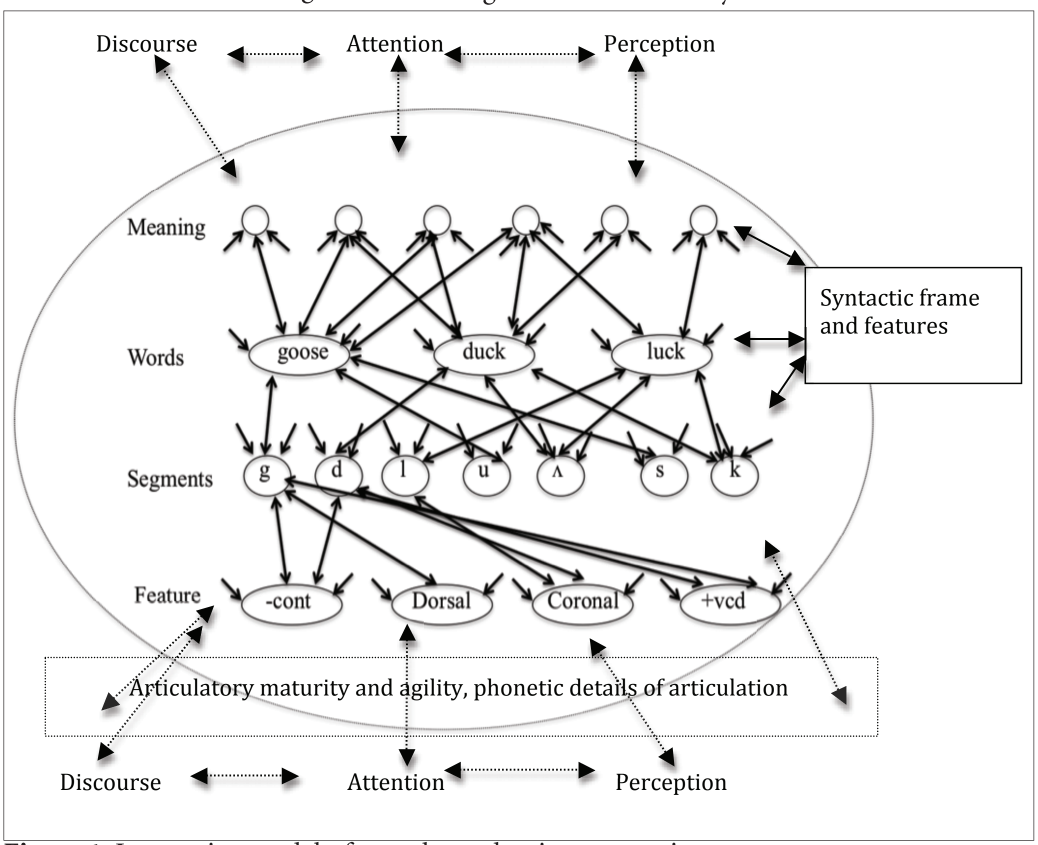

Figure 1: Interactive model of speech production processing.

Attention, perception, discourse constraints and pragmatics play a large role in message construction, but also play a role at other levels in language production. The message itself is meaning-based, and is generally viewed as involving the simultaneous representation of all parts of a proposition; i.e., in a sentence like *the red ball is rolling*, the ball, its color and its activity are represented simultaneously in the brain. The spoken output form, in contrast, is necessarily linear: a sequence of words and sounds. Part of the recoding process converts nonlinear meaning-based representations into linear sequences at several levels (words/morphemes, phonology/phonetics). Models may be similar in their positing of multiple levels of units between meaning and phonetics (i.e., words, syllables, phonemes/segments, features) and in inclusion of mechanisms for ensuring proper sequencing (syntax, syllable structure), but they differ in details and perspective. The following overview contrasts symbolic and interactive (connectionist) models, suggesting clinical implications where relevant. The discussion focuses first and foremost on the phonological domain, the core domain for speech production processing. The ensuing discussion outlines potential interactions of phonology with other domains or factors, i.e., the lexicon, morphosyntax, discourse, perception and attention.

Phonology

Language production involves a mapping from meaning (semantics and pragmatics) to output form (ultimately, articulation). Models differ in their description of how this mapping is achieved, i.e., (a) on whether the mapping is direct (in one step) or via a series of levels, which can be organized serially or interactively; (b) on whether output forms are permanently stored and accessed directly or constructed each time used; (c) on how developmental errors (or mismatches with the adult language targets) occur; and (d) on the mechanism for generalization (and overgeneralization) across elements in output forms. These dimensions are discussed in subsequent sections in terms of the various models.

We note here that the ultimate mapping in speech production is onto acoustics, and consequently some have questioned whether speech sounds are coded in terms of acoustic targets, with realization in articulatory/motor form aimed solely at reaching those acoustic targets (e.g., Callan, Kent, Guenther, & Vorperian, 2000; Guenther & Perkell, 2004; Perkell, Matthies, Svirsky & Jordan, 1995). Others (e.g., Browman & Goldstein, 1992; Fowler, 1993) argue that targets may be articulatory and reflect (invariant) constraints on articulator movement. Bernhardt and Stemberger (1998) argue that the majority of systematic errors in child phonology appear to be based on articulatory similarity rather than acoustic similarity. For example, the nasals [m, n] generally pattern with oral stops (as expected on the basis of articulation), and not with fricatives or glides (as might be expected on the basis of acoustic similarity, i.e., continuous acoustic energy or formant structure). They also note, however, that there are specific minority patterns which suggest an acoustics-based explanation. Both articulation and acoustics clearly play a role in production (for children and adults), and the decision here to view the articulatory encoding as the target must be viewed as controversial or at least oversimplified.

Meaning-to-form mapping: Simultaneous, sequential or both?

Models differ in the assumed depth of processing and time needed for mapping between meaning and form. More traditional *linear* models (e.g., Garrett, 1975; Levelt, Roelofs, & Meyer, 1999; Shattuck-Hufnagel & Klatt, 1979) posit a distinct set of levels between meaning and form; information flow is considered sequential and unidirectional (from one level to the next later down, never with feedback to an earlier level). For example, Garrett (1975) presupposes that meaning is first mapped onto lexical items, which then give access to syntactic and phonological form. Levelt et al. (1999) splits lexical processing into two levels (access of meaning-based lemmas, then form-based lexemes). Shattuck-Hufnagel and Klatt (1979) presuppose that phonological form, after being fully accessed, is inserted into sentence structure. Other models assume at least some simultaneous processing. For example, *Parallel Distributed Processing models* (PDP, or distributed connectionist models) map from an input to an output, with the two levels being meaning and form (e.g., Dell, Juliano, & Govindjee, 1993; McClelland & Patterson, 2002). *Usage-based models* (e.g., Tomasello, 2003; Bybee, 2006) and *exemplar-based models* (e.g. Pierrehumbert, 2001) are explicit that meaning-to-form is the level of mapping. In principle, all output units that one would want to consider "simultaneous" are accessed at the same time, and can be influenced directly by any aspect of meaning. Interactive activation models (local connectionist, e.g., Dell, 1986; Stemberger, 1985, 1992), assume more temporal gradience, such that words first access fairly coarse information (phonemes and syllable frames), then finer information (phonological features), and eventually very fine information (phonetic details of articulation). In interactive models, information flow is always bidirectional, such that information activated on later levels affects the activation of information at earlier levels. This bidirectional flow of activation is illustrated in Figure 1 with bidirectional arrows between units of meaning with word units, between word units and segment (phoneme) units, and between segment units and feature units. Activation of the meaning units for {duck} leads to strong activation of the word unit *duck* (but also intermediate activation of the word unit *goose*). Activation of the word unit *duck* leads to activation of the phonemes /d/, /ʌ/, and /k/, from which activation flows back to semantically unrelated word units (such as *luck*). Activation flows from /d/ and /k/ to feature units such as [Dorsal] and [+voiced], from which activation spreads back to nontarget segments such as /g/ (which may be erroneously output, as in [gʌk]). Interactionist approaches to intervention assume that targeting one aspect of the linguistic system can have ripple effects throughout the system in any direction. In terms of clinical implications, this suggests that intervention could start from a number of access points, from discourse to phonetics (as is presented in this volume). More symbolic linear models suggest that intervention needs to address the earliest level of breakdown in the language production process and build to the other later levels from that level; if work is done at the level of phonetic implementation (articulation), this in principle should have minimal or no impact on larger more abstract units of the system (syllable structure, word structure, sentence structure).

Output forms: Off-line storage or on-line access?

Models also differ in assumptions about whether output forms are permanently (and stably) stored and then accessed during language production, or whether they must be constructed each time, leading to a system where instability is predicted. Most symbolic models (e.g., Garrett, Levelt, usage-based models, exemplar models) suggest that output form is stored in lexical entries. A stored word is placed in a discrete chunk of neural material that is dedicated to that word only and not used to store any other word (parallel to the storage of words on the page in a physical dictionary). Generalization across stored words is only possible if there are mechanisms external to the stored items designed for that purpose. All connectionist models take the opposite view, that output form is *constructed* each time on the basis of activation passing through connections from higher levels. It is often said that all words are "stored" in the same set of units, so that their representations overlap. It is impossible to discretely access one word without (positive or negative) interference from other words (an automatic form of overgeneralization). Because construction-based systems emphasize competition between outputs, accurate output is predicted to be impossible (or nearly so) in early stages of learning (and after brain damage); stable outputs are only possible after learning.

Clinically, all approaches to speech intervention are concerned with learning over a set of trials (whether perceptual or articulatory). Errors are expected in early phases of learning, and stability after sufficient practice. Thus, speech intervention appears to operate with at least some connectionist assumptions. Approaches that draw attention to perception (e.g., Shiller et al., this volume) may also assume that intervention enhances the representation of (stored) lexical entries.

Sources of speech production errors (mismatches) during development

Models differ in how they view the systematic errors (mismatches between target and child pronunciations) that arise during development. Most symbolic models (e.g., Garrett, Levelt, usage-based models, exemplar models) are based on adult language and thus do not attempt to account for development. Usage-based and exemplar-based models address learning as generalizations across stored forms, but do not provide explanations of early phonological phenomena. Sosa and Bybee (2008), for example, discuss the implications of usage-based phonology relative to frequency and neighbourhood effects, but do not mention the mechanisms responsible for phonological patterns such as reduplication or the realization of fricatives as stops. Bybee (2006: 15) refers to "articulatory routines that are already mastered," which possibly implies that child phonological phenomena arise in the mapping from adult-like phonological representations (which the theory addresses in detail) to pre-packaged articulatory routines as described in Levelt et al. (1999), but which are not addressed in the Bybee paper. Presumably, the phenomena that arise during this mapping are unrelated to the basic generalization process of the usage-based approach. Generalization and accuracy in processing in such models favour high-frequency information, but high-frequency elements, e.g., [l] (one of the five most frequent consonants in English) and codas (found in about three-quarters of English monosyllables) are in fact often missing from child pronunciations. If the statistically constructed stored items are not the source of all errors that occur in development, then the source of at least some errors must be in a separate component, e.g., during phonetic implementation (articulation). Bernhardt and Stemberger (1998) agree that some aspects of mismatch pronunciations are articulatory-phonetic in origin, and that every model must have some way to account for that. They argue, however, that articulatory-phonetic effects reflect interactions between phonological and phonetic levels. Phonetic output states that are difficult to achieve make it more difficult for the phonological system to settle into the output state that would lead to that articulation (see below). The paper by Bacsfalvi (this volume) addresses the interaction of phonetic and phonological development, by its focus on the details of phonetic implementation (with a combination of visual and auditory feedback) while working to establish the cognitive basis for development of phonemes. (See also Bernhardt, Stemberger, & Bacsfalvi, 2010.)

Stemberger (1992) argues that connectionist models automatically produce the sort of systematic mismatches that we observe in child phonology, including variability across children, but notes that there are no computer simulations proving such claims. Such processing models assume that mapping from words to segments to features to phonetics must be learned, and so initially there are many aspects of the mapping that are inaccurate. Before any words are produced, the system (which began with partially random settings, such that different children have settings preadapted to accurate production of different sounds) learns some mappings during babbling. Sounds that are frequent during babbling thus tend to appear in the pronunciations of early words. When the child attempts to produce a sound that is impossible in his/her output (e.g., [l]), there will be accurate activation of some features, which then via feedback activate competing phonemes that share some features. Resonance between secondarily-activated segments and features ultimately leads to the access of a non-target segment that shares features with the /l/, such as [d] or [w]. Competition between the different segments leads to one segment being accessed, and which wins is different for different children and across time for a given child. One factor that affects the output is the weight settings of connections between segments and features. For example, do these settings favour the output of a coronal ([d]) or a sonorant ([w]), both of which share different features with the target /l/? While the details of what is output depend on the details of the system, the fact that there are changes from the target is derived automatically. Any construction-based processing model will account for the fact that children produce mismatches.

The individual nature of phonological development supports an individualized approach to assessment and intervention. While standardized articulation tests can give some idea of the developmental level of a child, norms are just statistical predictions about what phonemes may appear when and what types of deletions and substitutions are 'typical' or less typical. Each child has his or her own developmental path, and a comprehensive assessment and treatment plan (as in Bernhardt & Zhao, this volume) can help accelerate change along that path. Symbolic models may not preclude individualized treatment, but there is often a stronger universalist assumption about order of development in such accounts (from Jakobson, 1968/1941).

Further to accuracy of production, there are several important effects that models must account for, deriving from type and token frequencies of various types, including:

1. Lexical frequency: High-frequency lexical items may have more accurate phonology than low-frequency lexical items (for adults, e.g. Stemberger & MacWhinney, 1986; for children, e.g., Tyler & Edwards, 1993).

2. Phonological frequency: High-frequency phonemes and features are generally processed more accurately than low-frequency items (for adults, e.g. Stemberger, 1991; for children, e.g., Pye, Ingram, & List, 1987). Stemberger (e.g., 1991) notes, however, that there are (arguably predictable) exceptions in which the highest-frequency competitor is at a processing disadvantage and shows higher error rates than lower-frequency competitors.

3. Resemblance to other lexical items: Words that share elements of phonological form interact, such that aspects of the output that are shared with many words are more accurate than aspects that are shared with few words (for adults, e.g. Stemberger, 2004; for children, e.g., Zamuner, Gerken, & Hammond, 2004). This is type frequency. Words from high-density neighbourhoods are phonetically different from words from low-density neighbourhoods (see Baese-Berk & Goldrick, 2009, for recent discussion).

Further to neighborhood effects, words which are very similar to each other (differing by a single phoneme) tend to have the greatest amount of influence on each other. Symbolic models (most explicitly usage-based and exemplar-based models) draw a categorical distinction between words being in the neighbourhood or not. They have a direct effect on the size of the neighbourhood and no structure within the neighbourhood. However, Stemberger (1985, 1992) notes that, from a connectionist perspective, neighbourhoods comprise only the words that are most similar to the target word, and we also expect lesser effects from words that are similar to lesser degrees. Vitevitch (2002) and Dell and Gordon (2003) argue that large neighbourhoods lead to more accurate phonological processing in language production (at least for normal adults and adults with neurogenic disorders). However, Stemberger (2004) argues that the size of neighbourhoods *per se* has no effect, but rather subsets of words within the neighborhood. Words in the neighbourhood that have a particular characteristic in common with the target word (e.g., word-initial /s/) are "friends" that reinforce that characteristic in the output; the more friends, the greater the reinforcement of that output. Words in the neighbourhood that do not have that characteristic are "enemies" and reinforce something else. However, if each word reinforces something different (e.g., word-initial /f/ vs. /p/ vs. /k/, etc.), then the enemies form a diffuse group that has little overall impact on processing. Only when enemies share a common characteristic (e.g., beginning with a single consonant and not with a cluster, or ending with past-tense -ed) do they form a 'gang', and there is then a detectable impact on the accuracy of processing. None of the articles in this volume directly address the implications of neighborhood effects for intervention, but the models do suggest that word selection for treatment activities may affect rate of change (see, e.g., Morrissette & Gierut, 2002).

There are numerous ways that the positive or negative effects of other items in the lexicon could arise. In interactive activation models, activation is seen as spreading from one activated element to all elements to which it is connected, whether those elements are "later" in processing (closer to phonetic implementation) or "earlier" (closer to meaning) than the activated element (see Figure 1). As noted earlier, language production begins with the activation of meaning elements (semantic and pragmatic) that express some message that the speaker wants to share with an interlocutor. The activated elements activate lexical items, which sum activation and attain an activation level that depends on how many meaning units activate it. Thus, the meaning {duck} will activate the word *duck* most strongly, but will also activate related words such as *goose*; Stemberger (1985, 1992) assumes that target words inhibit competitors, such that only a single item is accessed at high levels, and that all others are reduced to low levels of activation. Inhibited competitors are still at non-zero activation levels (especially early in processing) and can influence elements later in processing, but at a low level that constitutes noise; only if large numbers of inhibited competitors share some phonological characteristic (e.g., word-final /k/) would phonological processing be affected to any great degree. The target word (here *duck*) spreads activation to its component phonemes (/d/,/ʌ/,/k/), which in turn activate their features. But the phoneme /k/ also spreads activation back to the word *luck* and to all other words that end with /k/. Each word of this gang is kept at a low activation level by the target word *duck*, but because they are a coherent gang in which all members reinforce the final /k/, they are friends that improve the processing of the final /k/. The phoneme /k/ also spreads activation forward to its features [Dorsal], [-voiced], etc., which are also accessed by other phonemes. To the extent that these are activated by other phonemes, their processing is improved, which in turn improves the processing of the /k/ (and of the word *duck*). Token frequency is encoded via resting activation level: higher-frequency words, phonemes, and features have higher resting activation levels and need less additional activation to be accessed. Resonance with competing lexical items and phonemes leads to type frequency effects (weighted by the resting activation level of the competing elements). Token-frequency effects thus arise early in processing (inherent in the access of a unit), while type-frequency arises later (via resonance with other units). Elements which are not represented as a single unit (e.g., the consonant cluster /bl/, which is represented as the two phonemes /b/ and /l/) are predicted not to have direct token-frequency effects, but only type-frequency effects (weighted for the lexical frequency of each word that contains /bl/, leading to some indirect token-frequency effects). The complex interaction of elements within words further reinforces the perspective that word selection is important during treatment. For a speaker who produces velars as coronals, words with two velars may be more accurately produced than words with one velar and one coronal in early phases of intervention.

Resonance in the system has two further consequences. First, resonance between phonological output elements and articulatory states either reinforces the activation of the phonological units, and hence facilitates access, or does not because a target articulation is either impossible or marginal. This leads to impaired processing of the phonological units, and the increased possibility of error/mismatch. In practice, if an articulatory state is impossible or marginal, the system will settle into some other phonological output pattern. Which phonological output state it settles into is related to similarity, in terms of shared phonological elements such as features, and resonance with the lexicon. Because the lexicon is constantly growing during development, the likely alternative output state can change over time due to changes in the lexicon. Secondly, resonance causes generalization and overgeneralization between different words and phonemes, another issue on which models disagree.

Generalization and over-generalization

In an interactive activation model, if access of /k/ is impossible or marginal, a related phoneme (e.g., [t]) that shares many features will tend to be accessed instead. This is because /t/ is activated by feedback from the features of [k], is reinforced by many lexical items containing /t/, and (unlike [k]) is already a possible output. As noted above, usage-based and exemplar-based models do not account well for the difficulties shown in phonological development, relegating such effects to a separate performance component. Insofar as predictions are made by such models, however, high-frequency patterns will be overgeneralized to replace low-frequency patterns, whether high-frequency in general or in a very specific environment. For example, if [k] is not possible in the output, the high type and token frequency of anterior coronals may lead to the overgeneralization of [Coronal, +anterior], for the output [t], in which the tongue is flat ([-grooved]). If a cluster such as /kl/ coalesces to a coronal fricative, however, the fact that /s/ is of far higher frequency than /θ/ in English may lead to the output [s] (e.g. *climb* /klaɪm/ [saɪm]), even though neither target is [+grooved]. Predictions from usage-based and exemplar-based accounts differ from connectionist predictions in two ways, both stemming from the fact that usage-based and exemplar-based models are locked into statistical generalization across stored forms: (1) connectionist models additionally allow for a random component in the initial weights in the system, before any learning takes place (see above), and tuning of the system to non-lexical phenomena such as babbling; and (2) weights in a connectionist model can be changed without any change in the make-up of the lexicon (see below).

Some researchers have claimed that standard terminology (substitution, deletion) implies that the output must be (a) phonetically identical to a similar sequence that correctly matches the adult target, and (b) can have no trace of the target elements. There is much research that shows that these putative implications are false, for at least some errors by some children (e.g., Gibbon, 1990) and by normal adults and adults with neurogenic disorders (e.g., Pouplier & Hardcastle, 2005). These subthreshold differences are referred to as “incomplete neutralization” or “covert contrasts.” However, Bernhardt and Stemberger (1998) and Stemberger (2007) note that these implications do not hold for connectionist models. Given variability of processing, and the complex interaction of elements at all levels, (a) no two tokens of the same word are identical in terms of timing of processing or final output strength of elements at any level, and (b) there is a large amount of subthreshold activation that constitutes “noise” and may occasionally have observable articulatory effects that are imperceptible to the listener. Bernhardt and Stemberger suggest that e.g. [t] as an error for /k/ has a strength distribution with a lower mean activation level than for target /t/ which, among other possibilities, is less effective at inhibiting the feature [Dorsal] and may be associated with subthreshold velar movement. Blumstein and Goldrick (2006) have recently shown for (tongue-twister) errors by normal adults that these small subthreshold differences are observable when the errors create nonwords but not when they create words. This is because resonance with the real word in the lexicon reinforces the strength of the output of the error segment. Developmentally, subthreshold differences are expected to arise especially just prior to changes in outputs; just before [k] becomes a possible output (meaning that it achieves higher activation levels than [t]), there may be a period at which the final activation level of target [k] is still low, but is high enough to decrease the activation level of error [t], leading to phonetic traces of the /k/. Any implication that errors and targets should be phonetically identical is restricted to other types of processing models, if any.

No matter what the intervention approach, treatment strategies are designed with a goal of efficiency, i.e., with hope of systemic generalization rather than element-by-element, item-by-item learning. Over-generalization may be seen as an impediment to efficiency. The usage- or exemplar-based and interactionist models both suggest that generalization will occur, but the greater variability across children predicted by the connectionist models suggests that this may not always occur easily for all children. Furthermore, both types of models imply that over-generalization is a possibility.

Further to this topic, interactive activation models operate with a perspective of 'error-driven learning', which is also seen to influence the nature of errors and generalization/over-generalization effects. The learner's system, after producing a mismatch with the language adult target, alters the weights on the connections between units on different levels, such that a mismatch will be (slightly) less likely on the next token of this particular target. Thus, if /l/ is pronounced as [d], the strength of the connection between the phoneme element /l/ and the features [+lateral] and [+continuant] will be increased, leading to greater activation of these features. But if target /l/ is still inaccessible, these error-driven changes in the weights make [+continuant] consonants better competitors than before, and so the mismatch for target /l/ may change from [d] to [z] or [j]. Over time, a child's pronunciation is expected to improve gradually, even if no new words are learned during this period, so that there are no changes in phonological type frequencies. In addition, as weights are increased or decreased to prevent mismatches, the balance of activation may shift so that one feature improves, but another gets less accurate, resulting in a (usually temporary) instance of U-shaped learning, often termed a *regression* in the phonological-development literature. Regressions can occur during intervention (all coronals becoming velars for a time after velars enter the system, with or without therapy); this is a possible and natural occurrence during error-driven learning and generally resolves itself as the system reorganizes itself.

Previously in this section, the relevance of word selection in treatment was indicated (neighborhood effects, type or token frequency). The concept of error-driven learning entails that, in clinical practice, it should be effective to work with known words, and that improvements can be made to the child's system without learning new words (to alter the statistical properties of the lexicon). Insofar as usage-based and exemplar-based models are compatible with such an expectation, the locus of the effect must belong to performance (about which the models provide little information and hence no guidance for clinical practice). New words, including nonsense words, are not precluded in treatment and may have the added advantage of increased attention (see the discussion below concerning interactions between phonology and other factors). But once lexicalized, nonwords are real words, and thus the system will react to them in a way that is similar to that of other words already in the lexicon.

Summary

The above discussion gave a brief overview of models of language production, showing some contrasts in perspectives and possible implications for phonological development and intervention. Models always underdetermine data and it is only through systematic exploration that creation, refinement or discarding of models can occur. The discussion suggests that an interactive activation model may be more congruent with an intervention process. Strength of activation of target units is enhanced through therapy input, and learning is promoted throughout the system by intervention starting at one or more points in the system. It is unknown whether there are stored, and possibly statistically defined, representations that also change as a result of intervention. Many alternative models (e.g., usage-based, exemplar-based, Levelt et al., 1999) do not always have clear clinical implications for protracted phonological development because they have not been sufficiently elaborated to account for phonological development. However, they have been profitably employed for, e.g. acquired neurogenic impairments in adults, where the adult system was achieved before the onset of the insult. For example, Laganaro (2008) applies the Levelt et al. (1999) model to the processing of syllables in aphasia. Maassen, Nijland & Van der Moelen (2001) did investigate syllable processing in children, based on the Levelt model. When testing children with and without a diagnosis of developmental apraxia of speech, they observed that children with the diagnosis of developmental apraxia showed less refined syllable boundaries, suggesting a breakdown in processing at the syllable level.

Phonology is not the only component of speech production as we observed at the outset of this section. The next section outlines potential interactions of phonology with other domains.

Phonology and Other Linguistic Domains: Semantics and Morphosyntax

In the mapping from meaning to output, a simultaneous, non-linear semantic representation for all parts of a proposition is converted into a linear sequence of words and sounds. Speakers must coordinate phonological processing with other levels of language processing, including selecting words whose semantic content matches the intended message, and building sentence structure. Production models remind us that phonological access may interact with or be influenced by these activities in different ways. In interactive activation models, modular feed-forward models and usage-based/exemplar-based storage models, phonological access depends at least in part on activation input from "higher level" representations of the word's meaning and grammatical category (Levelt et al., 1999; Stemberger, 1992). Interactive activation models are characterized by simultaneous processing for the access of a word and its sounds (via feedback). Most models do not require that all processing on a given level must go to completion before any processing may begin on the next level. Production can be *incremental*; e.g., when lexical access of a particular word in the sentence goes to completion, the speaker can begin processing that word phonologically, even though lexical access is still ongoing for other words in the sentence. As such, phonological processing for a given word can be completed concurrently with work completed at other levels for other parts of the sentence (e.g., Bock & Levelt, 1994; Dell, 1986; Ferreira & Slevc, 2007). Researchers are currently investigating how large a chunk of phonological content for a syntactic unit will receive activation at once. Proposals range from the phonological word (e.g., Levelt et al., 1999) to larger, phrase-sized units (e.g., Damian & Dumay, 2007; Jescheniak, Schriefers, & Hantsch, 2003). Most models additionally assume that the building of syntactic structures occurs at the same time as, and interactively with, lexical access (e.g., Bock & Levelt, 1994).

How might interactions arise between semantic and syntactic levels and phonological processing? The notion of *accessibility* is particularly useful for thinking about how these effects could occur. The accessibility of a phonological form – and thus the likelihood of error – is affected by the amount of activation it receives from connections to lexical-semantic levels. The accessibility of a phonological form may also be affected by the current activation level of other units. Simultaneous activation of more than one word – as might occur in syntactic phrase planning – increases the opportunity for either interference or support (Stemberger, 1992).

Finally, much of the child-focused research on interactions between semantics, syntax, and phonology has been guided by a *limited capacity* perspective, to which the notion of accessibility can also be usefully applied. According to this perspective, cognitive activity is made possible by a finite amount of processing resources that allow us to activate, manipulate and store or maintain information (Kail & Bisanz, 1982). Most discussions of processing resource and capacity include the notion of working memory, which refers to the system(s) responsible for computation and maintenance of information (Baddeley, 2002; Just & Carpenter, 1992; Miyake & Shah, 1999). However, models of working memory vary considerably (Miyake & Shah, 1999), as does the extent to which the terms "processing capacity" and "working memory" seem to be used interchangeably. Moreover, researchers describe the nature of processing resources and the limits on capacity in different ways, sometimes referring to the amount of mental fuel or energy that is available for a task, the size or amount of cognitive workspace that is available, or how quickly or efficiently a person can use available resources (Kail & Salthouse, 1994). Central to all of these descriptions, however, is the idea that the availability of processing resources imposes limits on the amount or complexity of cognitive work that an individual can complete at any given time (Kail & Bisanz, 1982). When a task demands more resources than are available, performance may suffer.

Language researchers have proposed that capacity limitations can lead to performance *trade-offs* between language domains due to processing resource allocation at the time of speaking: When work that is completed in one domain of language demands too much resource, decrements in performance in other domains might be observed (see Charest & Johnston, 2009; Crystal, 1987, for further discussion). For the purposes of this discussion, commitment of mental resources to complex or effortful work elsewhere in the production process may affect the accessibility of a phonological form because fewer resources are available to commit to the work of producing that form.

A small body of research has explored the effects of lexical semantics and syntax on children's phonological output. In the lexical realm, phonological success seems to vary with word class (Camarata & Schwartz, 1985; Weston & Shriberg, 1992). Camarata and Schwartz demonstrated that very young children with typical and impaired language development produced similar phonological mismatch patterns in action and object words, but had more mismatches overall in action words. The authors speculated that semantic processing is more challenging for verbs than objects, leading to decrements in phonological processing.

In the syntactic realm, some children appear to produce more phonological mismatches in multi-word than in single-word contexts. This has been observed in the transition from single-word to multi-word speech (Donahue, 1986; Scollon, 1976), and in comparisons of preschool-aged children's single-word productions to their productions of the same words in sentences (Andrews & Fey, 1986). In keeping with frequency effects as discussed above for models, Morrison and Shriberg (1992) reported that mismatch increases from single-word to sentence contexts were limited to those sounds that the children produced with generally high (i.e., > 50%) mismatch rates in single words. That is, forms with marginal accessibility were more vulnerable to interference from interactions of linguistic levels during production. Some studies have also reported that children with and without phonological and other language impairments show more phonological mismatches in long, complex sentences than in short sentences (Crystal, 1987; Masterson & Kamhi, 1992; Panagos, Quine, & Klich, 1979; Weston & Shriberg, 1992).

Not all children show greater phonological difficulty as their language complexity increases, however (Panagos et al., 1979; Kamhi, Catts & Davis, 1984; Masterson & Kamhi, 1992), and some mismatches in sentences may be due not to resource limitations but to other difficulties that can arise in the sentential context, such as difficulties with sequences of consonants arising at word boundaries (e.g., the /km/ sequence in the phrase *pick me up*). Whether or not phonology is affected might depend on several factors, including the child's overall speech, language and cognitive skills (and attention to such skills), whether or not the child (in spontaneous productions) attempts sufficiently challenging language forms, and individual differences in whether or not the child tolerates variability in their phonological output (Kamhi et al., 1984).

The above research suggests that, in some cases, children's phonological success will be affected – for better or worse – by lexical and syntactic processing. Given that it is not uncommon for phonological impairments to co-occur with challenges in other aspects of the language system (e.g., Paul & Shriberg, 1982), a perspective that includes consideration of lexical and syntactic influences can contribute helpful information about the strength of a child's access to a targeted speech form, factors influencing variable success rates, and strategies for improvement. The paper by Bernhardt and Zhao (this volume), based on Bernhardt and Stemberger (2000) draws attention to the interactions of phonology with other domains in the last phases of the phonological intervention planning process.

Phonology and Other Factors in Language Processing: Discourse, Attention and Perception

Interactions between distant parts of the system (e.g., discourse units and phonology) are not equally possible in all models of speech production. In modular feed-forward systems such as Levelt or Garrett, we expect no direct effects of pragmatics/discourse on phonological features, though a possible mechanism is there (if we allow the forwarding of pragmatic/discourse representations to lower levels). Interactive activation models are functionally modular between distant levels, because the amount of activation is attenuated by each level that it passes through. Phonological elements and discourse considerations should thus have little effect on each other. Distributed connectionist models and usage-based/exemplar-based models, in contrast, could in principle posit strong interactions due to their one-step processing from meaning to form. Pragmatics and discourse may have their greatest effects concerning phonological output via the control of different levels of formality (register) or dialects related to social factors. The "right" way to implement this is unclear. One possible way would be to implement it in a way similar to attention, with certain elements selected out and their activation thus increased. The paper by Baker and McCabe (this volume) provides data for further development of models in relation to discourse and speech production processing.

Attention has additional influences on acquisition and processing that may also allow strong interactions within interactive and modular feed-forward models, although such models have not yet addressed the issue of attention. Bernhardt and Stemberger (1998) note that children can and do pay greater attention to processing sometimes, and that their accuracy may improve because of that attention. The mechanism, however, is unclear. Norman and Shallice (1986) suggested that attention selects out particular elements and increases their activation levels, thereby improving processing. Attention may play a role in other phenomena that have been observed in the clinic. Morrisette and Gierut (2002) suggest that nonsense words can be more effective during treatment than known words. It has been suggested that the child's phonological mismatches on known words may be stored, and that greater accuracy can thus be obtained with nonwords (because they have no stored mismatches). Attention may also play a role. Known words can be produced automatically (e.g., in a picture naming task), The clinician wants the child to pay close attention to the sounds and to try to eliminate mismatches, but the child can produce the words without such attention. Nonwords by their very nature require attention in order to be produced, and thus may more effectively focus the child's attention on the task of eliminating mismatches with the target pronunciation.

Finally, although our focus in this issue is on the production of speech and language, perception of course cannot be ignored. Accurate production presupposes perception that is accurate (at least under optimal circumstances). If, for example, the interdental fricatives /θ, ð/ are misperceived as /f, d/, and true /f, d/ are never produced as interdental fricatives (in words such as *fish*, *door*), then we do not expect the interdentals to ever be produced accurately. However, the reverse is not true: even when perception is accurate, production may be inaccurate. It is our position (as in Bernhardt & Stemberger, 1998) that children with typical hearing have fairly accurate perception in general, especially for very salient acoustic differences (e.g., /s/ vs. /t/). Production difficulties arise in the process of accessing phonological output forms, on the basis of reasonably adult-like perceived forms. It does not follow, however, that training a child in perception will have no effect on production. Training perceptual contrasts can be effective if it successfully draws the child's attention to the fact that two categories (e.g., /s/ and /t/) are different categories and should be *produced* differently. If the child has heretofore not perceived that there is a contrast, perceptual contrast training can lead to the establishment of more accurate lexical representations, which (after a lag) can lead to more accurate production. However, perceptual contrast training also focuses the child's attention on the contrast *even when* they can already perceive the contrast accurately. This focus of attention can lead the child to also focus attention in production, which can lead to improved processing and the establishment and/or more frequent use of more accurate output pronunciations. Any technique that successfully leads to that focus of attention should lead to improvements in the child's pronunciations. Perception-based training is one possible technique for doing this. The paper by Shiller et al. (this volume) provides further elaboration of this topic for both English- and French-learning children.

The approaches in this issue are a small indication of what could be applied based on models of speech production. As Figure 1 reminds us, the production of an utterance, however short, is a complex process that occurs in a discourse context, has meaning and many types of form. It is surprising that the system is as robust as it is, considering the possibilities for error within and between domains. The interactive activation model assumption taken in this issue is that intervention can be initiated at different points in the process, and have effects both within and across domains. Only time will tell if the various approaches meet the rigours of randomized control trials in intervention outcomes. We thank the contributors to this volume for their time, research and thoughts, and encourage the readers to foray into new territory of their own through consideration of the various approaches and models of language processing.

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Author Note

Correspondence concerning this article should be addressed to May Bernhardt, PhD, School of Audiology and Speech Sciences, 2177 Westbrook Mall, Vancouver, British Columbia V6T 1Z3. Email: bernharb@interchange.ubc.ca .

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Nonlinear phonological analysis in assessment of protracted phonological development in Mandarin

Utilisation de l'analyse phonologique non linéaire dans l'évaluation des retards du développement phonologique en mandarin

May Bernhardt
Jing Zhao

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Abstract
Nonlinear phonological theories have motivated phonological assessment and intervention practices for English for two decades (e.g., Bernhardt & Stoel-Gammon, 1994; Bernhardt & Stemberger, 2000). Such practices focus on all aspects of the phonological system from word structure to segments (phonemes) and features, highlighting and capitalizing on a client's strengths while addressing his or her needs. The authors and several other international researchers are currently investigating typical and protracted phonological development cross-linguistically, and creating phonological assessment tools for the various languages in the process. The current paper demonstrates a qualitative nonlinear phonological analysis for Mandarin, utilizing data from a Canadian Mandarin-learning child with protracted phonological development.

Abrégé
Les théories sur la phonologie non linéaire sous-tendent les méthodes d'évaluation et d'intervention en anglais depuis deux décennies (p. ex., Bernhardt & Stoel-Gammon, 1994; Bernhardt & Stemberger, 2000). Ces méthodes sont axées sur tous les aspects du système phonologique, de la structure des mots aux segments (phonèmes) et aux traits distinctifs, et mettent en évidence et utilisent les forces d'un client pour cibler ses besoins. Les auteurs et plusieurs autres chercheurs internationaux procèdent actuellement à des études inter-linguistiques sur le développement phonologique typique et les retards du développement phonologique, et créent par le fait même des outils d'évaluation de la phonologie dans diverses langues. Le présent article démontre une analyse qualitative non linéaire de la phonologie en mandarin à l'aide de données recueillies auprès d'un enfant canadien apprenant le mandarin qui a un retard du développement phonologique.

Keywords: Mandarin phonological assessment, Mandarin phonological disorders, and Mandarin speech sound disorders

May Bernhardt, PhD
School of Audiology and Speech Sciences, University of British Columbia
Vancouver, British Columbia
Canada

Jing Zhao
Richmond Health Department
Vancouver Coastal Health
Vancouver, British Columbia
Canada

Nonlinear phonological theories have motivated phonological assessment and intervention methods for English over the past two decades (e.g., Bernhardt, 1990, 1992, 1994a,b; Von Bremen, 1990; Bernhardt & Stoel-Gammon, 1994; Bernhardt & Gilbert, 1992; Edwards, 1995; Bernhardt & Stemberger, 1998, 2000; Bernhardt, Bopp-Matthews, Daudlin, Edwards, & Wastie, 2010) and recently, for German (Ullrich, Romonath & Bernhardt, 2008). The authors and several other international researchers are investigating typical and protracted phonological development in a number of languages, and developing clinical tools in the process. The current paper provides a brief overview of the major aspects of nonlinear theories in clinical application, and demonstrates extensions to Mandarin.

The primary concept of nonlinear phonological theories is the hierarchical organization of the phonological system from phrase and word structure to segments (phonemes) and features (see Figure 1).

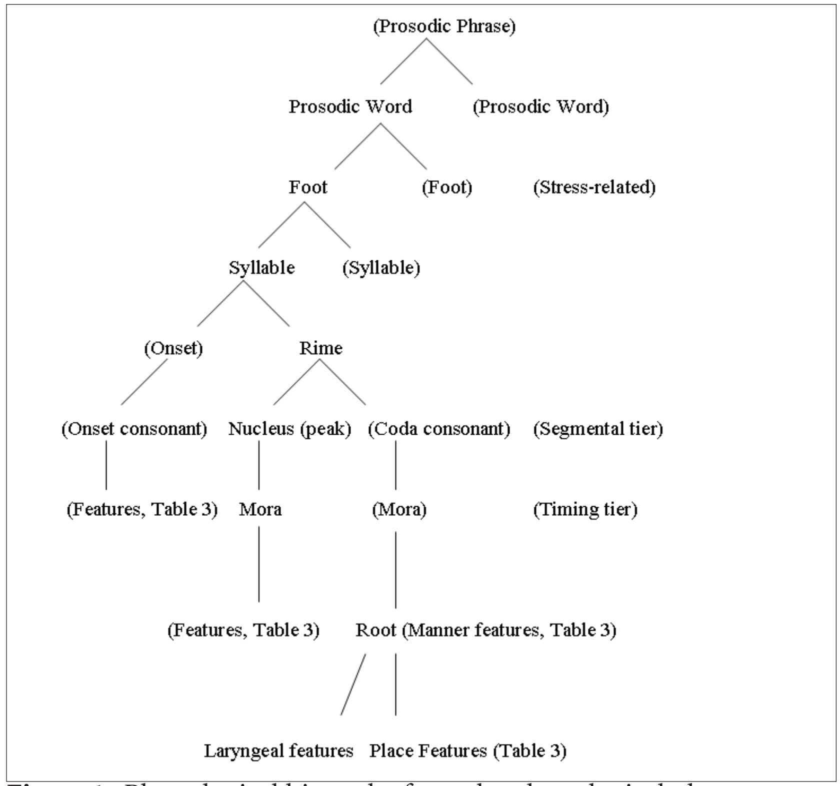

Figure 1 : Phonological hierarchy from the phonological phrase to the features.

Although linguists continue to debate over the exact characterization of phonological organization, the general principles hold that all units of the phonological system are important, and have independent operations and relationships with other aspects of the system. Analysis methods in speech-language pathology based on older theories, such as phonological process analysis, may refer indirectly to different levels of the phonological system. For example, such analyses typically identify patterns affecting syllable structure (cluster reduction, final consonant deletion) versus segments (velar fronting, stopping of fricatives). However, analysis methods based on the nonlinear theories explicitly investigate all the units or domains of a phonological system. In addition, nonlinear analyses explicitly consider the relative autonomy of various units and the interactions between them. While a specific phonological unit (e.g., a feature [+continuant]) may have its own set of constraints, this feature may also be positively or negatively affected when interacting with other units within the phonological system. For example, a client may be able to produce [+continuant] segments (vowels, glides, fricatives and liquids), but only in syllable-final (coda) word position in monosyllables, e.g., *bus*. Through investigation of all the elements of the phonological system, a client's strengths can be identified in addition to their needs. For example, a client may be able to pronounce only a few segments yet be able to produce word structures reasonably well. A 5-year-old child, Colin (pseudonym: Bernhardt and Stemberger, 1998, 2000) was initially able to produce words of up to three syllables with a variety of CV word shapes or sequences including complex ones such as CVCVC and CVCVCVC, yet primarily used only [g], [k], [h], [b] and [a], giving pronunciations such as [gak], [gagak], [baha], [gagagak]. The explicit analysis of his word structures demonstrated to both the clinician and family that, although unintelligible, he had relative strengths in the structural aspects of phonological development: word length, stress patterns and word shape. Small-scale studies applying nonlinear theories have supported the exploitation of the strengths in the system at one level of phonological organization to address needs in other areas (e.g., Bernhardt, 1990, 1992; Von Bremen, 1990; Edwards, 1995; Major & Bernhardt, 1998; Bernhardt & Major, 2005). The equal focus on strengths and needs represents another difference from phonological process analysis, which, being an error analysis, focuses primarily on needs. But comprehensive analysis is often time-consuming. Thus, time-saving methods for nonlinear phonological analysis were developed to increase clinical efficiency: qualitative or scan analyses (Bernhardt & Stemberger, 2000; Ullrich et al., 2008) and computerized quantitative analysis (e.g., Computerized Articulation and Phonology Evaluation System (CAPES), Masterson & Bernhardt, 2001; PHON, Rose & Hedlund, 2008).

The current paper exemplifies a qualitative nonlinear phonological analysis for Mandarin. It is assumed that a speech-language pathologist well-trained in phonetics and phonology can work with a client's family, and/or language support workers, to construct an intervention plan for that client in his or her native language. Facilitative to that enterprise is a standard word list, an organized phonological analysis form and a recording of a native speaker saying the words. Ideally, the clinician would be a native speaker of the child's language, but the reality is that most clinicians are primarily monolingual, with limited knowledge of other languages. The next section describes key aspects of Mandarin phonology as a basis for the demonstration analysis that follows.

Mandarin (also called Standard Chinese, Guóyǔ, Huáyǔ or Pǔtōnghuà)

In China there are several Chinese dialect/language families[1]: Mandarin, Wu (including Shanghainese, with over 70 million speakers), Yue, Min, Hakka, Xiang and Gan. Mandarin has the largest number of speakers (over 800 million) and is used in government, educational institutions and the media. It serves as a common language for people who speak the different Chinese dialects/languages, many of which are not mutually intelligible. Children receive instruction in Mandarin in the education system from age 3 on and parents also report active teaching of Mandarin at home (Angus & Lei, 2001, p. 2).

The Mandarin language has relatively simple word and syllable structure, an average-sized consonant inventory and a fairly large vowel inventory, with phonemic use of tone. (See also Duanmu, 2000; Bernhardt, Stemberger, Ayyad, Ullrich, & Zhao, in press). As with any language, there are regional variants. The paper focuses on Mandarin, but does discuss Shanghainese briefly in the case example section, because the client described was exposed to both Chinese languages/dialects.

Prosodic Structure: Word Length, Stress, Word Shape and Tone

Mandarin (like other Chinese languages/dialects) has predominantly monosyllabic and disyllabic words, but does have some longer multisyllabic words. According to Duanmu (2000), words of two or more syllables may show trochaic, or stressed-unstressed patterns. Vowel reduction (to schwa) and/or tone neutralization (see below) can occur in the unstressed syllable. There is some disagreement among researchers as to whether Mandarin is a stress-timed language like English (Avery & Ehrlich, 1992), or a syllable-timed language such as Italian or Cantonese (Lin & Wang, 2007; Mok, in press). Mok observes that regional variants of Mandarin may differ in their degree of syllable timing, with some regional variants such as Mandarin spoken in Singapore having fewer unstressed syllables and thus having clearer syllable timing (Mok, in press).

Syllable and word shapes include open (coda-less) syllables such as V, VV, CV, CVV, CVVV (VV = diphthong; VVV = triphthong), and closed syllables such as VC, CVC and CVVC. Sequences of consonants with syllable-final nasals in the first syllable can occur word medially (e.g. [kʰo^{MLM}ŋ.ɭo^{MH}ŋ 'dinosaur'), but there are no word-initial or final clusters. Duanmu (2000) suggests alternatively that there are syllable-initial consonant-glide clusters with [w], [j] or /ɥ/, and therefore fewer diphthongs and triphthongs with [u], [i] or /y/ as the first vocalic element.

Mandarin has four tones, plus a 'neutral tone' and several tone alternations (tone sandhi). Tones include both level and contour tones (i.e., tones with changes in pitch). Here we give the "tone letters," introduced by Chao (1930), but Duanmu (2000) points out that there is much disagreement among Chinese linguists as to the actual pitch realization of the various tones within and across dialects (Duanmu, p. 211-212).

- Tone 1 (T1): high (H) level /ʂu^{H}/ 'book'
- Tone 2 (T2): mid-rising (MH) /y^{MH}/ 'fish'
- Tone 3 (T3): mid-low-mid "dipping" /ma^{MLM}/'horse'
- Tone 4 (T4): high-low falling (HL), e.g. /ma^{HL} /'scold'

The neutral tone (0) occurs in a short, unstressed syllable following a stressed syllable (e.g. /ˈɚ^{MLM}tuo^{0}/'ear'); it tends to be 'relatively low' in many cases, and high after Tone 3. (Duanmu (2000) notes that the unstressed syllable in such contexts could be considered 'toneless', p. 224). T3 sandhi, the most common of the tone changes, shows the dipping tone MLM changing to the rising tone MH when it occurs before another dipping tone (i.e. T3→T2/__T3), e.g. for the syllable / ma^{MLM}/→ [ma^{MH}] when preceding another syllable with MLM tone; thus 'ant' is /ma^{MH}ji^{MLM}/, even though the root contained /ma^{MLM}/.

Vowels

Vowels (monophthongs, diphthongs and triphthongs) serve as the tone-bearing units in Mandarin. Although researchers are still investigating the vowels of Chinese dialects both acoustically and in terms of phonetic transcription (Li & Wang, 2003), Mandarin is reported to have eight to nine monophthongs /i y (e) ə ɚ u o ɤ a/. These include distinctions between front, central and back vowels, low, mid and high vowels, rounded and unrounded vowels and tense and lax vowels. Schwa occurs only in unstressed syllables. The /ɚ/ occurs both in isolation (e.g., /ɚ^{HL}/'two') and as a suffix (replacing a nasal consonant, e.g. /kan^{H}/ as [kaɚ^{H}], Duanmu, 2000). There are four diphthongs with rising sonority, /ai, ei, ou, ao/ and five with falling sonority, /ia ua uo ie ye/. The four triphthongs are /iao iou uai uei/. (Duanmu (2000) actually treats the initial /i/ and /u/ as glides; there is some disagreement about the final vowel in /uai/, whether it may actually be /e/.) Vowel-feature segment correspondences are listed in Table 1.

Consonants

Standard Mandarin has 24 consonants (see Tables 2 and 3.). All consonants except /ŋ/ occur syllable initially, but only /n/ and /ŋ/ occur syllable finally. In terms of manner of articulation, there are six stops, three nasals, five fricatives, six affricates, two liquids (/l/ and retroflexed /ɻ/)and two glides /w/ and /j/. Place of articulation includes labial, coronal (alveolar, alveopalatal) and dorsal (velar).

1 Research is ambivalent about the word 'language' versus 'dialect' for variants of Chinese. Duanmu (2000) notes that all the variants of Chinese use the same written system, and are very similar grammatically. They do differ phonologically in systematic ways, and Duanmu (2000) claims that, although the variants are at first mutually unintelligible, at least some speakers can learn to understand other variants, given time and exposure. This latter fact and the similarity in the grammatical and written systems suggests that the variants are dialects rather than languages. Here we use dialects/languages or languages/dialects so as to be inclusive of the various perspectives.

Fricatives and affricates can be grooved (strident) or ungrooved, and retroflexed or plain. Duanmu (2000) notes that the Coronal [+anterior] fricatives are produced more in the dental than in the alveolar region, but are still considered to be grooved (strident). In the current paper, we use the dental diacritic (̪) to indicate a lack of grooving, rather than an indication of exact place. Consonants differ in terms of the degree of glottis aperture, i.e., they are either aspirated ([+spread glottis]) or non-aspirated ([-spread glottis]). Fricatives are only [-voiced], i.e., [+spread glottis].

Table 1
Vowel-feature correspondences for Mandarin (adapted from Duanmu, 2000)

Vowel	[high]/[low]	[back] (Cor or Dor)	Labial ([+round])
i	[+high]	Dor [-back] & Cor	
y	[+high]	Dor [-back] & Cor	Labial ([+round])
e	[-high][-low]	Dor [-back] & Cor	
ə	[-high][-low]	(Dor [back])[a]	(Labial [round])[a]
ɚ	[-high][-low]	Dorsal [+back]	
u	[+high]	Dorsal [+back]	Labial ([+round])
o	[-high][-low]	Dorsal [+back]	Labial ([+round])
ɤ	[-high][-low]	Dorsal [+back][b]	
a	[+low]	(Dor [back])[a]	

[a]The schwa varies in context in backness and roundness; and thus is unspecified for these features. The /a/ also has several variants, from [+back] to more central. All vowels except schwa are [+tense] (two timing units/moras).
[b]Duanmu (2000) suggests that the unrounded mid back vowel /ɤ/ alternates with schwa in terms of length/syllable stress. The /ɤ/ has two timing units/moras,and occurs in stressed syllables, whereas schwa has one timing unit and occurs in unstressed syllables. Thus, he does not list /ɤ/.

Table 2
Consonant inventory of Mandarin[a]

	Labial	Dental	Retroflex	Alveo-palatal	Palatal	Dorsal (velar)
Stops	p p^h	t t^h				k k^h
Affricates		ts ts^h	tʂ $tʂ^h$	tɕ $tɕ^h$		
Fricatives	f	s	ʂ	ɕ		x
Nasals	m	n				(ŋ)[a]
Approximants	w[b]	l	ɻ		j[b]	

[a]All can occur in syllable-initial position except for /ŋ/. Only the /n/ and /ŋ/ occur syllable-finally.
[b]The glides /w/ and /j/ can be alternately noted as vowels [u] and [i] in diphthongs and triphthongs.

Nonlinear Phonological Analysis for Mandarin

A nonlinear phonological analysis describes forms from all levels of the phonological system (prosodic, segmental, sequences). Clinically, one purpose of the assessment is to determine the client's strengths in terms of phonological development; the other is to determine needs for treatment, if any. Depending on the severity of the problem, the analysis may be brief or extensive. Quantitative analyses are useful for setting baselines and showing change/effectiveness later. However, without computer assistance, they can be time-consuming and moreover, articulation patterns are often sufficiently clear without actually counting. Thus, a qualitative analysis (as is typical in linguistics) is often sufficient.

Both independent (inventory) and relational (match/accuracy) analyses are included. The inventory analysis informs the evaluator about what the client is doing, without regard for the language targets. This is useful, because some forms identified in the inventory can serve as supports for the development of new phonological forms during treatment. The relational analysis describes matches and gaps between the client productions and the target language. Matching forms provide further information about strengths in the system and supports for treatment, whereas gaps indicate potential needs and intervention targets. The case example below demonstrates the various steps of a qualitative analysis for Mandarin. The example begins with the prosodic units, and then proceeds through vowels, consonants and variability/sequence analyses. There is no necessary order of analysis but evaluating prosodic structure and vowels first draws attention to these less frequently evaluated domains in clinical practice.

Case Example

The participant for the case example was a girl (aged 4;1), who was living with her parents and two younger siblings in Canada. The child for this study had a birth weight of just under 7 pounds (i.e., average), although her mother did have gestational diabetes, which can result in heavier than average babies. She had been referred to a preschool health agency because of parental concerns about possibly delayed speech development. There were also concerns about her next-youngest sister in terms of speech development. In terms of language input, her parents reported speaking to her in both Mandarin and Shanghainese in approximately equal amounts. In addition, the child watched a Mandarin DVD for one half-hour daily. (Further information is not available.) This language use accords with Angus (2002)'s claim that speakers from Shanghai often consider both Shanghainese and Mandarin to be important dialects and that parents actively help their

Table 3
Consonant feature-segment correspondences for Mandarin

Consonant	Manner Features	Place Features	Laryngeal Features
p pʰ [a]	[+consonantal][-continuant]	Labial	[-/+spread glottis][a]
t tʰ	[+cons][-cont]	Coronal [+anterior]	[-/+spread glottis]
k kʰ	[+cons][-cont]	Dorsal	[-/+spread glottis]
m	[+cons][-cont][+nasal]	Labial	([+voiced])
n	[+cons][-cont][+nasal]	Coronal [+anterior]	([+voiced])
ŋ	[+cons][-cont][+nasal]	Dorsal	([+voiced])
f	[+cons][+cont]([-sonorant])	Labial [+labiodental]	([+spread glottis])
s	[+cons][+cont]([-sonorant])	Coronal [+anterior] [+grooved]	([+spread glottis])
ts tsʰ	[+cons][-cont,+cont]([-son])	Coronal [+anterior] [+grooved]	[-/+spread glottis]
ʂ	[+cons][+cont]([-sonorant])	Coronal [-anterior] [+grooved]	([+spread glottis])
tʂ tʂʰ	[+cons][-cont,+cont]([-son])	Coronal [-anterior] [+grooved]	[-/+spread glottis]
ɕ	[+cons][+cont]([-sonorant])	Coronal [-anterior] [-grooved]	([+spread glottis])
tɕ tɕʰ	[+cons][-cont,+cont]([-son])	Coronal [-anterior] [-grooved]	[-/+spread glottis]
x	[+cons][-cont,+cont]([-son])	Dorsal	([+spread glottis])
w	[-cons] ([+cont][+son])	Labial	([+voiced])
j	[-cons] ([+cont][+son])	Coronal-Dorsal (palatal)	([+voiced])
l	[+cons] ([+cont][+son])[+lateral]	Coronal [+anterior]	([+voiced])
ɻ	[+cons] ([+cont][+son])	Coronal [-anterior] (+retroflex)	([+voiced])

Note: Parentheses indicate that this feature is predictable for the given target, given other major features of the phoneme, and possibly not a necessary part of the underlying (lexical) representation.
[a]Aspirated obstruents are [+spread glottis] and unaspirated obstruents are [-spread glottis], hence the [-/+spread glottis] notation. These are considered contrasting phonemes (not allophones), but space in the table precludes separate lines.
[b]The table does not indicate [+sonorant], following Bernhardt and Stemberger (2000), where it was noted to be redundant. However, it is to note that nasals and approximants are [+sonorant] and stops and fricatives/affricates are [-sonorant].

children learn Mandarin at home. The child had started learning English in preschool at age 3, but did not use English at home.

The second author, a speech-language pathologist and paeditrician, conducted a speech/language assessment in Mandarin and made the diagnosis of protracted phonological development. (This author is a phonetically trained native speaker of both Shanghainese and Mandarin.) For speech production, a speech sample of 80 single, spontaneous words (constructed to elicit all major aspects of Mandarin phonology) was digitally audio-recorded monaurally with an M-Audio Microtrack recorder and high quality Senheiser wireless lapel microphones. The same author transcribed the sample, with consultation from a trained phonetician. Examples from the word list are provided in the appendix and throughout the analysis below.

Before proceeding to the analysis, major phonological differences between Shanghainese and Mandarin are noted here as a background to interpretation of some of her phonological patterns:

1. Syllables:

Duanmu suggests that Shanghainese does not have a pronounced distinction between stressed and unstressed syllables, whereas Mandarin does distinguish such syllables. However, for both Shanghainese and Mandarin, tones are only associated with the initial stressed syllables lexically, i.e., in underlying representation (2000, p. 230).

2. Tone:

a. According to Jin (1986), Shanghainese has five tones.

b. Shanghainese has a higher frequency of rising tones than Mandarin.

c. Shanghainese low tones are accompanied by murmur (breathy voice: Duanmu, 2000, p 212) and only the T3 of Mandarin appears to be like the [23] contour of Shanghainese, i.e., murmured.

d. Shanghainese tones are sometimes described as akin to registers or pitch accents (Dai, 1991) but are still designated with tone letters.

e. Neutral tones were found less often in a group of Shanghai speakers (Li & Wang, 2003), which accords with the lack of distinction in lexical syllable stress.

3. Consonants:

a. The syllable-final nasal is usually restricted to the velar nasal in Shanghainese (Dai, 1991). Sometimes the nasal is unpronounced and realized as nasalization of the preceding vowel (Ramsay, 1989, p. 91).

b. Shanghainese has voiced obstruents (stops and fricatives) word initially, unlike Mandarin. These voiced obstruents are apparently produced with breathy voice (murmur) and appear to be associated with the tone on the following vowel, i.e., voiced obstruents are associated with low tone or register, and voiceless ones with high tone or register (Ramsay, 1989, p. 91).

c. Shanghainese has no retroflexed consonants. In Li and Wang (2003), Shanghainese-Mandarin adult bilinguals with 'heavy accents' did not produce the retroflexes when speaking Mandarin, although those with less noticeable accents did produce some of the retroflexes accurately.

d. Some syllables may end in glottal stop, unlike in Mandarin (Ramsay, 1989, p. 93).

4. Vowels:

According to Ramsay (1989), Shanghainese has more monophthongs than Mandarin, because of sound changes reducing diphthongs to monophthongs (12 vowels in total instead of nine). For example, /lai/ of Mandarin is often pronounced as [le] in Shanghainese or /ao/ as [ɔ] (Ramsay, 1989, p. 92).

Clinical Analysis Part 1: Initial Overview

In starting a phonological analysis, it can be useful to begin with a short perusal of the data (5-10 minutes, depending on the complexity of the sample), called a "Bird's Eye View" in Bernhardt and Stemberger (2000). This initial overview (Table 4) can help identify (1) obvious strengths of a client's phonological system and (2) further needs for detailed analysis, i.e., targets showing obvious inconsistency or major gaps with respect to the adult language. In Table 4, a filled-in checkbox indicates general match with the adult target, and a blank checkbox and underlining, a general mismatch. Parentheses indicate inconsistent matches.

The overview showed the following:

1. Prosodic structure: Generally a strength. The following examples demonstrate inconsistency in use of (a) syllable-final nasals and (b) monophthong versus diphthongs versus triphthongs, and thus a need for further analysis of positional patterns_ (nasals) and wordshapes.

Word-final nasal and diphthong/monophthong matches:

Target	Child	English
/tʰai^{HL}jaŋ^{0}/ >	[tʰai^{HL}jaŋ^{0}]	'sun'
CVVCVC >	CVVCVC	
/tsai^{HL}tɕiƐn^{HL}/ >	[dai^{HL}tɕiƐn^{HL}]	'goodbye'
CVVCVVC >	CVVCVVC	

Word-final nasal and diphthong mismatches:

/tɕʰiƐn^{MH}/ >	[tɕʰiƐi^{MH}]	'money'
CVVC >	CVVV	

Medial nasal match and mismatches:

/ɕioŋ^{MH}mao^{H}/ >	[ɕioŋ^{MH}mao^{H}]	'panda'
/CVVCCVV >	CVVCCVV	
piŋ^{MLM}kan^{H}/ >	[pi^{MLM}kan^{H}]	'cookie'
CVCCVC >	CVCVC	

2. Vowels: A relative strength. Inconsistency (as seen in the above examples) suggested a need for further vowel analysis.

3. Consonants: Many matches with the target but inconsistency for most sound classes. Examples in the Appendix and the detailed consonant analysis section show further needs for analysis, particularly for coronal fricatives, affricates and liquids, and unaspirated targets.

4. Variability and sequences: Some variability (noted above) for: (a) word shapes with nasal codas, (b) specific consonant types and (c) vowels. Very few assimilation or metathesis patterns were observed. However, sequences were a relative strength. (*If a client shows variability across words plus assimilation, metathesis, coalescence or dissimilation* for the variable productions, suggesting sequence constraints, further analysis of cross-vowel consonant sequences, CV interactions, or VV/VVV sequences is indicated.) Diphthong sequence analysis was indicated because of metatheses in certain targets.

Detailed Analyses

The following outlines more specifically various aspects of the child's speech production. Possible influences of Shanghainese on Mandarin use are noted.

Table 4
Overview of Case Example

Domain	Specific forms	Strength (General match with target)	Needs further analysis
Prosodic structure	Word length	☑	☐
	Word shape	(☑)	☑
	Tones	☑	☐
	Position-specific patterns[a]	☐	☑ *Nasals in coda?*
	General prosody (rate, pitch, etc.)	☑	☐
Vowels	Overall	(☑)	☑
	Monophthongs?	(☑)	☑ *Some vowel mismatches*
	VV and VVV	(☑)	☑
Consonants	Overall	(☑)	☑
	Manner of articulation	Stops ☑ (Nasals ☑) (Fricatives ☑) (Affricates ☑) (Liquids ☑) (Glides ☑)	☑ All but stops?
	Place of articulation	Labials ☑ Coronals: Dentals ☑ (Alveolars ☑) (Retroflex ☑) (Alveopalatals ☑) (Palatal ☑) (Dorsal ☑)	☑ Coronals?
	Laryngeal status	Aspirated ☑ (Unaspirated ☑)	(☑) Unaspirated?
Variability and sequences	Overall	(☑)	☑ (Vowels? More variable in connected speech?)
	Same word	((☑))	☐
	Same target	(☑)	☑ (Vs, coronal frics. and affricates, word shapes)
	Assimilation or metathesis?	(☑)	☑ (Diphthongs?)

[a]Position-specific patterns include general omission of a target in a word position, or frequent segment (phone) use in one position (such as [t] or glottal stop).
Note: Parents understood about 70% of speech in context, others about 20-30%.

Prosodic Structure: Word Length, Word Shape and Tone

For prosodic structure, it is important to abstract away from the actual segments. The question is whether the consonants and vowels produced help maintain a particular word structure: e.g., for CVC, it only matters that there may be an initial and final consonant and a vowel, not necessarily segments that match the adult target. Table 5 shows a more detailed prosodic structure analysis.

The checkboxes in the first column indicate presence of particular forms (inventory). Mismatches with the language targets ('errors') are underlined. For the adult targets, parentheses around individual Vs or Cs are abbreviations, i.e., (C)VV indicates both CVV and VV. A parenthesis around the entire form (CV(V)C) indicates client inconsistency in matching the target. If there is some obviously frequent form for a particular domain, this can be circled or highlighted in some way. In the current data, no particular form was especially frequent, and thus no highlighting was indicated. Noting the most complex (maximum) form within a domain shows the client's current potential, even if those complex forms are inconsistent or infrequent. At the bottom of the table is indicated whether the domain is a strength or shows needs, and if there are needs, which ones. The information from this row will be returned to during selection of treatment targets (needs) and treatment strategies (strengths).

As noted in the Overview, prosodic structure was a relative strength across domains for this child. The columns of Table 5 are nevertheless completed for demonstration purposes, even though the Overview indicated a need for analysis of word shape only. Examples in the Overview section, Appendix and Table 5 indicated possible minor needs for development of CV(V)C and CVC. CV(V)(C), as a result of inconsistency in vowel complexity and use of syllable-final nasals. The segmental analysis below further elucidates these needs.

Table 5
Prosodic Structure: Inventory and Matches (mismatches underlined)

Additional Analysis	Word length inventory	Word shape inventory	Tone inventory
	1 syl ☑	(C)V ☑	T1 – H (high) ☑
		(C)VV ☑	T2 – MH (mid-high) ☑
		(C)VVV ☑	T3 – MLM (mid-low-mid) ☑
		VC ☑	T4 – HL (high-low) ☑
		(CVC) (☑)	Other:
		(CVVC) (☑)	
	2 syl ☑	(C)VCV(V) ☑	Tone Sequences
		CVVV(C)V(V) ☑	1-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☐*
		CV(V)CV(V) ☑	2-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☑
		(C)V(V)CV(V)C ☑	3-0 ☑ -1 ☑ -2 ☑ -4 ☑
		(CVC.CV(V)(C)) (☑)	4-0 ☑ -1 ☑ -2 ☑ -3 ☑ -4 ☑
		CVVCCVC ☑	Tone sandhi? 3-3 > 2-3 ☑
		CVVC.CVV(V) ☑	Other:
		Other:	*No data but see 1-4-4-1
	3+ syl ☑	CV(V)CCVCV) (☑)	2-4-0 ☑
		CVVVCVCCVV ☑	3-2-0 ☑
		CVCCVCCVCV ☑	1-4-4-1 ☑
Maximum	4-syl	CVCCVCCVCV	1-4-4-1
Substitution and deletion patterns	No	(Deletion, syl-fin nasals) (Addition of V in some CV(V)C syllables)	No
More data needed?	No	No	No
Strength or need?	Strength	Minor needs: CV(V)C, inclusion of coda nasals	Strength

Segments and Features

The segmental and feature analysis examines all the vowels and consonants of the language, with specific analyses of consonants across word positions. Both independent (inventories) and relational comparisons with the adult target are done. Substitutions for the adult targets are evaluated in terms of target features present, missing or changed. Feature analyses capture generalizations across segments. Analysis may reveal that certain features are present in the system, but not in all the necessary combinations with other features.

Vowels

Only a few targets required further analysis, but for demonstration purposes, all vowels are indicated in Tables 6a to 6c. Table 6a shows monophthongs categorized in terms of their individual features, Table 6b focuses on a specific problematic feature combination (simultaneously co-occurring features) and Table 6c on diphthongs (VV) and triphthongs (VVV). Inventory and relational perspectives are provided, with mismatches underlined and inconsistent matches parenthesized.

Vowels were relative strengths in single word production -- all vowels and their features showed some matches. However, in her connected speech, there appeared to be more variability in vowel production, and in the single-word sample, monophthong mismatches were noted for mid back vowels /o/ and /ɤ/. Substitution patterns included:

a. insertion of a high vowel (diphthongization) as in: /mɤn^{MH}/ > [miɤn^{MH}] ('gate'), /xoŋ^{MH}sɤ^{HL}tə^{0}/ > [xouŋ^{MH}sɤ^{HL}tə^{0}] ('red'); and
b. lowering of /ɤ/ > [a]) as in /kʰɤ^{MH}sou^{0}/ > [kʰa^{MH}sou^{0}] ('cough').

Falling diphthongs /ia/ and /uo/ showed mismatches, with a rising sequence created through:

a. metathesis: /uo/ > [ou], as in /ɚ^{MLM}tuo^{0} /> [ɚ^{MLM}tou^{0}] ('ear'); or
b. addition of a high vowel after the low vowel, as in /tɕʰiɛn^{MH}/ > [tɕʰiɛi^{MH}] ('money').

Shanghainese may have influenced some aspects of her vowel production, in particular the diphthongs, because Shanghainese has fewer diphthongs than Mandarin. The insertion of a high vowel in /tɕʰiƐn^{MH}/ [tɕʰiƐi^{MH}] 'money' may be a result of the nasal deletion, another Shanghainese influence, but this is speculative. It is unlikely that vowel metathesis was a direct result of Shanghainese influence.

Consonant Inventory and Word Position

Consonant analyses include: (a) an evaluation of consonant inventory and matches by word position; (b) a substitution analysis of individual consonant features by manner, place and laryngeal status; and (c) evaluation of simultaneous feature combinations. The inventory and match analysis by word position divides targets into true consonants ([+consonantal]) and glides ([-consonantal]), as shown in Table 7.

The rows in Table 7 provide four evaluations: (a) consistent; versus (b) inconsistent matches with the language targets; (c) non-Mandarin substitutions; and (d) consonants or glides missing from the inventory. As noted in the Overview, and further demonstrated in Table 7, the child showed consistent matches for many consonants and glides, but inconsistency concerning coronal fricatives, affricates and /l/. Examples presented in the Overview show inconsistent match for the [Dorsal] nasal /ŋ/ in word-internal syllable-final position, and inconsistent match for the [Coronal] nasal /n/ in word-final position. These inconsistencies may reflect the influence of Shanghainese, where only the velar nasal is used, and even that is sometimes elided. Non-Mandarin substitutions included [d s̺ ts̺ʰ ç]. The [d] may also show influence from Shanghainese, which has voiced obstruents. Missing from the word-initial inventory were the affricate /ts/ and retroflex /ɻ/. Missing from the word-medial inventory were the /ts/, /ʂ/ and /tʂ/ and /tʂʰ)/. (Further examples are provided in the substitution analysis below.) The lack of retroflexes may reflect the influence of Shanghainese, which has no retroflexes. However, she also used retroflexes on occasion where they do not occur in Mandarin, possibly reflecting over-generalization of a developing category in Mandarin. Because the nasals and the retroflexed fricative and affricates were matched in some word positions, but not others, they would be considered 'positional' (syllable structure) rather than 'segmental' goals.

Table 6a
Vowel Inventory and Match Analysis (mismatches underlined)

Feature or Combination[a]	Vowel Inventory	Strengths/Needs	
Dorsal [+back]	u ☑ (o ☑) (ɤ ☑) a ☑ ə ☑ ɚ ☑	(Strength ☑)	Need ☑
Coronal	i ☑ y ☑ e ☑	Strength ☑	
Dorsal [+high]	i ☑ y ☑ u ☑	Strength ☑	
Dorsal [-high] & [-low]	e ☑ ə ☑ ɚ ☑ (o ☑) (ɤ ☑)	(Strength ☑)	Need ☑
Dorsal [+low]	a ☑	Strength ☑	
Labial [+round]	u ☑ (o ☑) y ☑ ɚ ☑	(Strength ☑)	Need ☑
[-round]	i ☑ e ☑ a ☑ (ɤ ☑)	(Strength ☑)	Need ☑
[+tense]	i ☑ u ☑ y ☑ e ☑ a ☑ (o ☑) (ɤ ☑) ɚ ☑	(Strength ☑)	Need ☑
[-tense]	ə ☑	Strength ☑	

[a]By using the features [Dorsal], [Coronal] (front vowels), and [Labial] (+round vowels), consonant and vowel features can be seen to share place of articulation (Bernhardt & Stemberger, 1998). All vowels use the tongue body and therefore have a [Dorsal] component. Mid vowels are neither [+high] nor [+low] but a combination of [-high] and [-low].
Note. In all tables, parentheses indicate inconsistent matches.

Table 6b
Vowels: Feature Combinations

Vowel Needs for Feature Combinations		Patterns
o ɤ	Dorsal [+back] [-high] [-low]	1. Diphthongization with a [+high] feature: /o/ to [ou] /ɤ/ > [iɤ] 2. Lowering of /ɤ/ > [a]

Table 6c
Diphthongs and triphthongs

VV/VVV	VV, VVV Inventory	Patterns	Strengths/Needs
Rising	ai ☑ ei ☑ ou ☑ ao ☑		Strength ☑
Falling	(ia ☑) ua ☑ (uo ☑) ie ☑ ye ☑ iao ☑ iou ☑ uai ☑ uei ☑	/ia/ > [iai] /uo/ > [ou]	(Strength ☑) Need ☑

Table 8 shows all the substitutions (and deletions, indicated with ø) for consonants, divided by manner, place and laryngeal (voiceless) features. The first two columns indicate the adult targets by feature (Column A) and sound class and segments (Column B). Substitutions are entered in a row only if they pertain to the target feature. Some of the substitutions for a given consonant appear in more than one place on the chart, because the consonant shows at least two of manner, place and laryngeal feature substitution patterns.

A summary of the feature substitutions follows with examples.

Table 7
Consonant and glide inventory and matches

Feature	Word-initial	FW[a]	Medial, Syllable-initial	Word-final
[+consonantal]				
Consistent match	p pʰ t tʰ k kʰ m n f tɕ tɕʰ x	n	p pʰ t tʰ k m n f s ɕ tɕʰ	ŋ
Inconsistent match	s ʂ̜ tʂ̜ tʂ̜ʰ ɕ l	ŋ	tɕ l	n
Non-Mandarin substitutions	d ʂ̪ tʂ̪ tʂ̪ʰ ɕ̪		d tʂ̪	
Missing targets	ts ɻ		ts ʂ̜ tʂ̜ tʂ̜ʰ	
[-consonantal]				
Consistent match	w j			
Inconsistent match			(j)	

[a] FW means Syllable-Final-Within-Word

Note: The word-initial and word-medial inventories show some positional constraints: inconsistency for syllable-final nasals and for use of the retroflexed fricative and affricates (missing word medially but occurring word initially).

1. Liquids /l/ and /ɻ/ and glide /j/: There was not yet a strong contrast between the liquid and glide categories, or within the liquid category, although both /l/ and /j/ sometimes matched. The /l/ sometimes appeared as [j] and the /j/ sometimes as [ɕ] (only word medially).

/jye^{HL}liaŋ^{0}/ > [jye^{HL}jiaŋ^{0}] 'moon'

/ʂua^{H}ja^{MH}/ > [ʂua^{H}ɕa^{MH}] 'brush teeth'

The /ɻ/ appeared consistently as /l/, as in /ɻou^{HL}/ > [lou^{HL}] 'meet.'

2. Coronal fricatives and affricates: As can be seen in Table 8 and the examples below, coronal fricatives and affricates either inconsistently matched, or were absent from the inventory. In terms of substitutions by manner of articulation, coronal fricatives remained fricatives, even if the place or laryngeal features changed, as in:

/suo^{MLM}/ > [ʂuo^{MLM}] 'lock'

/ʂu^{H}/ > [su^{H}] 'book'

However, affricates sometimes lost their [+continuant] (fricative) component as in:

/tsʰai^{HL}/ > [tʰai^{HL}] 'vegetable'

/tʂuo^{H}tsi(ə)^{0}] > [tuo^{H}tʂi^{0}] 'table'

Substitutions by place of articulation showed various changes. The contrast between (dento-) alveolar ([+anterior]) and post-alveolar ([-anterior]) fricatives was not yet well-established. The /s/ showed more consistent matches than /ʂ/, but the two did interchange with one another, as the examples above for /suo^{MLM}/ and /ʂu^{H}/ show. Similarly, the post-alveolar affricates /tʂ(ʰ)/and /tɕ/ and fricative /ɕ/ sometimes appeared as dento-alveolars ([+anterior]), whereas the [+anterior] affricate /ts/ sometimes appeared as the [-anterior] [tʂ]. In addition, [+grooved] coronals were often replaced with a [-grooved] consonant.

/tʂ^{H}itʂu^{H}/ > [tʂi^{H}du^{H}] 'spider'

/tsuei^{MLM}pa^{0}/ > [tʂuei^{MLM}pa^{0}] 'mouth'

Finally, although there was a high degree of accuracy for the laryngeal (voiceless) features, the voiced stop [d] sometimes substituted for the voiceless target, as in 'spider' above, and in:

/fei^{H}ɕi^{H}/ > [fei^{H}di^{H}] 'plane'

/tsai^{HL}tɕiƐn^{HL}/ > [dai^{HL}tɕiƐn^{HL}] 'goodbye'

Within the coronal fricative and affricate set for Mandarin, the child showed clear needs for development of manner features (affricates), place features (all) and laryngeal features (primarily affricates).

Variability and Sequences

As indicated in the overview, assimilations, dissimilations, coalescences and metatheses were not observed, except for diphthongs (as noted above under vowels). Thus, for this child, no further analysis was indicated. Other variability was already addressed in the above analyses.

Summary, Goal Selection and Treatment Strategies

The above information is integrated into a final table for analysis, to determine any potential goals and treatment strategies (Table 9).

The general perspective of the nonlinear approach to phonological intervention is to use strong word structures to support new segments and features and vice versa (Bernhardt & Stemberger, 2000). In addition, it is crucial to consider all other aspects of the child's development, in order to set priorities and strategies for intervention. Table 9 first summarizes the strengths and needs across domains of prosodic structure, word position and sequence and features and segments (sub-divided into single features versus feature combinations). Initial goals for Mandarin development are then suggested from this set, with treatment strategies indicated that use strengths to support needs and take other aspects of the child's linguistic system, personality, cognitive development and environmental support into consideration. Finally, a goal order is described which reflects the interactions of phonology with other

Table 8
Consonant substitutions and deletions designated by feature category and word position

Target feature	Target consonants	Word-initial	Medial SF[a]	Medial SI[a]	Word-final
Manner:					
[-consonantal]	Glides w j			(j > ɕ)	
[+sonorant] & [+consonantal]	Liquids l ɻ	(l > j)		(l > j)	
[+lateral]	Lateral l	(l > j)		(l > j)	
[+nasal]	Nasals m n ŋ		(ŋ > ø)		(n > ø)
[-continuant] (& [-nasal])	Oral stops p pʰ t tʰ k kʰ				
[+continuant] (& [-sonorant])	Fricatives f s ʂ ɕ x				
[-continuant], [+continuant]	Affricates ts tsʰ tʂ tʂʰ tɕ tɕʰ	ts > d tsʰ > tʰ tʂ > t, tʰ, d		tʂʰ > tʰ tʂ, tɕ > d	
Place: Labial Labiodental	Labials p(ʰ) m f w f				
Coronal [+anterior]	t tʰ s ts tsʰ n l	(s > ʂ) (l > j) ts > tʂ		(l > j)	(n > ø)
[-anterior]	ʂ tʂ tʂʰ ɕ tɕ tɕʰ ɻ j	(ʂ > s, s̪) (tʂ, tʂʰ > tʰ, d, tsʰ) (tʂʰ > ts̪ʰ) (ɕ > ɕ̪) ɻ > l		ʂ > s tʂ > d tʂʰ > tʰ (tɕ > tʰ, d)	
[+grooved]	s ts tsʰ ʂ tʂ tʂʰ (plus ɻ j)	(ts > d) (ʂ > s̪) (tʂʰ > tʰ, d, ts̪)		ts > t̪, ts̪ tʂ > d tʂʰ > tʰ	
[-grooved]	ɕ tɕ tɕʰ (plus stops, l, n)				
Dorsal	k g ŋ x w j		(ŋ > ø)	(j > ɕ)	
Laryngeal: [-spread glottis]	Unaspirated p t k ts tʂ tɕ	(ts, tʂ > d)		ts > d (tɕ > d, tʰ)	
[+spread glottis] (asp; [-vc] frics.)	pʰ tʰ kʰ tsʰ tʂʰ tɕʰ f s ʂ ɕ x				

Note. Substitutions are entered only if they apply to the target feature. Parentheses = inconsistent substitution.SF = syllable-final medial; SI = syllable-initial, medial.

factors and the relative strengths in the system.

For this child, there were no high priority prosodic structure needs and therefore no goals for this domain. This indicated that all prosodic structures were available for addressing segment and feature needs, except those with the mismatching vowels and syllable-final nasals (a positional need). Nevertheless, the monosyllable might be the preferred word length in early phases of treatment for such a child, in order to allow specific focus on the particular features/segments in question. When there is apparent variability in connected speech, however, as was the case here, treatment would need to proceed from monosyllables to longer words and phrases. The major needs for this child were coronal fricatives, affricates and liquids, other needs including mid back vowels, the diphthong /uo/ (especially in connected speech where the vowels appeared to vary more), and syllable-final nasals.

The child received treatment over a 10-month period,

Table 9
Summary, Goal Selection and Treatment Strategies

	Prosodic Structure	Word Position or Sequence	Features and Segments
Strengths	Length: ✓ to 4 syl. Word Shape: Most Tone: All	Consonant by position: Most ✓ Sequences: Most ✓ for consonants, vowels, tones	Cons: Stops, labials, dorsals, fric. manner, asp. Vowels: Most ✓ Tones: All ✓
Needs	Length: None Word shape: (CV(V)C), as part of vowel treatment Tones: None	Consonant by position: (a. Syllable-final /n/, /ŋ/) b. Medial /ʂ, tʂ, tʂʰ/ Sequences: /uo/	Consonants: a. Cor frics: [anterior] b. Cor affrics: [-,+cont], [anterior], [-spr glottis] c. Liquids: (l) ɻ: [+/-lat] d. (Glides: /j/) Vowels: Mid back /o/, /ɤ/
Initial goals		a. Medial /ʂ, tʂ, tʂʰ/	Single features: [lateral] Combinations: a. Cor [ant] & [+cont] b. [-,+continuant]: Affric. c. Cor & [-spread glottis] e. Vowels: Mid back
Other factors	Child was exposed equally to Shanghainese and Mandarin, and to some English at preschool. Shanghainese influence was noted for some of the developmental patterns, but not all. She had otherwise normal development and personal-social contexts. A younger sister also had mildly protracted phonological development. Connected speech appeared more variable than the single-word context (general observation).		
Treatment strategies	Tx not indicated (positional, feature)	Observe vowels and coda nasals for spontaneous change after addressing coronal fricatives and affricates	a. Use any structure except those with positional/ sequence needs b. Monosyllables, word-initial (WI), then longer words, phrases
Goal order		2b. Medial [-anterior] fric. /ʂ/ 3b. Medial /tʂ, tʂʰ/	1. Vowels: mid back 2a. [+/-anterior] fric. WI 3a. [-,+continuant] affric. (asp vs unasp), WI (3. [+/-lateral]: (l) ɻ)

with the following goal set and sequence:

1. Vowels: mid back vowels and diphthong /uo/ (because of the apparent greater variability in vowels in connected speech).
2. The fricative [+anterior]/[-anterior] contrast between /s/ and /ʂ/, first word-initially (single feature), and then word medially (positional goal).
3. Affricates, including the sequence [-continuant]-[+continuant], and contrasts in [anterior] (alveolar/post-alveolar) and [spread glottis] (aspiration).
4. Finally, liquids; because she already used [l] some of the time, the focus was on /ɻ/. (Because she had some exemplars of retroflexes, /ɻ/ was considered an appropriate goal for her age.)

Needs not addressed were /l/, /j/ and the syllable-final nasals.

The family noted that, after targeting the vowels, the child's intelligibility increased noticeably. Following consonant intervention, the coronals also improved, although she continued to produce ungrooved variants some of the time (consistent with her age). In terms of the overall treatment program, her parents reported understanding about 70% of her speech face-to-face within context before treatment, and almost 100% post-treatment. Her grandparents reported understanding about 20% of her speech pre-treatment and about 80% post-treatment when speaking Mandarin to her on the phone from Shanghai.

Conclusion

The objectives of the paper were to outline the major aspects of the Mandarin phonological system and to provide a sample analysis for a child with mild-moderately protracted phonological development based on Bernhardt and Stemberger (2000) methodology. This particular child additionally showed some influences of Shanghainese. The study was not designed as a treatment study, but observation indicated positive treatment effects. The nonlinear analysis provided (a) confirmation of strengths in many areas of the child's phonological development that could be exploited when addressing needs; (b) a detailed investigation of vowels, which appeared to influence intelligibility notably for this child; and (c) positional and feature information regarding consonant acquisition. For a child with more severely protracted phonological development, more needs would of course be identified across phonological domains, nonlinear analyses providing a framework for detailed analysis within and across the multiple domains (Bernhardt & Stemberger, 2000). However, it is important to note that there are always strengths to be identified in the phonological system, no matter how severely protracted development might be. Through a thorough analysis of the various hierarchical levels of phonological form, these strengths can be identified and used as supports for addressing the needs. More traditional sound-by-sound analyses or phonological process analyses often neglect the positive aspects of development, and furthermore, focus minimally on prosodic structure, giving an incomplete picture, and less specific information for treatment planning.

In an ongoing study, for which these are preliminary data, we will be investigating normal and protracted Mandarin development in Shanghai and Taiwan to develop the data collection and analysis procedures for Mandarin further. Additionally, adaptations of nonlinear analysis procedures are in process with German (Ullrich et al., 2008) and Spanish and are planned for several other languages.

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Author Note

Correspondence concerning this article should be addressed to May Bernhardt, PhD, School of Audiology and Speech Sciences, 2177 Wesbrook Mall, Vancouver, British Columbia V6T 1Z3. Email: bernharb@interchange.ubc.ca .

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Importance of the auditory perceptual target to the achievement of speech production accuracy

Importance de la cible perceptive auditive dans l'atteinte d'une production adéquate de la parole

Douglas M. Shiller
Susan Rvachew
Françoise Brosseau-Lapré

Abstract

The purpose of this paper is to discuss the clinical implications of a model of the segmental component of speech motor control called the DIVA model (Directions into Velocities of Articulators). The DIVA model is implemented on the assumption that the infant has perceptual knowledge of the auditory targets in place before learning accurate production of speech sounds and suggests that difficulties with speech perception would lead to imprecise speech and inaccurate articulation. We demonstrate through a literature review that children with speech delay, on average, have significant difficulty with perceptual knowledge of speech sounds that they misarticulate. We hypothesize, on the basis of the DIVA model, that a child with speech delay who has good perceptual knowledge of a phonological target will learn to make the appropriate articulatory adjustments to achieve phonological goals. We support the hypothesis with two case studies. The first case study involved short-term learning in a laboratory task by a child with speech delay. Although the child misarticulated sibilants, he had good perceptual and articulatory knowledge of vowels. He demonstrated that he was fully capable of spontaneously adapting his articulatory patterns to compensate for altered feedback of his own speech output. The second case study involved longer-term learning during speech therapy. This francophone child received 6 weeks of intervention that was largely directed at improving her perceptual knowledge of /ʃ/, leading to significant improvements in her ability to produce this phoneme correctly, both during minimal pair activities in therapy and during post-treatment testing.

Abrégé

Le but de cet article est de décrire les implications cliniques d'un modèle de la composante segmentale du contrôle moteur de la parole, plus précisément du modèle DIVA (« Directions into Velocities of Articulators »). Le modèle DIVA repose sur la prémisse que le nourrisson possède la connaissance perceptive des cibles auditives avant d'apprendre à produire correctement les sons, et suggère que les difficultés de perception de la parole engendrent une parole imprécise et une articulation inexacte. Nous démontrons à l'aide d'une revue de la littérature que les enfants présentant un trouble phonologique ont, en moyenne, des difficultés significatives avec la connaissance perceptive des sons qu'ils ne prononcent pas correctement. En se basant sur le modèle DIVA, nous posons l'hypothèse qu'un enfant qui présente un trouble phonologique et qui possède une bonne connaissance perceptive de la cible phonologique fera les ajustements articulatoires appropriés pour atteindre les cibles phonologiques. Nous présentons deux études de cas pour appuyer cette hypothèse. La première étude de cas implique un apprentissage à court terme dans une tâche en laboratoire par un enfant présentant un trouble phonologique. Malgré le fait que l'enfant n'articulait pas correctement les consonnes fricatives, il avait une bonne connaissance perceptive et articulatoire des voyelles. Il a démontré qu'il était pleinement capable d'adapter spontanément ses patrons articulatoires à de la rétroaction modifiée de sa propre parole. La deuxième étude de cas implique de l'apprentissage à plus long terme lors d'intervention en orthophonie. Cet enfant francophone a reçu six semaines d'intervention largement dirigée à améliorer la connaissance perceptive du phonème /ʃ/, menant à une amélioration significative de son habileté à produire ce phonème correctement lors d'activités de paires minimales en thérapie et lors de l'évaluation après la fin de l'intervention.

Keywords: speech sound disorders, speech motor control, speech perception, and speech therapy

Douglas M. Shiller, Ph.D., S-LP(C)
Université de Montréal
Montreal, Quebec
Canada

Susan Rvachew, Ph.D., S-LP(C)
McGill University
Montreal, Quebec
Canada

Francoise Brosseau-Lapré, M.Sc.A., S-LP(C)
McGill University
Montreal, Quebec
Canada

Accuracy

When designing an intervention for a child with primary speech delay (SD), the speech-language pathologist will typically begin with a description of 'what is wrong' in the child's overt speech. Over the past three decades there has been enormous change in the theoretical constructs used to conceptualize speech errors. Take for example, this excerpt from a child who was assessed at the age of 4;8 (Rvachew & Brosseau-Lapré, 2010): [bebi jeɪn daʊn ɪn gas̺̚ tʰæni ʌpʰ] (" baby laying down and dog's standing up"). Traditionally, one would describe omissions, distortions, and substitutions of segments, noting for example the child's substitution of [j] for /l/ in the word 'laying' (Van Riper, 1963). A phonological process analysis (Hodson, 2004) would take note of patterns of error in the child's speech such as the consistent reduction of the consonant sequences (e.g., /nd/, /gz/, /st/). Meanwhile, nonlinear phonological theories have focused our attention on interactions between features, segments and the prosodic aspects of the phonological system, allowing an explanation for the child's production of the word 'dog' that involves spreading of Dorsal from the place node of the coda to the place node of the onset segment combined with delinking of the coda itself from the skeletal tier (Bernhardt, Stemberger, & Major, 2006; Bernhardt & Stoel-Gammon, 1994). This historical shift in focus from the surface characteristics of the child's segment errors to a description of the child's underlying phonological knowledge[1] has led to the development of more efficient and effective approaches to speech therapy (Klein, 1996; Pamplona, Ysunza, & Espinoza, 1999). Nonetheless, the majority of children with SD make slow progress, failing to achieve normalized speech prior to school entry (Rvachew, Chiang, & Evans, 2007; Shriberg, Kwiatkowski, & Gruber, 1994), suggesting that these advances in phonological theory are not enough. Efficacious intervention programs require us to go beyond describing what the child is doing wrong and move toward explaining why the child is making those specific errors (Stackhouse & Wells, 1993). As highlighted by Bernhardt, Stemberger, and Charest (this issue), the task of imagining the possible sources of the child's errors requires that the speech-language pathologist consider models of language processing. In this paper, we begin with a discussion of a model of the segmental component of speech motor control. The DIVA model (Directions into Velocities of Articulators) is supported by research that ranges from computational modeling to clinical investigations involving behavioral and neuro-imaging methods (Callan, Kent, Guenther, & Vorperian, 2000; Ghosh, Tourville, & Guenther, 2008; Guenther, 1995; Guenther, Hampson, & Johnson, 1998; Perkell et al., 2000; Perkell et al., 1997).

The DIVA model contains a number of modules — each its own separate neural network — that capture the various steps in the transformation from the abstract phoneme string (the model's input) to the output articulatory motor sequence. The modules are connected by synaptic weights that implement the transformations, or *mappings*, between these representations. The model accounts for speech production development as the acquisition of three such mappings: the *phoneme-to-auditory* mapping, the *auditory-to-articulatory directional* mapping, and the *articulator-to-auditory* mapping. A critical assumption underlying the DIVA framework is that words are represented as a sequence of segments and that these segments are represented as spatio-temporal auditory goal regions (Perkell et al., 2000). While the model does not capture the full complexity of phonological representations (e.g., features at levels other than the individual segment, or the link between phonology and the lexicon) the implication is that the goal of the talker is to produce a specific auditory goal that will be perceived by the listener as the desired phoneme sequence, as opposed to producing a specific constellation of articulatory gestures. For example, if one wishes to convey the word 'we', comprising the phoneme sequence /wi/, one must produce an auditory product that corresponds to the phones [ui]. The corresponding auditory goals are invariant while not being point values. Rather, they are multi-dimensional regions in acoustic space as illustrated in Figure 1, depicting formant values appropriate for a child talker (represented here in only two dimensions, however, for the sake of simplicity). The talker could produce a variety of articulatory gestures that would result in the auditory goal of a second formant that is initially low and relatively close to the first formant but rising to a higher value that is much closer to the third formant in value (note that this characterization of the auditory goals in terms of relative locations of the formant frequencies allows for talker normalization so that the infant can learn to match his or her own speech output to auditory goals derived from adult input). The mapping between language-specific target phonemes and the corresponding auditory goal regions is learned very early in life but refined throughout childhood (Edwards, Fox, & Rogers, 2002; Hazan & Barrett, 2000; Kuhl, 2004; Maye, Werker, & Gerken, 2002; Nittrouer, 2002).

In the model, the auditory-to-articulatory directional and articulator-to-auditory mappings correspond to an internal model that is learned early in life on the basis of accurate sensory feedback. It is posited that the internal model is acquired during babbling as the infant learns to relate articulator movements to their orosensory and acoustic consequences. The critical role played by auditory input in the acquisition of auditory-motor mappings in the model is consistent with the empirical finding that hearing impairment in infancy delays the onset of the canonical babbling stage and reduces the amount and quality of speech-like babble produced by infants (Eilers & Oller, 1994; Koopmans-van Beinum, Clement, & van den Dikkenberg-Pot, 2001; Rvachew, Slawinski, Williams,

1 We use the term "knowledge" to refer broadly to information that is neurally encoded and accessible to the child, either with or without conscious awareness.

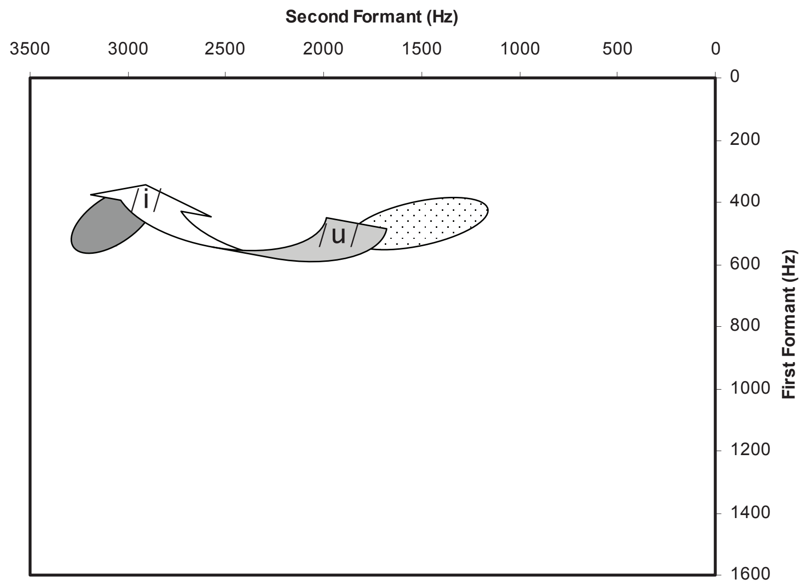

Figure 1: Illustration of hypothetical auditory goal regions when producing the word 'we'.

& Green, 1999). During the early word learning phase, the DIVA model is implemented on the assumption that the infant has perceptual knowledge[2] of the auditory targets already in place before learning accurate production of the requisite speech sounds (Guenther, 2003; Guenther, Ghosh, & Tourville, 2006). Perceptual knowledge of the target is essential if the infant is to use auditory feedback effectively to learn to plan articulatory movements that will result in the desired phone-sequences. The model further postulates that auditory feedback is used intermittently throughout childhood to reset the parameters of these mappings so that the child can cope with maturational changes in the size and shape of the vocal tract (Callan et al., 2000).

Perkell et al. (2000) argue that it is unlikely that auditory feedback is used by mature talkers to control articulatory movements in real time because of relatively long neural transmission times. Rather, the internal model allows the talker to rapidly translate information about the current vocal tract configuration into an estimate of auditory feedback by way of the articulatory-to-auditory mapping, which can then be used to drive the system toward the auditory goal. The internal model further allows the talker to plan a trajectory of movement from the current auditory region (e.g., the /u/ location marked on Figure 1) toward the target auditory goal region (e.g., the /i/ location), using an articulatory trajectory that maximizes *economy of effort*. The planned articulation trajectory in turn leads to the planning and execution of specific muscle activation patterns.

The planning of the articulatory trajectory in auditory space also allows the model to achieve similar acoustic outcomes (e.g., similar formant values) using different articulatory configurations (*motor equivalence)*, as is commonly observed in speech. For example, the articulatory trajectories from rounded vowels or consonants into /i/ will vary predictably from those produced in other phonetic contexts (Nittrouer, Studdert-Kennedy, & McGowan, 1989). The production of /u/ probably requires a change in constriction location from the palatal to the velar area during the infant period as the vocal tract is reshaped (Ménard, Schwartz, & Boë, 2002, 2004). This aspect of the model has important clinical implications and may help to explain in part the superior results of phonological interventions over traditional approaches even for children with structural deficits (Pamplona et al., 1999). In short, it implies that the focus of intervention should be on the successful achievement of phonological goals rather than specific articulatory gestures.

Turning to potential explanations for primary speech delay (of unknown origin), we now turn our attention away from causes related to the execution of the motor action plans and focus on the factors that might disrupt the development of the internal model, i.e., the three associated mappings: the *phoneme-to-auditory* mapping, *auditory-to-articulatory directional* mapping, and *articulator-to-auditory* mapping. It is clear that the ability to process acoustic-phonetic information is central to all three mappings. The acquisition of the *phoneme-to-auditory* mapping (that constitutes the auditory target regions for phonemes) requires the infant to detect statistical regularities in speech input in order to identify language specific phone-categories and the acoustic goal regions that are associated with those categories. Auditory feedback during babbling is essential if the infant is to learn to predict the articulatory patterns that give rise to a given acoustic pattern (auditory-to-articulatory directional mapping) and to predict the acoustic outcome of specific vocal tract configurations (articulatory-to-auditory mappings). Although speech delay is a heterogeneous diagnosis and there are other potential explanations (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997), there is evidence to support the hypothesis that a very large subgroup of children with speech delay has a primary problem with the processing of the acoustic-phonetic characteristics of the speech input (Rvachew, 2007).

It is now fairly well established that, on average, children with speech delay of unknown origin have significant difficulty with speech perception. We searched the titles of journal articles published by the American Speech-Language and Hearing Association and identified 14 papers published since 1952 in which the speech perception abilities of children with speech delay were compared with

2 Perceptual knowledge includes a language-specific strategy for deriving phonological structure from acoustic input at multiple levels of the phonological hierarchy (e.g., features, segments, syllables, words). Speech perception is also influenced by sensory and nonsensory factors such as attention.

the speech perception abilities of children with normally developing speech (studies involving childhood apraxia of speech or secondary speech delay were omitted). These studies described collectively the perceptual abilities of 325 children with speech sound disorders, aged 3 to 9 years. With one ambiguous exception[3], every study demonstrated unequivocal evidence for significantly poorer speech perception abilities on the part of children with delayed speech. Speech perception deficits were observed when the children listened to live-voice or recorded natural speech (Cohen & Diehl, 1963; Hoffman, Stager, & Daniloff, 1983; Kronvall & Diehl, 1952; Marquardt & Saxman, 1972; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Sherman & Geith, 1967; Smit & Bernthal, 1983), digitally altered natural speech (Edwards et al., 2002; Monnin & Huntington, 1974; Raaymakers & Crul, 1988), and synthesized speech (Broen, Strange, Doyle, & Heller, 1983; Hoffman, Daniloff, Bengoa, & Schuckers, 1985; Rvachew & Jamieson, 1989). In these studies the children with speech delay were shown to have difficulties with both discrimination and identification tasks involving the perception of their own speech as well as speech produced by other talkers. Cohen's d (with Hedge's correction), calculated for the comparison of clinical and typical groups, ranged from $d = 1.35$ (Rvachew & Jamieson, 1989, Study 1, n = 12) to $d = 8.75$ (Kronvall & Diehl, 1952, n = 30), indicating very large effect sizes for each of the 13 studies that provided usable data.

The nature of the perceptual deficits observed appeared to be in the realm of acoustic-phonetic representations (i.e., knowledge of the specific acoustic cues that permit identification of the relevant phonetic categories). In many studies (e.g., Rvachew & Jamieson, 1989) the children were able to perform the task with live-voice stimuli, indicating phonological knowledge of the target contrast, even though they had significant difficulty with the experimental task that did not provide visual and other nonstandard cues to the test contrast. Munson, Edwards, and Beckman (2005) addressed this question by asking children to repeat nonwords in which word length was held constant but the phonotactic probability of phoneme sequences within the words was varied, yielding better repetition performance for high probability sequences than low probability sequences. As would be expected, absolute accuracy of repetition varied between typical and clinical groups and was significantly correlated with speech perception and speech production skills. However, children with SD did not show a greater disadvantage when repeating low-frequency sequences than did typically developing children, relative to repetition accuracy for high-frequency sequences. These findings suggest that difficulties with abstract phonological knowledge are not the source of the articulation errors that are observed in children with SD. Rather, these children have difficulties constructing word representations in the more primary perceptual domain, an interpretation that is reinforced by more recent investigations involving a long-term repetition priming paradigm (Munson, Baylis, Krause, & Yim, 2006). Specifically, when repeating nonwords, children with SD did not benefit from prior hearing of the nonwords during a passive listening task, indicating that they had difficulty forming new perceptual representations after brief exposure to the novel words; in contrast, their typically developing peers were able to store memory traces for new words after minimal exposures during passive listening that supported improved repetition accuracy on subsequent trials.

In short, the children's performance in these studies suggests that they have some phonological knowledge of the target contrasts but they differentiate the contrasting phonemes on the basis of nonstandard and unreliable acoustic cues leading to inappropriate auditory goal regions for each phoneme. Edwards, Fourakis, Beckman and Fox (1999) demonstrated the close relationship between perceptual deficits and speech production errors in a study of six children with speech delay. As in other studies, the children with speech delay were able to identify words such as 'cape' and 'cake' in a picture pointing task when the words were presented live-voice. Compared with children with normally developing speech, they had significant difficulty with the task when small portions at the ends of the recorded words were excised or when the amplitude of the vowel portion of the words was attenuated. The authors concluded that the children's perceptual representations for these words were "vulnerable to diminished redundancy in the acoustic signal. (p. 182)" Acoustic analysis of the children's productions of words such as 'Timmy' and 'kitty' suggested poor speech motor control, even though perceptually correct /t/ versus /k/ contrasts were produced by most of the children. Compared with the control group, the children with speech delay demonstrated poor control over speaking rate, greater overlap in the skewness and centroid values for intended /t/ and /k/ productions, and larger transition slope values from lingual consonants into vowels. The authors concluded that the children with speech delay "were less able to maneuver jaw and tongue body separately."

In summary, the DIVA model of speech motor control suggests that difficulties with the acquisition of the phoneme-to-auditory mapping during early childhood leads to imprecise speech and inaccurate articulation, since that mapping defines a principal goal of the speech motor system. In the model, a precisely defined auditory goal region forms the basis for the feedback of error signals that tune the feed-forward command for production of the

3 Sommers, Cox and West (1972) published the only study of the 14 located that did not show evidence of speech perception deficits for children with SD. In this study, 8 groups of 7 children were selected on the basis of grade (kindergarten or grade 1), speech status (articulation normal or defective) and stimulability (high or low scores on a stimulability test). They concluded that "Superior articulators had significantly better scores than the deviant and defectives on the oral sensory discrimination task, but scores on the auditory tasks were not significantly different. Comparison of the performances of /s/ and /r/ defectives revealed the latter group to be inferior on some auditory tasks compared with the superior articulators. (p. 579)" However, the published paper includes the data for the oral sensory discrimination task for all groups but omits the speech perception data for the groups with normal speech development and thus it was impossible to confirm the findings or calculate effect sizes from the data as reported.

sound. Therefore, only once the perceptual target is known will the child be able to learn the precise articulatory gestures required to produce the phoneme[4]. When the perceptual target is unknown (e.g., when a child identifies [w] as /ɹ/), the child will be unable to learn the articulatory gestures associated with the target /ɹ/ or will be unable to achieve carry-over of /ɹ/ production to spontaneous speech. When the child's perceptual category for a given phoneme is too broad and/or defined by inappropriate cues (e.g., when the child focuses on the second formant of word-final /ɹ/ rather than the third formant, as in /w/), the child's production of the target may be marked by distortions and/or inconsistent substitution errors.

We have argued that a large proportion of children with speech delay have difficulties with speech perception that will interfere with the acquisition of the phoneme-to-auditory mapping. We now turn to two case studies with the intention of further demonstrating the importance of knowledge of the auditory target to speech development. The first case study involves short-term learning in a laboratory task by a child with speech delay. In this case, the child was forced to adapt to altered auditory feedback during a speaking task. The case study demonstrates that, when the auditory target is known, at least some children with speech delay are capable of speech motor learning over a short time. The second case study involves the application of a speech perception approach to intervention over a six-week period with a French-speaking child with speech delay. This case study demonstrates that an intervention that focuses on improving auditory-perceptual knowledge of the therapy target can lead to improved articulatory accuracy.

Case 1

The central role played by auditory representations in speech production has been highlighted in a number of recent studies investigating the effect of altered sensory feedback on the control of speech movements (Baum & McFarland, 1997; Houde & Jordan, 1998; Jones & Munhall, 2000, 2003; McFarland & Baum, 1995; Nasir & Ostry, 2006; Purcell & Munhall, 2006a; Savariaux, Perrier, & Orliaquet, 1995; Shiller, Sato, Gracco, & Baum, 2009; Tremblay, Shiller, & Ostry, 2003; Villacorta, Perkell, & Guenther, 2007). In studies of sensorimotor adaptation (SA), sensory feedback during speech production is altered either by introducing a mechanical perturbation to the oral articulators (e.g., an intra-oral prosthesis that alters palatal shape), or through the use of real-time signal processing to directly manipulate acoustic spectral properties (e.g., fundamental frequency, or vowel formant frequencies). A central aim of these studies has been to investigate the extent to which talkers alter their control of articulator movements to reduce the impact of the perturbation on the achievement of acoustic outcomes. In other words, they are a direct test of the hypothesis that speech production is organized around the achievement of precise auditory targets.

While physical manipulations are an effective means of disrupting auditory feedback, their overall impact on speech production is somewhat complex due to their multi-sensory nature (tactile, proprioceptive and auditory) and the fact that they may reduce the available articulatory degrees-of-freedom (e.g., in the case of jaw fixation using a bite-block, or lip-fixation using a lip-tube). Using real-time signal processing, it is possible to more precisely manipulate properties of the speech acoustic signal without impacting other sensory modalities or interfering with articulator motion. Studies have used this approach to investigate sensorimotor adaptation in adult talkers to a range of acoustic manipulations, including fundamental frequency (Jones & Munhall, 2000, 2003), vowel formant frequency (Houde & Jordan, 1998, 2002; Purcell & Munhall, 2006a, 2006b; Villacorta et al., 2007), and fricative spectral properties (Shiller et al., 2009). These studies have all demonstrated that following a period of speech practice under feedback-altered conditions, talkers tend to adjust their speech output in order to reduce the perceived magnitude of the manipulation (i.e., compensation was observed). Importantly, these studies have also demonstrated a continued effect on speech output following the unexpected removal of the feedback manipulation, indicating that the change was not simply the result of direct feedback-based adjustments, but rather a change in the way articulator movements were planned in advance (i.e., motor learning, or adaptation).

The fact that adult talkers readily adjust their speech motor output in order to maintain (relatively) consistent acoustic outcomes provides strong, direct evidence for the primacy of auditory sensory goals in speech production (as opposed to goals defined in terms of specific vocal tract configurations, for example). While some questions remain as to the precise sensorimotor processes underlying SA, the phenomenon is consistent with models such as DIVA, in which ongoing comparisons between auditory feedback and desired auditory sensory outcomes are used to maintain the accuracy of internal models involved in speech motor planning. Indeed, Villacorta et al. (2007) recently demonstrated the ability of the DIVA model to capture numerous aspects of sensorimotor adaptation to an auditory feedback manipulation.

Given the success of the SA paradigm in demonstrating a central role for auditory targets in the speech production of healthy adults, we were interested in the possibility that it might similarly allow us to demonstrate a role for precise auditory goals in children with speech delays. If

4 While in the model, accurate speech perception and auditory feedback allow for the establishment of auditory target regions for different speech sound categories, it is presumed that with practice (i.e., repeated production attempts), a set of analogous somatosensory target regions are also learned. Somatosensory feedback is then used alongside auditory feedback in order to detect errors and maintain speaking accuracy. The inclusion of a somatosensory feedback subsystem and somatosensory goals provides the model with *part* of what would be necessary to acquire speech production skill in the absence of auditory input. However, the model relies upon an intact auditory speech perceptual system to establish those targets by informing the system, during the early "babbling" stage, about whether a given movement attempt has resulted in the production of a particular speech sound.

we are to consider the possibility that an impairment in auditory perceptual representations is a factor in speech delay, it is necessary to demonstrate that these children in fact strive to achieve precise acoustic goals. Otherwise, the status of auditory representations might simply not be expected to have a large impact, and therapy focusing on phonemic perception would not be expected to have much impact on speech production. To this end, we present a case study of a child (CH) with a primary speech delay (primarily impacting his production of sibilant fricatives) who underwent a test of sensorimotor adaptation to altered auditory feedback.

It is important to note that the goal of examining sensorimotor adaptation in a child with speech delay was *not* to directly evaluate the relationship between perception and production of his misarticulated phonemes. Indeed, targeting the child's misarticulated consonants would likely yield results that are difficult to interpret, as any number of factors — including deficits in sensory, motor or cognitive processes — could lead to a failure to adapt, thus providing little information about the child's speech motor control processes. Rather, the goal was simply to demonstrate that: 1) children with speech delay spontaneously use auditory feedback in order to maintain the accuracy of speech motor planning, and 2) children with speech delay strive to achieve precision with respect to their achievement of acoustic outcomes, rather than striving to achieve a specific sequence of articulatory movements. Such findings have been demonstrated in prior studies of sensorimotor adaptation in healthy adults, but never before in children with atypical speech development. To this end, the test of sensorimotor adaptation that was carried out in this child examined his production of a *previously mastered* phoneme: the vowel ɛ/ (as in "head").

Participant

CH is a 6;6 year-old native English-speaking boy with a speech sound disorder but no reported history of language impairment, and no history of hearing impairment. At the time of testing, CH passed a pure-tone hearing screening and an oral mechanism exam that revealed no structural or functional abnormalities of the articulators and surrounding structures. Age appropriate expressive language skills were confirmed using the Formulated Sentences subtest of the Clinical Evaluation of Language Fundamentals, Fourth Edition (Semel et al., 2003; standard score = 13, 84th percentile). Receptive language and non-verbal cognitive abilities were also confirmed to be age-appropriate using the Kaufman Brief Intelligence Test, Second Edition (Kaufman & Kaufman, 2004; Verbal standard score = 103, 58th percentile; Non-verbal standard score = 121, 92nd percentile). CH's diagnosis of speech delay was confirmed by a standard score of 68 (6th percentile) on the Goldman Fristoe Test of Articulation, Second Edition (Goldman & Fristoe, 2000). CH's speech errors included a substitution of [θ] for /s/ and /ʃ/, substitution of [ð] for /z/ and /ʒ/, substitution of [w] for /r/, and a substitution of [f] for /θ/.

Method

Sensorimotor Adaptation Task

Similar to a number of previous studies of SA using auditory feedback manipulations (Purcell & Munhall, 2006a, 2006b; Villacorta et al., 2007), the present manipulation involved a real-time shift in the frequency of the first formant (F1) during repeated productions of /ɛ/ within the target word "head". F1 frequency was increased by approximately 175 Hz, which had the effect of reducing the separation between F1 and F2, yielding a vowel that was perceptually closer to /æ/ ("had").

While seated in a sound attenuating testing room, CH was instructed to produce the word "head" five times at a comfortable rate and volume, after which he would pause for 4 seconds while a visual "reward" was presented on a nearby computer monitor. This sequence was repeated 52 times, for a total of 260 productions of the target word.

The speech acoustic signal was transduced using a head-worn microphone, amplified, processed (see below for details), and then presented back to CH through circumaural headphones. The experimental protocol included four phases, carried out in the following sequence: 1) 50 repetitions of the target word under conditions of unaltered feedback (baseline phase), 2) F1 shift introduced in 30 Hz steps over a period of 60 trials (10 repetitions per step; ramp phase), 3) 120 repetitions of the target word under conditions of maximum F1 shift (hold phase), 4) 30 productions following the sudden removal of the F1 manipulation (after-effect phase) to evaluate the persistence of any compensatory change in vowel output.

The auditory feedback manipulation was achieved using a commercial digital signal processor (VoiceOne, TC Helicon) that is designed to manipulate speech acoustic signals. The VoiceOne is capable of real-time source-filter modeling of the incoming vocalized acoustic signal, and hence is capable of altering the shape of the spectrum with minimal impact on fundamental frequency and harmonics. In the present study, the formant shift was restricted to the F1 range using a low-pass filter to apply the spectral shift only to the low-frequency (< 1000 Hz) portion of the signal.

Compensatory changes in /ɛ/ production were evaluated on the basis of digitized acoustic recordings of the subject's speech output. The acoustic signal was initially digitized at 44.1 kHz and subsequently low-pass filtered and down-sampled to 10kHz for the purpose of formant analysis. For each production of the target word "head", a 30 millisecond portion of the signal located at the vowel midpoint was subjected to a formant analysis utilizing the Burg algorithm within Praat (Boersma & Weenik, 2009). The analysis provided estimates of the first four formant frequencies, of which only F1 and F2 were retained for further analysis.

While the manipulation of vowel feedback involved an increase in F1 frequency, the corresponding perceptual change was likely related to a decrease in the difference between F1 and F2 (F2-F1), an acoustic measure that has

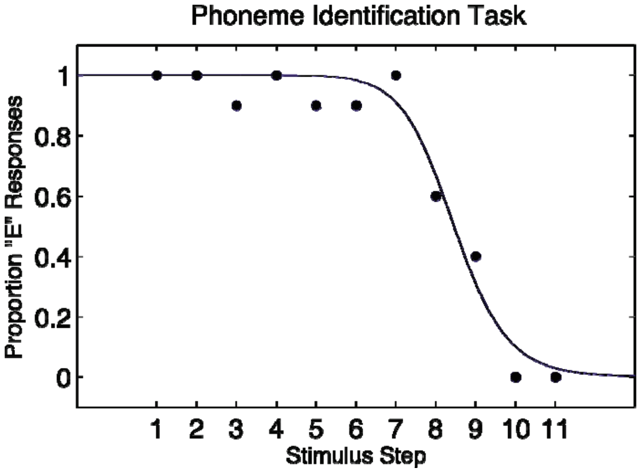

Figure 2: Response data for the vowel identification task. The filled circles show the proportion of /ɛ/ responses at each stimulus step. The solid line shows the best-fit logistic function.

Table 1
Mean change in F1 and F2 frequency (in Hz) relative to baseline at each phase of the sensorimotor adaptation task

Phase	F1 Change		F2 Change	
	Mean	SE[a]	Mean	SE[a]
Begin Hold	-35	3	-36	10
End Hold	-15	4	+132	6
Early After-Effect	-45	5	+48	9
Late After-Effect	-26	6	-4	8

[a] Standard error of the mean.

been found to be a stronger cue to tongue-height contrasts (e.g., /ɛ/ vs. /æ/) than F1 frequency alone (Kingston, 1991; Syrdal, 1985; Syrdal & Gopal, 1986). As a result, the acoustic analysis of CH's speech output focused on the F2-F1 feature, rather than changes in F1 frequency alone.

Phoneme Identification Task

Prior to the test of sensorimotor adaptation, a procedure was carried out to evaluate CH's perception of the /ɛ-æ/ contrast. The procedure involved the presentation of a synthetic vowel continuum that varied in 11 steps from [ɛ] and [æ]. The continuum was constructed by increasing the F1 frequency of a naturally produced [ɛ] token (spoken by an adult male in the context of the word "head") from approximately 550 Hz to 725 Hz (the talker's natural F1 frequency for "had"), using a signal processing approach similar to that used in the sensorimotor adaptation procedure. Following a practice run in which it was determined that CH understood the task and was able to correctly identify the endpoint vowel stimuli as /ɛ/ and /æ/, CH was presented with 10 repetitions of each of the 11 stimuli (always within the "h_d" context) in a fully randomized sequence. Following each stimulus presentation, CH indicated whether he had perceived the sound "E" as in "head" or "A" as in "had" by pressing the appropriate key on a keypad. In order to maintain his attention to the task, a child-friendly image was presented on a computer display following each block of 5 consecutive responses.

CH's response data were analyzed by first computing the proportion of /ɛ/ responses for each stimulus step (1.0 = 100% "E" responses), and then fitting a logistic function to the resulting data points in order to quantify the location and slope of the perceptual boundary between phoneme categories.

Results

Perception of the /ɛ–æ/ contrast

CH's response data for the vowel identification task (proportion of /ɛ/ responses for each stimulus step) are presented in Figure 2, along with the best-fit logistic function. The results show a sudden perceptual shift from /ɛ/ to /æ/ in the vicinity of stimulus 8-9, demonstrating an ability to perceive the contrast between these two vowel categories.

Sensorimotor adaptation

Baseline F1 and F2 frequencies were estimated from the final 10 productions of "head" under normal feedback conditions (immediately prior to the onset of the ramp phase). Mean F1 and F2 frequency were 753 and 2392 Hz respectively. Subsequent changes in vowel formant frequencies were evaluated by computing mean F1 and F2 values within four different blocks of trials (10 trials per block): 1) at the beginning of the hold phase (early training), 2) at the end of the hold phase (late training), 3) immediately following removal of the feedback manipulation (early after-effect), 4) at the end of the after-effect phase (late after-effect). Mean formant values for each block are presented in Table 1, and changes in F2-F1 are presented graphically in Figure 3.

While CH showed little change in F2-F1immediately following the ramped onset of the feedback manipulation (-1 Hz change), a compensatory change (i.e., an increase in F2-F1) was observed at the end of the hold phase (+147 Hz change). The compensatory F2-F1 change was found to persist immediately following removal of the feedback manipulation (though at +93 Hz, it was smaller than the effect observed at the end of the hold phase), indicating that underlying motor plans for the production of the vowel had in fact been altered (i.e., adaptation). By the end of the after-effect phase (following 20 productions under conditions of unaltered auditory feedback), CH's F2-F1 values had returned close to baseline (+22 Hz).

The reliability of these F2-F1 effects was evaluated using a one-way, independent measures ANOVA, treating each block of trials as a random sample of scores (N=10). An overall main effect of trial block was found ($F[4,42]=5.16$, $p < 0.01$). Post-hoc comparisons using Tukey's method revealed reliable differences ($p < 0.05$) between baseline

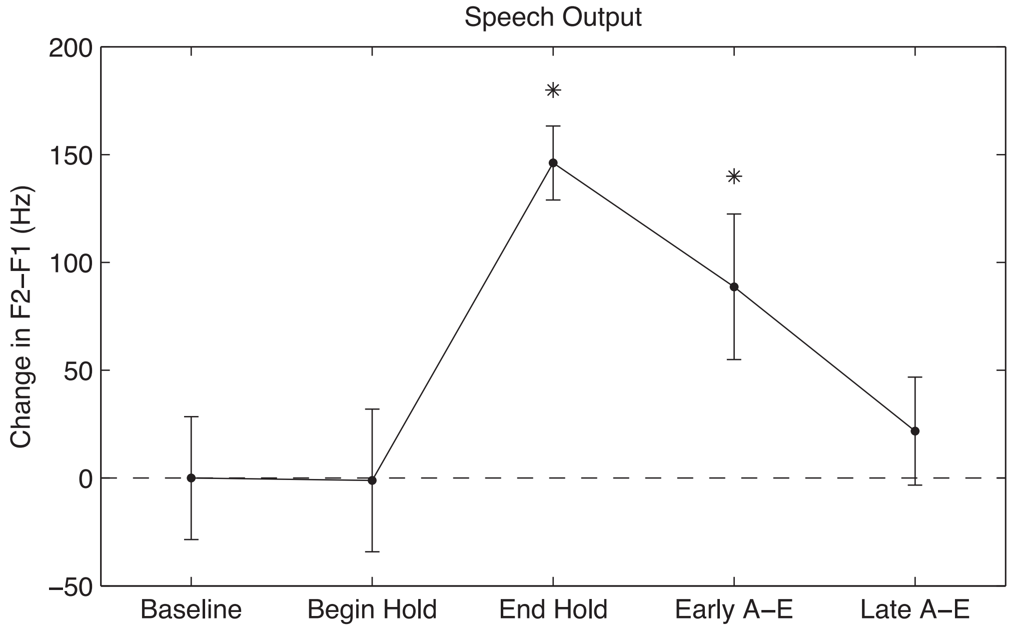

Figure 3: Mean change in F2-F1 (in Hz) at each phase of the sensorimotor adaptation task.

and late training blocks, between early training and late training blocks, and between the late training and late after-effect blocks (Figure 3).

Discussion

The finding that CH, a 6;6 year old child with a primary speech delay, readily adapted his speech output in response to a manipulation of auditory feedback adds a small but valuable piece of information to the present discussion about auditory perceptual goals in speech production. Phoneme identification testing indicated that the child had good perceptual knowledge of the phonological target. When auditory feedback was manipulated to create the impression that his speech output was deviating from this goal, he spontaneously adapted his speech output to the auditory feedback. His performance demonstrated accurate knowledge of the relationship between articulatory movements and relative formant frequency locations as well as sufficient speech motor control to achieve his speech goals. While only a single case, it nevertheless supports the notion that children with speech delays organize their control of speech production around the achievement of precise auditory goals (though, not necessarily accurate ones). It leads to the hypothesis that ensuring adult-like perceptual knowledge of phonological targets will facilitate the acquisition of articulatory knowledge of those targets. The next case study demonstrates that an intervention that targets perceptual knowledge of the phonological target can lead to improvements in articulatory accuracy.

Case 2

The Speech Assessment and Interactive Learning System (SAILS) is a computer game that was developed to teach children the appropriate acoustic-phonetic goal regions for commonly misarticulated phonemes (for literature review and video tutorial, see Rvachew & Brosseau-Lapré, 2010). The software presents children with recorded versions of single syllable words produced by adult and child talkers. The listener's task is to point to a picture of the word when they hear a well-produced version of the target and to point to an 'X" when they hear something that is not the target. The task was designed to reflect Locke's (1980) call for clinically relevant speech perception test procedures that assess the match between adult surface forms and the child's own internal representations for words, targeting those phonemes that the child misarticulates. This program has been shown to facilitate the acquisition of correct production of the target phoneme in a series of single subject experiments (Jamieson & Rvachew, 1992), a quasi-experiment (Rvachew, Rafaat, & Martin, 1999), and three randomized control trials (Rvachew, 1994; Rvachew, Nowak, & Cloutier, 2004; Wolfe, Presley, & Mesaris, 2003). For example, Rvachew (1994) was conducted with preschool children presenting with moderate speech sound disorders who received six therapy sessions once weekly, in all cases targeting /ʃ/ for which the children were unstimulable. All children received perceptual training in addition to traditional speech therapy but only a third of the children listened to various productions of the target /ʃ/, both articulated correctly and incorrectly, by completing the SAILS intervention modules targeting this phoneme. Children in the other conditions either listened to a single well-produced version of the word *shoe* contrasted with one version of the word *moo,* or to the words *cat* and *Pete.* In this study, the perception training component lasted for one third of each session while two-thirds of all therapy time was devoted to production training. The production training procedures were behaviorist in nature, involving phonetic placement, progressive approximation and practice with progressively longer utterances. Feedback was provided about the accuracy of the children's articulatory gestures and a high rate of accuracy was required before children could advance from one step of the treatment program to the next (for example, they were required to imitate syllables with 90% accuracy before practice with the imitation of words was introduced). Children who had completed the SAILS intervention modules made more progress with respect to production of /ʃ/ than other children in the study. In fact, children in the control group failed to achieve stimulability for /ʃ/ in isolation whereas children who received speech perception training learned to produce this phoneme in phrases.

Currently we are conducting a randomized control trial that involves a French version of SAILS (Essai Clinique Randomisé sur les Interventions Phonologiques). The francophone children that are enrolled in this trial receive 6 weeks of individual intervention directed at improving their articulation accuracy followed by six weeks of group intervention targeting phonological awareness skills. Half of the children in the trial are randomly assigned to receive individual therapy that is focused on improving their perceptual knowledge of their speech targets. The intervention differs from that employed in previous studies in that the proportion of time devoted to listening activities versus speech production practice is much greater. Furthermore, speech practice activities take place in the context of minimal pair activities that are designed to provide feedback about the communicative effectiveness of the child's speech. Phonetic placement and overt feedback about articulatory gestures are discouraged. Overall the program is designed to ensure that the child gains good perceptual knowledge of the target and then has opportunities to discover the articulatory movements that are necessary for accurate achievement of speech goals. In this case study we present the results for one child who is enrolled in this study. The child's performance will be described for the first 6-week period when she received individual therapy from a student speech-language pathologist under the supervision of the third author who is coordinating this trial.

Participant

Participant 1113 was four years eight months at the intake assessment and presented with a moderate speech delay. Her vocabulary skills were within normal limits, her score on the Échelle de vocabulaire en Images Peabody (EVIP; Dunn, Thérialut-Whalen, & Dunn, 1993) being at the 50th percentile rank. She also obtained a standard score of 103 on the matrices subtest of the Kaufman Brief Intelligence Test – Second edition (K-BIT-2; Kaufman & Kaufman, 2004) indicating average non-verbal IQ. Participant 1113 also passed the Oral Speech Mechanism Screening Examination - Third edition (OSMSE-3; St-Louis & Ruscello, 2000), revealing normal structure and function of the oral mechanism. At the present time, there is no normed and validated test of phonology available for French; clinicians typically use a language sample and their clinical judgment to qualify the degree of severity of the phonological impairment in this language. Participant 1113 obtained a diagnosis of a moderate speech delay by the community speech-language pathologist who had re-assessed her two weeks prior to her referral to the ECRIP research project. The Test Francophone de Phonologie (TFP) is currently being developed by Paul & Rvachew and contains 54 single words representing the characteristics of the phonology of Quebec French. On the TFP, administered during the intake assessment, participant 1113 did not produce responses spontaneously and therefore delayed imitation and immediate imitation were used in order to obtain responses for every test item. She obtained a percentage of consonants correct of 81 based on phonetic accuracy of each consonant articulation, i.e., omission, substitution, and distortion errors were scored as incorrect. Her error patterns included fronting of /ʃ/ to [s], reduced consonant clusters and deletion of syllables in multisyllabic words. Intelligibility in conversation was more affected and was severely reduced in unknown contexts.

Methods and Results

Pretreatment Assessment

Following the intake assessment, three specific therapy targets were selected for participant 1113, one of which was to improve auditory-perceptual knowledge of /ʃ/. Prior to the first therapy session, participant 1113 was asked to produce 20 words containing /ʃ/. Pictures of the target words were presented in four blocks of five items each, with the clinician naming each block before prompting the child to name the items in the same order. She obtained a score of 1 out of 20, producing [s] for all other items. During the same probe session, speech perception of /ʃ/ was assessed using the French version of the Speech Assessment and Interactive Learning System (SAILS, AVAAZ Innovations, Inc., 1994). Participant 1113 obtained a score of 50% on both the modules 'chat' [ʃɑ] (*cat)* and 'tache' [taʃ] (*spot)*, indicating poor perceptual knowledge of this phoneme.

Treatment

Intervention for participant 1113 consisted of three types of activities: SAILS, focused stimulation, and minimal pairs. SAILS is a computer game that uses a two-alternative forced choice identification task. The child listens to stimuli recorded from adults and children with and without speech sound disorders and needs to indicate whether each word presented is a good exemplar of the target or not. Each block contains five correctly and five incorrectly articulated target phonemes corresponding to typical misarticulations from younger children and children with SSD. During intervention, feedback is provided by the clinician when the child chooses the wrong response alternative and then the stimulus is repeated. The feedback includes a brief explanation as to why the presented stimulus did not match the child's response, and the child must then select the correct response to continue to the next trial. Participant 1113 completed a different SAILS module during each of the first three therapy sessions; approximately ten minutes were devoted to each module, which consisted of a practice block and two intervention blocks. In the module "chat", the practice block contrasts five adult productions of the word "chat" [ʃa] and five adult productions of the word [ma]; foil items in Block 1 are child productions of [ta] and [da]; foil items in Block 2 are child productions of [sa], [s̪a] and [ʃa]. The practice block of the "chaude" (hot) module contains adult productions of [ʃod] and adult productions of [mod]; foil items are child productions of [tod] and [dod] in Block 1 and child productions of [sod], [s̪od] and [ʃod]. In the "tache" module, which targets word-final /ʃ/, practice items are [taʃ] and [tap]; foil items are [tat] in Block 1 and [tas], [tas̪] and [taʃ] in Block 2. It should be noted that Participant 1113 enjoyed completing the SAILS modules.

Second, focused stimulation activities provided participant 1113 with many opportunities to hear words containing /ʃ/. For example, the clinician selected books that contained frequent repetitions of one or a few words containing the target phoneme. Activities involving toys were also used, for instance while playing with a farm the clinician repeated the words "cheval" [ʃəval] (horse), "cochon" [koʃõ] (pig) and "vache" [vaʃ] (cow) on numerous occasions (targeting /ʃ/ in all three word positions). Participant 1113 was never asked to produce the target words during these activities, but had opportunities to do so. If she attempted production of the target words the clinician would recast her attempted production if necessary by repeating her utterance and correctly producing the target word. No explicit feedback was given to participant 1113 regarding the accuracy of her productions. Focused stimulation activities were completed during the second, third and fourth therapy sessions, for five to seven minutes each.

Third, perceptual and production minimal pairs activities were used. During perceptual minimal pairs, participant 1113 had to identify whether the clinician produced the target word correctly or produced the child's mispronunciation. For instance, if the clinician produced the word "choux" [ʃu] (cabbage) properly, the child was expected to glue the picture of a cabbage in the garden but if the clinician said "sous" [su] (penny) the child was expected to take a penny placed on the table and to give it to the clinician. The clinician provided feedback to the child, represented the stimulus word and helped the child select the correct object if needed. During production minimal pairs activities, participant 1113 was required to produce the target word. Activities were designed so that she could not achieve her goals if she produced [s] instead of [ʃ]; for example if she said "ça" [sa] (this) instead of "chat" [ʃa] she could not obtain the cat stickers to complete the activity. Perceptual minimal pairs activities were carried out in the third, fourth and fifth therapy sessions. Performance was found to improve across the three sessions, with the child correctly identifying only 1/10 productions of [ʃ] in the first session, and 10/10 by the end of the third session. Production minimal pairs activities were completed during the fifth and sixth sessions. The child showed improvements between these two sessions, with word-initial [ʃ] improving from 0% to 100% correct, and word-final [ʃ] improving from 0% to 60% correct.

Post-treatment Assessment

Following the six therapy sessions, participant 1113 correctly produced 13 of the 20 probe words in delayed imitation; more specifically she correctly articulated all words containing /ʃ/ in the onset position (CV, CVC, CVCV and CVCVC word structures), 1 of 5 words containing /ʃ/ in the word-medial position which had been targeted during two therapy sessions and 2 of 5 target phonemes in the coda position (CVC word structure). The focus on speech perception during intervention probably allowed participant 1113 to develop an internalized perceptual-acoustic representation for /ʃ/ so that she was able to self-monitor and self-correct her own speech. The ultimate goal of the perceptual intervention is to allow the child to discover the articulatory gestures associated with the correct production of the phoneme so that she can accurately produce the target phoneme with greater frequency. The TFP was re-administered seven weeks later, following a six-week period of phonological awareness intervention. Participant 1113 produced all words in a delayed imitation task, and obtained a percent of consonants correct of 84.

General Discussion

According to the DIVA framework, the achievement of accurate speech production is wholly dependent upon a learned mapping between phonemes and the auditory goal regions that correspond to those phonemes (phoneme-to-auditory mapping). Knowledge of the auditory target allows the child to discover the predictive relationships between the various articulatory patterns that give rise to a given acoustic pattern (auditory-to-articulatory directional mapping) and the acoustic outcomes of specific vocal tract configurations (articulatory-to-auditory mappings). Knowledge of these relationships allows the talker to plan articulatory movements in order to achieve speech production goals with precision and economy of effort.

Studies that involve the manipulation of auditory feedback show that adult talkers readily adjust their speech motor behaviour in order to maintain (relatively) consistent acoustic outcomes, providing evidence for the primacy of auditory sensory goals in speech production. In the first case study, we demonstrated that a child with SD had an adult-like ability to adapt his speech motor output to achieve a phonological/auditory goal corresponding to the word 'head' (distant F2-F1 during /ɛ/) when feedback of his speech productions was manipulated to produce a percept similar to 'had' (i.e., close F2-F1 during /æ/). He was able to learn this task very quickly with no explicit instruction. The demonstration that this child strives to achieve precision with respect to his achievement of acoustic outcomes (rather than aiming to achieve a specific sequence of articulatory movements) suggests that his sibilant misarticulations may be due to mis-specified auditory goal regions for these phonemes rather than an inability to adjust articulatory patterns to achieve the necessary vocal tract configurations for accurate production. Without a direct test of his perceptual categorization of the sibilants, it is not possible to state this with absolute certainty, however.

In a second case study we demonstrated that a child who had very poor perceptual knowledge of /ʃ/ could make significant gains in articulatory accuracy for this speech sound with minimal speech production practice. This child received approximately 90 minutes of intervention for this phoneme but only about 15 minutes of this time, at the very end of six week intervention period, was devoted to overt speech production practice in the context of meaningful minimal pairs activities. Treatment activities involved primarily speech perception training, focused stimulation, and receptive minimal pair activities, designed to ensure that the child improved her perceptual knowledge of /ʃ/ as presented in a variety of syllable structures. When minimal pair production activities were introduced during the last two treatment sessions she quickly achieved success at these tasks. In pre- and post-treatment probes, she improved her performance from 5% to 65% correct, demonstrating correct articulation in a variety of word positions. Although she did not achieve consistently correct production of this phoneme, she demonstrated self-correction of her misarticulations very shortly after the introduction of speech practice activities.

Many studies conducted over the past five decades have shown that children with SD have significant difficulties with the perception of speech sound contrasts that they misarticulate. These children's speech perception difficulties may reflect auditory goal regions for phonemes that are overly broad, and hence overlapping with other phonemes. The DIVA model explains how these speech perception difficulties impact on the development of speech motor control and provides a rationale for the effectiveness of speech perception training as a means of facilitating children's response to speech therapy.

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The potential contribution of communication breakdown and repair in phonological intervention

Contribution potentielle des bris et des réparations de la communication lors de l'intervention en phonologie

Elise Baker
Patricia McCabe

Abstract

This paper explores the potential contribution of communication breakdown and repair sequences in phonological intervention. The paper is divided into two parts. In part one, we examine the inclusion of communication breakdown and repair sequences across three current approaches to phonological intervention. The review of this literature highlights a need for researchers to better document the teaching dialogue used in therapy. In part two of this paper, we consider how a unique type of clarification request containing an incorrect production could be applied in an intervention context. Reasons why such a unique counterintuitive clarification request might help children's speech are considered. The need to better understand the effect of different types of clarification requests on children's speech production skills during phonological intervention is discussed.

Abrégé

Cet article explore la contribution potentielle des séquences de bris et de réparation de la communication lors de l'intervention phonologique. Il est organisé en deux sections. La première examine l'inclusion des séquences de bris et de réparation de la communication dans trois méthodes actuelles d'intervention en phonologie. Cette analyse documentaire met en valeur la nécessité de mieux documenter l'enseignement de dialogues utilisés en thérapie. Dans la deuxième section, un type unique de demande de clarification contenant une production incorrecte pouvant être utilisé dans un contexte d'intervention est proposé. Des raisons sont données expliquant pourquoi une telle demande de clarification contre-intuitive unique pourrait aider la parole des enfants. Le besoin de mieux comprendre les effets de différents types de demandes de clarification sur les habiletés de production de la parole des enfants lors de l'intervention en phonologie est abordé dans la discussion.

Keywords: intervention, phonology, request for clarification, pragmatics, and polysyllables

Elise Baker, PhD
Discipline of Speech Pathology
Faculty of Health Sciences
University of Sydney
Lidcombe, Australia

Patricia McCabe, PhD
Discipline of Speech Pathology
Faculty of Health Sciences
University of Sydney
Lidcombe, Australia

Clinician: *What are you going to put on your pizza?*
Mark: *White capsicum* [waɪ kæʔtən]
Clinician: *A what?*"
Mark: *Capsicum* [kæptən]
Clinician: *Hmm, I'm not sure what you mean. A captain?*
Mark: *You know capsicum* [ju noʊ kæptətən]
Clinician: *Ah! Capsicum.*

Mark is 4 years old and has a phonological impairment. One of the consequences of his impairment is that breakdowns in communication occur. As shown in the above conversation between Mark and his speech-language pathologist (S-LP), breakdowns are signaled when listeners request clarification of speakers' utterances (Fagan, 2008). Requests for clarification (RQCL) are unsolicited queries from listeners inviting speakers to revise or repair their original utterances so that listeners can better understand speakers' originally intended messages (Brinton, Fujuki, Loeb & Winkler, 1986; Yont, Hewitt & Miccio, 2002). RQCL and the ensuing conversational exchanges between speakers and listeners are called repair sequences (Brinton et al., 1986). These sequences need to be resolved so that the topic of conversation can continue (McCartney, 1981). Resolutions may be achieved by speakers successfully revising their original message and/or listeners deducing speakers' intended meaning. As shown in the above example, breakdowns in communication may motivate children to repair their speech in order to be understood. In this paper, we reflect on the potential contribution of communication breakdown and repair sequences in phonological intervention as a pragmatic strategy for promoting speech change. The paper is divided into two parts. In part one, we explore the inclusion of communication breakdown and repair sequences across three approaches to phonological intervention. We consider whether communication breakdown and repair sequences can be evidence-based kernels (Embry & Biglan, 2008) of phonological intervention, that is, whether they are specific and unique teaching procedures shown through experimental manipulation to positively change children's phonological abilities. In part two, we examine the literature on the impact of different types of clarification requests on children's speech. We consider how the findings from this research could be applied to the management of phonological impairment in children, particularly with respect to children's difficulties producing polysyllables.

Part One: Inclusion of Communication Breakdown and Repair Sequences across Current Approaches to Phonological Intervention

Children who have a phonological impairment are thought to have a linguistic difficulty with the organization and use of phonemes to signal meaning (Howell & Dean, 1994). Phonological intervention aims to facilitate the re-organization of children's phonological systems through the careful analysis and strategic selection of intervention targets, with the hope of promoting generalization. Complexity-based approaches to phonological intervention (e.g., maximal oppositions) focus almost exclusively on the role of intervention targets in facilitating widespread change in children's phonological systems (e.g., Gierut, 1992, 2007). While consideration of what to target in intervention is important, S-LPs still need to know how intervention targets are best taught.

Strategies for teaching intervention targets could be divided into one of two types: articulation-based teaching strategies and concept-based teaching strategies. To put it simply, articulation strategies focus on the mouth while conceptual strategies focus on the mind (Grunwell, 1983). Examples of articulation strategies include instructions about tongue-placement (e.g., "*put your tongue behind your teeth when you say [s]*") and imitation of clinicians' models (e.g., "*watch my mouth and say [s] with me*"). Examples of conceptual strategies include using imagery terms to classify sounds according to classes of voice, place or manner characteristics (e.g., Klein, 1996; Howell & Dean, 1994), and using communication breakdown and repair sequences that capitalize on the functional impact of the homonym in children's speech when they attempt to say minimal pair words (e.g., Weiner, 1981). For the practicing S-LP, decisions about which of these teaching strategies to use needs to be guided by research evidence. By this, we do not simply mean evidence in support of a particular intervention approach such as minimal pairs therapy (e.g., Weiner, 1981), but insight into the status of teaching strategies within approaches as evidence-based kernels of intervention (Embry & Biglan, 2008). An evidence-based kernel is "a behaviour–influence procedure shown through experimental analysis to affect a specific behavior and that is indivisible in the sense that removing any of its components would render it inert" (Embry & Biglan, 2008, p. 1). In this section of the paper, we consider whether communication breakdown and repair sequences are evidence-based kernels within three phonological intervention approaches that use minimal pair words.

Communication breakdown and repair sequences have been used as teaching strategies across many (but not all) approaches to phonological intervention. Perhaps the most well-known approach associated with such sequences is the minimal pair approach (e.g., Weiner, 1981). This approach was developed on the assumption that the "the social-communicative basis of the speaker-listener interaction serves as a powerful source of phonological learning" (Weiner, 1982, p. 141). In a review of the evidence base for this approach, Baker (2010) identified 42 peer reviewed published investigations. A close inspection of this literature showed how the use and timing of communication breakdown and repair sequences had varied. For instance, across the 42 investigations Baker found that 53% explicitly noted using communication breakdown and repair sequences. An additional 7% of studies explicitly stated that they did not induce communication breakdown, while the procedural details regarding the use of communication breakdown and repair sequences was difficult to discern for the remaining 40% of studies. In one of the first studies of the minimal pair approach, Weiner (1981) reported that minimal pair intervention including such sequences was successful at reducing the occurrence of the phonological processes of stopping of fricatives, final consonant deletion and velar fronting in two boys (4;10 and 4;4 years) with a phonological impairment. The exact contribution of this conversational device on the intervention outcomes was unknown because additional teaching strategies were included following participants' unsuccessful attempts to repair episodes of communication breakdown. Specifically, Weiner (1981, p. 98) reported that the clinician said "*You keep saying "bow." If you want me to pick up the boat pictures you must say the /t/ sound at the end. Listen, "boat, boat, boat." You try it. Okay, let's begin again*." In this brief dialogue example, metaphonological instruction is include ("*you must say the /t/ sound at the end*") and auditory models are provided for imitation ("*listen, "boat, boat, boat*"). In one of the few minimal pair investigations to not use communication breakdown and repair sequences, Saben and Costello-Ingham (1991) noted that the results may have been better if communication breakdown had been used. In their study, they attempted to make the participants aware of the homonymy in their speech by having them produce minimal pair words consecutively. They also provided the children with opportunities to imitate spoken models of minimal pair words, and asked them to point to named minimal pair pictures. Although the children learned how to say the treatment words, phonological generalization, described as the suppression of the targeted phonological processes in non-treatment words containing the targeted speech sound and other untreated phonemes affected by the targeted processes, did not occur. They suggested that real communication breakdown may have been needed to evoke phonological generalization. Together, the findings from these two investigations suggest that communication breakdown and repair sequences might be a useful teaching strategy for helping children learn how to use phonemes to signal meaning. Assuming that the strategy is useful, it would be important to know when it might best be used.

Across the evidence-base for the minimal pair approach identified by Baker (2010), 56% of studies using communication breakdown and repair sequences used them only once participants were able to imitate the treatment words, at word level. For example, Tyler, Edwards and Saxman (1987, p. 396) did not use "activities designed to take advantage of the semantic confusion created by an error production," that is, communication breakdowns and repair sequences, until their participants could produce the target sound in words. Tyler et al. (1987) note that "based on previous clinical experience, this was believed necessary in order for the child to experience success" (p. 396). By contrast, other studies of the minimal pair approach (e.g., Baker & McLeod, 2004; Blanche, Parsons & Humphreys, 1981; Crosbie, Holm & Dodd, 2005; Weiner, 1981) indicated that they used such sequences at word level from the outset of intervention. For example, Baker and McLeod (2004) reported saying the target word and minimal pair cognate as part of a RQCL (e.g., "*Do you mean nail or snail? I'm not sure what you mean. Tell me again*") during spontaneous speech production activities at word level. An initial imitation phase was not included in this study. Crosbie, Holm and Dodd (2005) reported using activities that resulted in communication breakdown if the participants did not say the target words correctly, initially in an imitation context at word level. Crosbie et al. (2005, p. 480) exemplified their feedback following error productions as "*I didn't hear a /p/ on the end when you said beep — it sounded like bee to me*." Weiner (1981) used communication breakdown and repair sequences from the outset of intervention based on an assumption that children experience a need to learn to change their speech within the context of such sequences. According to Weiner (1982), breakdown and repair sequences provide children with an opportunity to discover Malinowski's (1949) phenomenon of *word-magic*: successfully communicated words are powerful because they have the potential to cause action during a speaker-listener interaction. When spoken words do not work like magic, Weiner (1982) suggests that the frustration children experience when communication breaks down motivates them to change their phonology so that they can be understood. Inclusion of such breakdown and repair sequences from the outset of intervention prior to any imitation activities presumably ensures that such learning opportunities occur. Although this sounds intuitively appealing, the relative benefits of including communication breakdown and repair sequences from the outset of intervention, or, after imitated-based activities remain to be understood.

Other phonological intervention approaches in which communication breakdown and repair sequences involving minimal pair words have been used include Metaphon (e.g., Dodd & Bradford, 2000; Jarvis, 1989) and Parents And Children Together therapy (PACT; Bowen & Cupples, 1999). Across the evidence on these two approaches, the potential contribution of such sequences was difficult to establish because the sequences were included as one of a number of teaching strategies. For example, in a case study of the PACT approach, Bowen and Cupples (1999) used a variety of strategies such as auditory bombardment, production practice using meaningful minimal pair words, in addition to activities involving communication breakdown and repair sequences. Bowen and Cupples also included metalinguistic talk about 'fixing up' speech errors. Bowen and Cupples (1999, p. 80) commented how Ceri, 4;10 years, said to her mum, "*I fixed that one* *up, didn't I mum*?" following a self-correction. Therapy dialogue examples of clarification requests and feedback on error as part of communication breakdown and repair sequences were not provided. The effect of this latter conceptual teaching strategy on Ceri's speech was unclear. Similar comments could be made about a case study of the Metaphon approach. Jarvis (1989) reported using a variety of teaching strategies with Luke, 4;9 years. Some of the strategies included teaching him the difference between noisy and quiet sounds, activities targeting his perception of /p/ and /b/ in sound, syllable and word level contexts, activities using candles, bubbles, and straws to highlight the aspiration involved in producing initial /p/, and, activities in which communication breakdown and repair sequences occurred using the minimal pairs *pear* and *bear* at the single-word level. Although Jarvis noted that Luke successfully repaired his speech following a RQCL during a conversation with a peer in the classroom at school following a block of intervention, examples of teaching dialogue from intervention sessions were not provided.

In summary, although communication breakdown and repair sequences have been used across different contrast approaches to phonological intervention involving minimal pair words, the effect of such sequences as a teaching strategy on treatment outcomes remains to be clearly understood. If we are to determine whether communication breakdown and repair sequences are in fact evidence-based kernels of intervention, we need more carefully controlled efficacy research examining the relative contribution of clearly defined and exemplified episodes of communication breakdown and repair. A first step could be to determine the best type of RQCL that initiates a communication breakdown and repair attempt from children who have a phonological impairment. For instance, it would helpful to understand whether a RQCL containing a target word and minimal pair cognate (e.g., "*Did you say key or tea*?") is more effective than a simple RQCL (e.g., "*What did you say*?"). Part two of this paper reviews the existing literature on the effect of different types of RQCLs on the speech production skills of children with typically developing speech, and children who have a phonological impairment.

Part Two: Children's Responses to Different Types of Clarification Requests

Children's responses to different types of RQCL have been studied for over 30 years (e.g., Brinton et al., 1986; Fagan, 2008; Gallagher, 1977; McCartney, 1981). Yont, Hewitt and Miccio (2000) proposed a helpful system for describing and coding types of RQCL including (a) nonspecific or neutral requests for repetition (NRR), such as "*what*?"; (b) specific requests for confirmation (SRC), such as "*did you mean ring*?"; (c) specific requests for repetition (SRR), such as "*you found a what*?"; (d) specific requests for specification (SRS) that ask the speaker to provide more information to clarify a misunderstanding, such as "*you said you played with Tim*? *Who is Tim*?"); and (e) nonverbal requests (NVB), such as a confused facial expression. Of particular interest to the present paper are the studies that have considered whether children with typically developing speech or phonological impairment could repair their speech in response to different types of RQCL.

In a study of typically developing children's responses to a contrived NRR ("*what*?"), Gallagher (1977) reported a group of 21 children, aged 21-29 months, were more likely to repair their speech rather than repeat or ignore their listener's request. McCartney (1981) examined the effect of various types of RQCLs on the speech production skills of three boys with a severe speech disorder of unknown etiology. She reported that only eight responses to 113 RQCLs contained a speech repair and that the request type associated with such repairs was an SRC containing a model of the target word. For example:

"M. *What's he called?*
NE. *Sheriff* [ˈtɛwɪ]
M. *Sheriff?*
NE. *Yea, the sheriff* [ˈʃɛwɪ]"
McCartney (1981, 156)

Weiner and Ostrowksi (1979) provided 15 children, aged 3;1-5;6 years, with three different types of SRC ("*did you say* ____?"): (a) SRC using correct pronunciation of the target word, (b) SRC using child's pronunciation of the target word, and (c) SRC using an incorrect but novel pronunciation of the target word that differed from the child's incorrect pronunciation. Novel pronunciations were described as misarticulated responses that differed from the participants' responses. No further details were provided as to how or in what ways the misarticulated responses were developed. They described their participants as having misarticulated at least four fricatives or affricates. The status of the participants' speech as typically developing or impaired was not provided, although it was stated that none of the participants had received speech remediation. Confusion about the status of the participants' speech production skills exists in the extant literature, with one study indicating that the participants were typically developing (McCartney, 1981), and another suggesting that the participants had impaired speech (Paul-Brown & Yeni-Komshian, 1988). This issue aside, Weiner and Ostrowski (1979) reported that the children's repair responses following the novel SRC had the fewest speech production errors. They likened this condition to real communication breakdown, suggesting that children may be more motivated to make changes to their speech when they are clearly not understood. This suggestion is of course limited by the ambiguity surrounding the speech status of the children involved in the study. This phenomenon was replicated by Gozzard, Baker, and McCabe (2008) in a study of six typically developing children aged 4;1-4;9 years. In this particular study, the children were able to improve their pronunciation of polysyllabic words in response to a SRC containing an incorrect novel pronunciation in both a single-word context, and during conversational speech. As shown in the following example, Megan

Table 1
Summary of Robbie's language and phonological processing assessment results at age 4;6 years

Assessment tool	Standard Score	90% Confidence interval	Percentile Rank
Clinical Evaluation of Language Fundamentals-Preschool 2 Australian: Expressive Language Score (Wiig, Secord & Semel, 2006)	92	+/- 6	30%
Clinical Evaluation of Language Fundamentals-Preschool 2 Australian: Receptive Language Score (Wiig et al., 2006)	102	+/- 7	55%
Peabody Picture Vocabulary Test 4th Edition (Dunn & Dunn, 2007)	104	+/- 7	61%
Children's Nonword Repetition Test (Gathercole & Baddeley, 1996)	74		<10 %
Preschool and Primary Inventory of Phonological Awareness Subtests (Dodd, Crosbie, McIntosh, Teitzel & Ozanne, 2000)		95 % Confidence interval	
- Syllable segmentation	4	+/- 2.4	2%
- Rhyme awareness	10	+/- 1.9	50%
- Alliteration awareness	8	+/- 2.4	25%
- Phoneme isolation	9	+/- 0.7	37%

successfully repaired a breakdown in communication during conversational speech when the researcher requested clarification using a novel SRC containing a segmentally incorrect yet suprasegmentally correct production of her target word, echidna.

"Megan: *The echidna* [ˈkɪdnə] *has to go here*

Researcher: *Was that an* [əˈbɪdnə]?

Megan: *Echidna* [əˈkɪdnə]"

(Gozzard et al., 2008, p. 256)

In summary, it would seem that children are not only capable of revising their speech in order to repair a breakdown in communication, but, that the type of RQCL used by a listener may influence the extent to which children's speech revisions match the adult target. In light of the findings by Weiner and Ostrowski (1979) and Gozzard et al., (2008) it would seem reasonable to consider whether a SRC containing a novel pronunciation of children's target words could be used as a teaching strategy during phonological intervention with children who struggle to use their own relatively complete phonetic inventories accurately in polysyllables. What follows is a description of a preliminary clinical case in which this novel type of SRC was used. The primary purpose in presenting this clinical example is to illustrate how the novel SRC might be used in an intervention context. Using Fey and Finestack's (2009) five-phase plan for evaluation interventions, the case study merely serves as a pre-trial study to stimulate thought and discussion about the potential contribution of communication breakdown and repair sequences in phonological intervention. The case is not intended to provide empirically robust efficacy data but simply preliminary information that could be used in future evaluations of the efficacy of this conceptual teaching strategy.

Clinical Case Study: Background

Robbie (pseudonym) is the third child of English-speaking parents with no immediate family history of phonological or language impairment, no structural or anatomical cause for his speech impairment and normal hearing. At the age of 4;6 years, he was seen by a speech-language pathologist (second author) for a review speech and language assessment. Prior to this time, he had received blocks of intervention primarily targeting his segmental skills over a two-year period. The focus of this case example is Robbie's speech production skills at 4;6 years.

In summary, Robbie presented with an unusual phonological impairment. Despite having an almost complete phonetic inventory (20 vowels and 23 consonants with the exception of /ɵ/) and a wide range of word shapes, word lengths (up to five syllables) and stress patterns, his percentage of consonants correct (PCC) in a single-word context was 57.9%. Robbie's speech was more accurate in single words than in connected speech, and more accurate in monosyllables than in di- and polysyllables. He also had considerable difficulty with iambic stress. Across a sample of 15 words beginning with weak stress (e.g., *computer, potato*), he frequently omitted the initial weak syllable or changed the syllable stress from weak to strong (e.g., *giraffe* /dʒəˈraf/ was [ˈdɔwaf]). Of the words showing syllable omission, his attempts were either variable (e.g., *echidna* /əkɪdnə/ was [ˈtɪdʌ] and [ˈkɪdnə]) or included segments from the omitted weak syllable (e.g., *spaghetti* /spəˈgɛti/ was [ˈstɛti]) suggesting that he may have had more intact underlying phonological representations than individual surface representations suggested. Robbie was also frequently unable to change or update established productions of polysyllabic words as his phonological system developed. For example, despite being able to articulate word initial

Table 2
Summary of Robbie's phonological skills based on an independent and relational analysis of a single-word sample*

Independent analysis	
Phonetic inventory	Singletons: [p b t d k g m n ŋ h f v s z ʃ ʒ tʃ dʒ l j w r] with one instance of [ð] Consonant clusters: Word-initial [br tr kr bl sp st sn sm sw sl gw bw fw ʃn] and word-final [nt, nd, mp, mt, ns, ndʒ, ŋk, kt, ts, dz, vz, ld] Absent from inventory: [θ], some 2-element clusters /sk, kl, gl, fr, bj, kj, tr, θr/ and 3-element word-initial clusters[b]
Word shape/length inventory:	Monosyllables: $C_{0-2}VC_{0-2}$ e.g., V, CV, VC, CVC, CCV(C), C(C)VCC, Disyllables: $C_{0-2}VC_{0-3}VC_{0-2}$ e.g., CVCV, VCVC(C), CVCVC, CVCCV(C), CCVCV(C), CVCCCVCC Polysyllables: • 3-syllable words: $C_{0-2}VC_{1-2}VC_{1-2}VC_{0-2}$ e.g., C(C)VCVCV, CCVCVCV, CVCCVCVC • 4-syllable words: CVCVCVCV(C) • 5-syllable word *hippopotamus* CVCVCVCVCVC
Stress pattern inventory (S= primary stress, s= secondary stress, w= unstressed)	S, SS, Sw, Sws, Ssw, Sww, Swsw, Sssw, Swssw (once) Absent from inventory: wS, wSw, wSs, wSww
Relational analysis	
Percent Consonants Correct (PCC)	Total PCC = 57.9% PCC Early = 73.8%; PCC Middle = 51.6%; PCC Late = 46.5% PCC stops = 63.1%; PCC nasals = 84.8%; PCC fricatives = 58.9%; PCC affricates = 8.3%; PCC glides = 63.6%; PCC liquids = 58.5% PCC clusters = 31.2%
Percent Vowels Correct (PVC)	Total PVC = 82.7%
Percent Word Shapes Correct	Monosyllables = 73.9% Disyllables = 58% 3-syllables = 28 % 4- and 5-syllable words = 42%
Stress patterns	SS = 100%; Sw = 84%; wS = 0% (all attempts changed to SS) Sws/Sww/SwS = 61% (incorrect productions were either SS or SW) wSw / wSs = 0% (all attempts were changed to SS or Sw) Swsw / Swss/ Swws / Sssw = 36% (incorrect productions typically were the result of weak syllable deletion)

[a]Sample from 138 spontaneous single-word responses from Robbie during DEAP Phonology Assessment (Dodd et al, 2003) and the Gozzard et al., (2006) single-word test of polysyllables.
[b]Sampling constraints meant that some initial 2-element consonant clusters including /dr, pr, gr, ʃr, tw, tj, nj, pj/ were not sampled. The inventory status of these clusters was unknown.

/st/ clusters in single-word and conversational speech contexts at assessment, his production of *stegosaurus* was [ˈtɛgtɔ]. Apparently, he had been using this production for *stegosaurus* since developing a keen interest in dinosaurs as a toddler.

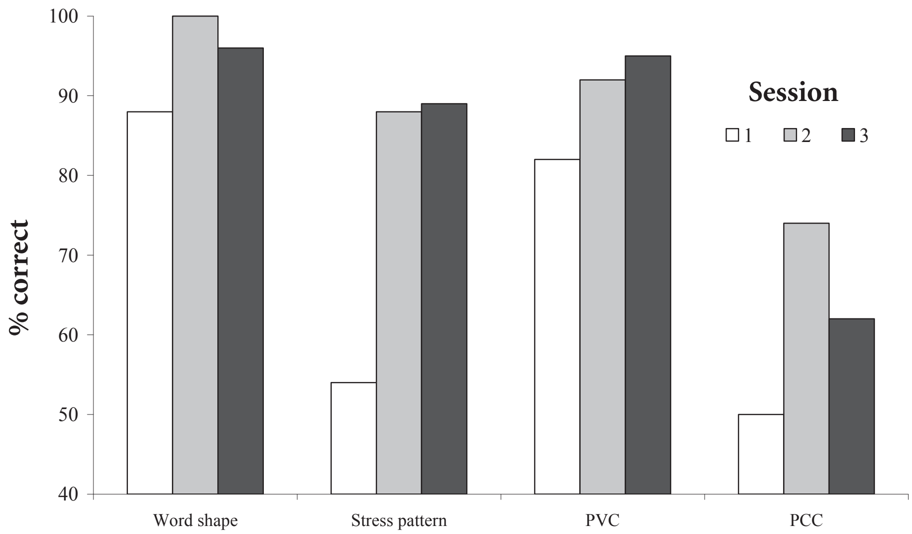
Robbie's language comprehension and production test scores were within the normal range. Measures of his phonological processing ability, including phonological working memory and phonological awareness suggested that he may have had difficulty encoding, storing and/or retrieving phonological information. However, the degree to which his phonotactic constraints influenced his performance on measures of phonological processing was unknown. Tables 1 and 2 provide a summary of Robbie's speech and language assessment results.

During conversational speech, Robbie was responsive to his communication partner's needs. When there was a breakdown in communication, he typically responded by repeating or repairing his original utterance. Using the repair categories described by Gozzard et al., (2008), his repair attempts typically involved semantic, syntactic or suprasegmental revisions. That is, he either changed the word he was trying to say, re-phrased his utterance or spoke louder and with greater emphasis on any unintelligible words or phrases. Over the three sessions required to conduct the speech and language assessment, Robbie did not use the strategy of revising the phonological or phonetic content of his speech in any repair utterance in response to naturally occurring neutral clarification requests (e.g., "*pardon*?", "*what did you say*?").

Clinical Case Study: Methodology

Given that Robbie did not change his speech in response to neutral RQCLs during conversation, and that he seemed to have more detailed underlying phonological representations than his surface representations for individual words suggested, we speculated whether the novel SRC used by Gozzard et al., (2008) with typically developing children might prompt him to repair his speech and use more adult-like productions of polysyllabic words. We conducted a trial of this repair strategy at the beginning of three of Robbie's regular weekly 50-minute intervention sessions. At the time of the trial, his regular intervention sessions focused on his phonemic awareness, letter and sound knowledge, based on Gillon (2005). The trial component within each therapy session lasted approximately 20 minutes. What follows is an overview of the procedure, measurements and outcomes of this preliminary trial.

Figure 1: Robbie's percentage of word shapes, stress patterns, vowels and consonants correct for target words in response to the clinician's specific request for confirmation (SRC) containing a different incorrect production of the target words, across the three trial sessions.



The trial sessions involving communication breakdown and repair were embedded in a clinician-directed play activity involving a set of 27 felt animals representing nine polysyllabic words and an African landscape scene mat. We limited the target polysyllabic words to the semantic category of African animals in keeping with the theme of the play activity. The novel SCR used to initiate the communication breakdowns contained a repetition of Robbie's incorrect attempt at one of the nine target polysyllabic words; however, the pronunciation was characterized by pre-prepared non-developmental segmental errors dissimilar to his errors with correct (or near correct) word/syllable shape, correct word length and correct stress patterns relative to the Australian English pronunciation. The novel error productions were phonotactically permissible in Australian English and did not contain metathetic errors (see the Appendix for details).

The clinician, Robbie and his mother Lucy (pseudonym) all sat on the floor around the mat while the clinician held the felt animals under a guise of sorting them. Robbie was invited to ask the clinician for the animal he wanted to place on the mat. If Robbie's request contained a phonological error, the clinician signaled a communication breakdown by stating "*Did you want a* (predetermined error production)?", in keeping with Gozzard et al (2008). For example, when he asked for [loʊp] (*antelope*), the clinician responded with a puzzled facial expression and said "*Did you want an [ˈæskedoʊp]?*" If his repair response matched the adult pronunciation or he changed his production to more closely match the adult pronunciation, the clinician acknowledged that the communication breakdown had been repaired by stating "*Oh an antelope, you want an antelope, now I understand you*". If his repair response did not change, the clinician offered feedback to acknowledge that she had still not understood but that the communication breakdown and repair sequence was completed by stating "*I **think** this is what you want*". No further breakdown was expressed for that turn. Play then proceeded with Robbie deciding where to put the animal and the participants talking about the developing scene. Over the natural course of this conversation, he was exposed to accurate auditory models of the target words spoken by the clinician and/or Lucy. Lucy also took turns requesting an animal from the clinician. Lucy was instructed to make deliberate mistakes in her production of the polysyllabic words in order to model communication breakdown and repair sequences. This allowed Robbie to observe both the consequence of a speech error and speech repair behavior. No other productions of the target words were requested or reinforced and no other therapy was provided on speech production (e.g., no feedback was given on phonetic errors). The decision to use the novel RQCL during the activity was based on the clinician's correct/incorrect judgment without regard to the type of error Robbie used. No homework was provided involving the novel communication breakdown and repair sequences and Lucy was requested to avoid incidentally using the technique during everyday conversation over the period in which the preliminary trial was conducted. However, Lucy was provided with homework focused

Table 3
Number of Robbie's productions of the trial polysyllabic words following the clinician's SRC showing correct, more accurate and less accurate productions over the three trial sessions

	Session 1 (number of opportunities = 24)	Session 2 (number of opportunities = 24)	Session 3 (number of opportunities = 27)
Correct	0	3	2
More accurate segmental production	11	9	12
More accurate suprasegmental production[a]	6	3	1
More accurate segmental and suprasegmental production	1	1	0
No change	2	5	8
Less accurate segmental production	3	0	0
Less accurate suprasegmental production[b]	1	3	4
Less accurate segmental and suprasegmental production	0	0	0
Imitation of clinician's incorrect production	0	0	0

[a]Suprasegmental includes word shape and/or stress pattern.
[b]Note, although the numbers suggest a decline in Robbie's accuracy overtime, it should be noted that these numbers are relative to his productions prior to the clinician's SRC in the same session. As shown in Figure 1, Robbie's percent correct word shape and stress pattern increased from session one to session two.

on Robbie's phonemic awareness, and letter and sound knowledge to complement the therapy provided in the regular intervention portion of the trial.

Robbie's production of the nine target words before and after each SRC was gathered during each of the three trial sessions. His production of an additional nine words not used in the trial was gathered at the beginning of each session. These nine words were limited to the semantic category of Australian animals in contrast with the African animal names used within the trial sessions, and were used to evaluate any generalized change in his production of polysyllables. The generalization words are listed in the Appendix – some of which may be unfamiliar to readers but are commonly known to Australian children. All of Robbie's productions of the trial and generalization words were phonetically transcribed online, audio- and video-recorded and checked for transcription reliability following the session. Point-by-point intra-rater transcription reliability was 92%.

Clinical Case Study: Results

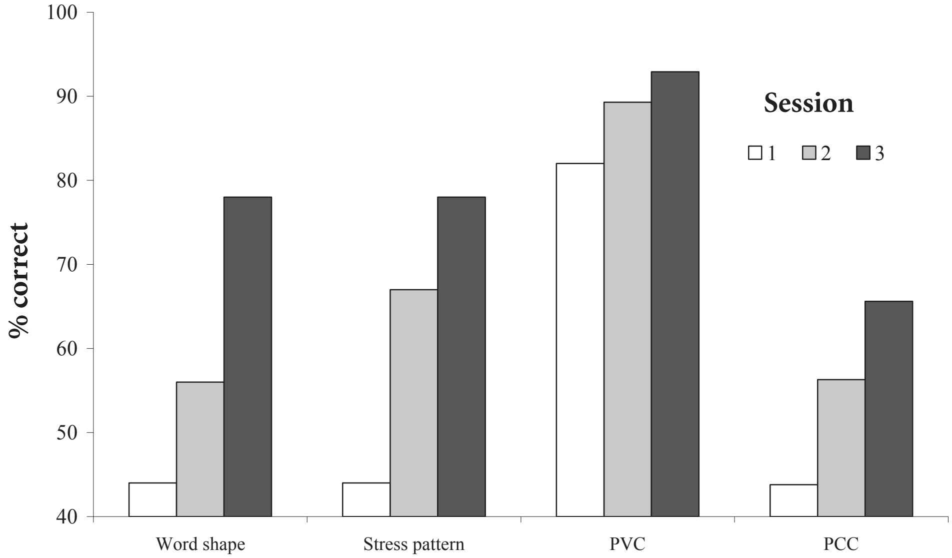
As shown in Figure 1, the percentage of consonants, vowels, word shape, and stress patterns correct for Robbie's production of the trial words following the clinician's SRC steadily improved from session 1 to session 3. The increase in his percentage of stress patterns correct (54% in session 1 to 88% in session 2) shows how this skill improved the most relative to the other measures. The following dialogue sequence from session 1 exemplifies this finding.

Robbie: *Alligator* [ˈdeɪtɔ]
Clinician: *Did you say* [ˈækəˌʃeɪnə] ?
Robbie: *No, alligator* [ælɪdeɪdə]

Also shown in Figure 1, Robbie's percentage of word shapes correct was higher than his percentage of stress patterns correct. This was primarily due to Robbie changing his dominant pattern of weak syllable deletion into syllable-stress alteration with weak syllables becoming strong syllables (i.e., wS > sS or SS). For example gorilla /gəˈrɪlə/ was produced as [dɒrɪlə] following the clinician's SRC. This latter example also highlights how although word shape and stress patterns seemed to improve, Robbie's PCC was relatively lower because he substituted other consonants for the target consonants. It seemed that he prioritized matching the word shape and/or stress pattern over matching the required consonants to the adult pronunciation.

Table 3 provides a quantitative summary of the nature of the changes (or lack thereof) in Robbie's productions of the trial words following the clinician's SRC relative to his production of the same trial words prior to the clinician's SRC. A number of observations were made. First, although the number of productions showing no change in response to a SRC increased from session 1 to session 3, the accuracy of his productions particularly with respect to word shape and stress patterns showed a gradual improvement. This may have meant that he had reached a point in session 3 where relatively fewer revisions were needed because he was producing the necessary syllables in words but that he

Figure 2: Robbie's percentage of word shapes, stress patterns, vowels and consonants correct for the generalization words, across the three trial sessions.



Session 3

Clinician: *Which one next?*
Robbie: *Antelope* [æbəloʊp]
Clinician: *Did you say* [ˈæskədoʊp]?
Robbie: *Antelope* [æmpəloʊp]

Similar trends were evident in the generalization words. As shown in Figure 2, there was a gradual increase in the percentages of consonants, vowels, word shapes and stress patterns correct across words from session one through to session three. It seemed that as Robbie included weak syllables and/or improved his production of word shapes, there was a corresponding increase in the percentages of consonants and vowels correct. In contrast with the data for the target words shown in Figure 1, his percentage of word shapes correct was better for the target words than the generalization words. It was difficult to clearly discern why this was the case. In part, it may have been due to the fact that the generalization words contained two instances of weak onsets (*koala, echidna*) in contrast with one instance (*gorilla*) for the target words. Robbie typically omitted the weak onsets in *koala* and *echidna,* thereby altering the word shape. By contrast, he tended to maintain the word shape for *gorilla* while altering the stress pattern from /gəˈrɪlə/ to [dɒrɪlə]. Robbie's difficulty updating earlier established words as his phonological system develop may have also contributed to the difference. Specifically, it may have been that he learned the names for the Australian animals (generalization words) as a young toddler when his word shapes were less well-developed (e.g., *koala* as [ˈwalə]) and continued to use these words shapes, while learning the names for the target words at a later point in time when his word shapes were perhaps better developed. It may also have been that because the word lists were not identical with respect to word shape, word length and stress pattern, that Robbie's performance across the lists was not comparable.

With respect to the nature of the changes (or lack thereof) across the generalization words, 67% (6/9) were more accurate, 22% (2/9) showed no change and 11% (1/9) evidenced a less accurate production. As shown in Table 4, consonant accuracy was more accurate for four of the words (e.g., *rosella* changed from [ɹoʊzɛwə] to [ɹoʊzɛlə]) while consonants, word shape and stress pattern was more accurate for two of the words (e.g., *kookaburra* changed from [tʊbʌwə] to [tʊkəbʌɹə]). The one word to show a less accurate production involved a change in word shape and consonants but not stress, specifically, *platypus* in session one was produced as [pwæwəpʊts] while in session three Robbie said it as [bædəpʊs]. Readers are reminded that these observations are from a non-experimental clinical case and

was less able to use all segments needed for an accurate production.

Secondly, although the majority of changes were positive (more accurate word shape, stress pattern and/or segments), only a small number of productions were completely correct (0 in session one, 3/24 in session two and 3/28 in session three). Moreover, some of Robbie's productions were less accurate relative to his production immediately prior to the novel SRC (3/23 in sessions one, 3/24 in session two, and 4/28 in session three). This latter observation was of some concern. Ideally, intervention facilitates progress towards a goal, not away from a goal. If the novel SRC were to be used as a conceptual teaching strategy in phonological intervention, the risks and benefits relative to other teaching strategies would need to be carefully considered. Thirdly, Robbie seemed to have a variety of realizations for the same word, within and across sessions. Finally, at no time did he imitate the clinician's incorrect production in the SRC. The following dialogue sequences from session 1 through 3 illustrate these observations. Prior to the first trial session, Robbie said antelope /æntəloʊp/ as [ænloʊ] and [loʊp].

Session 1

Clinician: *What is it?*
Robbie: *Antelope* [æməloʊ]
Clinician: *You didn't say* [ˈæskədoʊp] did you?
Robbie: *Antelope* [æləloʊp]

Session 2

Clinician: *What next?*
Robbie: *That one*
Clinician: *Which one?*
Robbie: *Antelope* [ætəloʊt]
Clinician: *Did you just say* [ˈæskədoʊp]?
Robbie: *No antelope* [æmbəloʊt]

Table 4
Robbie's production of the generalization words from session one to session three

Generalization word	Session one	Session two	Session three
platypus /ˈplætəˌpʊs/ (Sws)	[pwæwəpʊts]	[fætəpʊs]	[bædəpʊs]
pelican /ˈpɛləkən/ (Sww)	[pɛndɪn]	[pɛndən]	[pɛlətən]
cockatoo /ˈkʰɒkəˌtu/ (Sws)	[tɒgədu]	[dɒkədu]	[tɒkətu]
kangaroo /ˌkʰæŋgəˈɹu/ (swS)	[tæŋgəwu]	[tæŋgəɹu]	[tæŋgəɹu]
rosella /ˌɹoʊˈzɛlə/ (sSw)	[ɹoʊzɛwə]	[toʊdɛlə]	[ɹoʊzɛlə]
goanna /ˌgoʊˈwænə/ (sSw)	[doʊnænə]	[doʊmænə]	[doʊnænə]
echidna /əˈkʰɪdnə/ (wSw)	[tɪdnə]	[tɪn.nə]	[tɪdnə]
koala /kəˈwalə/ (wSw)	[walə]	[walə]	[doʊwalə]
kookaburra /ˈkʰʊkə/ˌbʌɹə/ (Swsw)	[tʊbʌwə]	[tʃʊkəbʌɹə]	[tʊkəbʌɹə]

that is it impossible to determine what in the clinician's interaction with Robbie may have prompted any of the observed positive and/or negative changes in his speech.

How might Communication Breakdown and Repair Sequences Improve Children's Speech Production Skills?

Our anecdotal clinical case in conjunction with the observations from Weiner and Ostrowksi (1979) and Gozzard et al's (2008) study suggests an interesting phenomenon. Typically developing children and at least one child with a phonological impairment seem to be able to improve their speech in response to a unique type of clarification request containing an incorrect production that differs from their own incorrect productions. How might children be able to do this? The very idea of requesting clarification using an incorrect production that differs from children's incorrect productions challenges the established practice of providing children with clear, accurate models of target words as part of phonological intervention. The type of incorrect production used in both Robbie's case and in Gozzard et al (2008) may hold some answers. Perhaps the correct components of the clinician's overall incorrect production inadvertently served as a model. This may have been the case for Robbie, given the improvement in his percentage of word shapes and stress patterns correct relative to measures of his PCC. Perhaps the novel production operated alone in prompting the change or in combination with the correct productions of the target words provided by the clinician and Robbie's mother over the natural course of conversation during the conversation-based play activity. The lack of experimental control in Robbie's case means that little can be said about the causal influence of the novel production on Robbie's production of polysyllables. It would have been interesting to compare his responses following different types of RQCL such as a SRC containing an accurate model of a polysyllable only, a SRC containing a novel production as was used in this investigation, and simply a SRC containing a word completely unrelated to the target word. Greater improvements in all measures given an accurate model would provide evidence against using the novel type of SRC. Equal or greater improvements in all measures given an unrelated word may help isolate the relative contribution of the breakdown in communication (pragmatics) from the relative contribution of the clinician's pronunciation of the target word. Well-controlled experimental studies would be needed to address such speculations.

Using Crystal's (1987) bucket theory of language disability, perhaps the incorrect production may have simply served as an attention device alerting the children to a pragmatic need to allocate more processing resources to the phonology domain so as to repair the breakdown in communication. The children may have been able to make the repair because they had the resources, in the form of more richly specified underlying phonological representations than their habitual or spontaneous use indicated. This may have been the case for Robbie given his surface realizations containing consonants from deleted weak syllables and his variable realizations. The breakdown in communication may have alerted the children to a need to create and execute a better motor plan based on their representations. This idea suggests a parsimony of speech output in which the least effort for effective communication is used as an unconscious default until the strategy is unsuccessful, as indicated by the novel SRC. These ideas are of course speculative and open to alternative theoretical interpretation.

Conclusion and Future Directions

Communication breakdown and repair sequences have been thought to be integral to the success of contrastive approaches to phonological intervention involving minimal pair words (e.g., Weiner, 1981). A review of the evidence across three different approaches suggests that such sequences may be valuable. However, there is insufficient evidence to unequivocally support the statement that they are in fact evidence-based kernels. Four issues need to be addressed in future research to better understand the potential contribution of communication breakdown and repair sequences in phonological intervention. First, the effect of phonological contrast intervention with and without communication breakdown and repair sequences on children's phonological generalization learning needs to be established. Second, there is a need to determine the appropriate timing of the use of communication breakdown and repair sequences. To date, some studies of phonological intervention have used such sequences from the outset of intervention while others have suggested that they are more appropriate following imitation-based activities. Third, there is a need to evaluate the relative benefits of different types of RQCL on children's phonological abilities, such as SRCs containing correct models, SRCs containing novel productions, and SRCs containing phonologically and semantically unrelated words, in both assessment and intervention contexts. It would be particularly interesting to explore the possibility of a relationship between children's abilities to respond to different types of SRCs prior to intervention and their rates of intervention progress. It may be that those children who do not show any change in their speech following different types of SRCs may benefit from explicit instruction to repair their speech (e.g., "fixed-up-one" routine as described by Bowen & Cupples, 1999). It may be that those children with richer underlying phonological representations relative to their surface representations may benefit from being given a reason to make better use of their underlying representations via breakdowns in communication. Finally, it would be important to examine the impact of communication breakdown and repair on children's overall experience of intervention. If children are frustrated from the outset of intervention, it would be important to gauge the relative benefits and risks of this experience on children's motivation and willingness to participate in future intervention sessions. Some children may simply be disheartened and lose motivation in intervention when faced with repeated episodes of communication breakdown. In such cases, sequences of communication breakdown and repair may need to be avoided. Conversely, if children are unaware of the need to respond to listeners' RQCL, they may benefit from the inclusion of such sequences.

Breakdowns in communication are a daily experience for children with unintelligible speech. It would seem obvious that such experiences be embedded within phonological intervention, so as to help children learn how to cope with and better manage misunderstandings. However, obvious suggestions are not always the best suggestions. Based on our reflection on the use of communication breakdown and repair sequences across three different contrast approaches to phonological intervention, and the literature on children's responses to different types of RQCLs, there is a need to better understand the potential contribution of this pragmatic device on children's phonological abilities.

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Author Note

Correspondence concerning this article should be addressed to Elise Baker, PhD, Discipline of Speech Pathology, Faculty of Health Sciences, University of Sydney, PO BOX 170, Lidcombe 1825, Australia. Email: elise.baker@sydney.edu.au

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Appendix

Target words, pre-prepared error productions and generalization probe words[a]

Word length and stress pattern	Target words	Adult pronunciation and word shape	Pre-prepared error productions	Generalization words	Adult pronunciation and word shape
3-syllable words					
Sww	elephant	[ˈɛləfənt][b] VCVCVCC	[ˈɛgəpət]	pelican	[ˈpʰɛləkən] CVCVCVC
Sws[c]	buffalo	[ˈbʌfəˌloʊ] CVCVCV	[ˈzʌtəˌloʊ]	platypus	[ˈplætəˌpʊs] CCVCVCVC
	antelope	[ˈæntəˌloʊp] VCCVCVC	[ˈæskəˌdoʊp]	cockatoo	[ˈkʰɒkəˌtu] CVCVCV
sSw[c]	hyena	[ˌhaɪˈjɪnʌ] CVCVCV	[ˌgaɪˈjɪmʌ]	rosella	[ˌɹoʊˈzɛlə] CVCVCV
				goanna	[ˌgoʊˈwænə] CVCVCV
swS[c]	chimpanzee	[ˌtʃɪmpænˈzi] CVCCVCCV	[ˌfɪnwænˈsi]	kangaroo	[ˌkʰæŋgəˈɹu] CVCCVCV
wSw	gorilla	[gəˈɹɪlə] CVCVCV	[nəˈvɪlə]	koala	[kʰəˈwalə] CVCVCV
				echidna	[əˈkʰɪdnə] VCVCCV
4-syllable words					
Swsw[c]	alligator	[ˈæləˌgeɪtə] VCVCVCV	[ˈækəˌʃeɪnə]	kookaburra	[ˈkʰʊkəˌbʌɹə] CVCVCVCV
sSww[c]	rhinoceros	[ˌɹaɪˈnɒsərəs] CVCVCVCVC	[ˌʤaɪˈbɒləgəs]		
wSww	chameleon	[kʰəˈmilɪjən] CVCVCVCVC	[səˈbɪligən]		

[a]Words are arranged in the columns according to word length and stress pattern. Given the relatively limited numbers of polysyllables for African animals (target words) and Australian animals (generalization words), word length and stress patterns were a close but not exact match (e.g., there were three 4-syllable target words compared with only one 4-syllable generalization word).
[b] Glottal stops are optional in vowel-initial words and are not included in the transcription.
[c]Syllables that are unreduced are considered to have either primary or secondary stress, depending on degree of prominence.

Attaining the lingual components of /r/ with ultrasound for three adolescents with cochlear implants

Établissement des composantes linguales du son /r/ à l'aide d'ultrasons chez trois adolescents avec un implant cochléaire

Penelope Bacsfalvi

Abstract

Children with hearing loss frequently have difficulty learning North American English /r/. The purpose of the present study was to investigate the remediation of North American English /r/ by establishing its tongue movement components for three adolescents with recent cochlear implants (CIs) through the use of ultrasound as an adjunct to speech therapy. The three adolescents had all been diagnosed with severe-to-profound bilateral sensorineural hearing loss, and had recently received unilateral CIs. All three students wore a hearing aid in their other ear. Ultrasound was used to assist in establishing the gestural components of /r/ as a starting point for accurate /r/ production: tongue root retraction, retroflexion or bunching and midline grooving. A single subject design was used, with analyses of the gestural components of /r/ before, during and after intervention. All participants were able to learn the gestural components of /r/ with ultrasound. Furthermore, one of the participants gained accurate production of /r/ in isolation and at the word level.

Abrégé

Les enfants ayant une perte auditive ont souvent de la difficulté à apprendre le son /r/ de l'anglais nord-américain. La présente étude visait à examiner la correction de la production du /r/ de l'anglais nord-américain en établissant les mouvements linguaux nécessaires à sa production à l'aide d'ultrasons en plus de la thérapie orthophonique chez trois adolescents ayant un implant cochléaire. Les trois adolescents avaient eu un diagnostic d'une surdité neurosensorielle bilatérale sévère à profonde et avaient récemment reçu un implant cochléaire unilatéral. Les trois portaient un appareil auditif à l'autre oreille. Les ultrasons ont servi à établir les composantes gestuelles du /r/ comme point de départ pour la production adéquate de ce son : la rétraction, la rétroflexion ou l'épaississement de la base de la langue et la formation d'un creux médian. L'étude utilise une méthode à sujet unique où l'analyse des composantes gestuelles du /r/ a été effectuée avant, pendant et après l'intervention. Tous les participants ont pu apprendre les composantes gestuelles du /r/ à l'aide des ultrasons. De plus, un des participants a acquis une production précise du /r/ en isolation et dans un mot.

Key words: single subject design, hearing impairment, CIs, lingual gestures, speech therapy, and ultrasound

Penelope Bacsfalvi, PhD, CCC-SLP(C)
Department of Linguistics, University of British Columbia, Vancouver, British Columbia, Canada

Figure 1a: From rest position to retroflex North American /r/ as produced by author

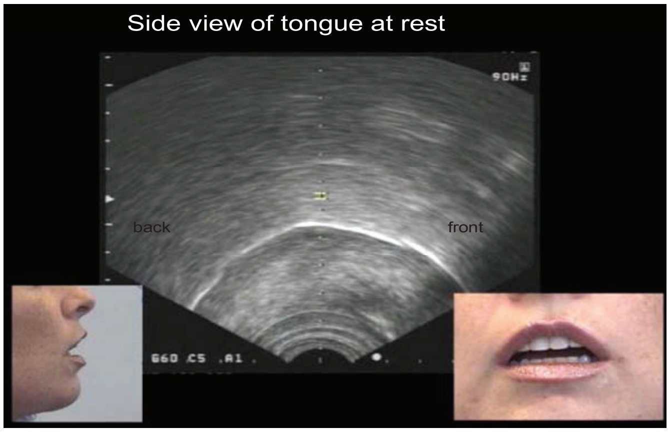


Figure 1b: Side view of tongue as it slides back into /r/ as produced by author.

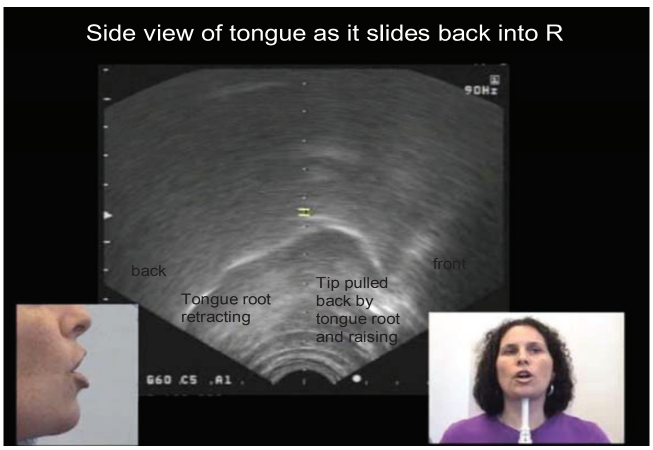


Figure 1c: Side view of tongue producing /r/ as produced by author.

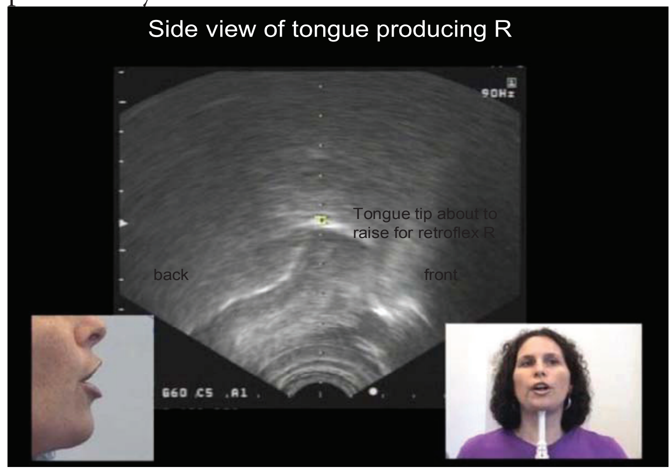
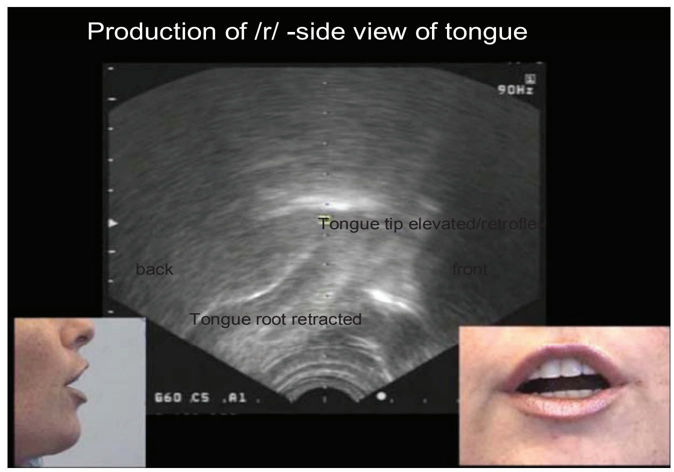


Figure 1d: Production of retroflex /r/ as produced by author



Note lip rounding for Figure 1 photos.

As cochlear implant (CI) technology continues to evolve, greater access to the speech signal through audition is expected, and with it, potential for increased skills in speech production. The success of CIs for improving auditory perception, regardless of age at implantation, has been frequently reported in recent years (*Zwolan et al., 2004; Schramm, Fitzpatrick, & Seguin, 2002*). With this evolution, there has been an increased demand for CIs. Adults and children of all ages are taking advantage of the opportunity to have greater access to sound and speech through amplification with a CI. Many people now have an opportunity to hear what was unavailable to them previously (Svirsky, Robbins, Kirk, Pisoni & Miyamoto, 2000). Students with severe to profound hearing loss may obtain CIs as a final attempt to increase hearing and thereby improve speech production (Ertmer, Leonard & Pachuilo, 2002). Most of the research shows that children benefit the most in terms of speech, language and hearing outcomes when receiving their CI before the age of 5 (Flipsen & Colvard, 2006; Geers, 2004). However, older children and adolescents with congenital hearing loss are also receiving CIs in the region in which this study took place. For older children and teenagers, one of the primary aims is the potential for improvements in speech production. However, many of these later recipients of CIs continue to require speech-language therapy (Bernhardt, Loyst, Pichora-Fuller, & Williams, 2000). At the time of our study, a significant number of teenagers and older children were continuing to receive CIs. Contributing factors to this included newly established funding, technological advances of the CI itself, and changing candidate criteria.

The CI bypasses the external and middle ears by using electrical stimulation of electrodes implanted in the cochlea to reintroduce the signals carried by auditory nerve fibers to the brain. The goal of this technology is to elicit patterns of nerve activity that mimic those of a normal ear for a wide range of sounds. Ideally, such a system can enable people deafened later in life to recognize all types of sound (including speech) spontaneously, and can also provide input required for children deafened at a young age to acquire speech (Eddington & Peirschalla, 1994). However, while restoring hearing to individuals who are deaf has been quite successful, the spontaneous development of speech post-implant has not always occurred (Bernhardt, et al. 2000). Many CI recipients continue to need extensive speech therapy to become intelligible speakers. Others never quite develop intelligible speech, even though they have improved hearing ability (Ertmer, Leonard & Pachiullo, 2002). Studies of speech production of people with severe to profound hearing loss have revealed that, even years after receiving a CI, difficulties with speech production may continue, with clients showing limited tongue movement and reduced vertical range (Higgins, McCleary, Carney and Schulte, 2003). With more CI users receiving bilateral CIs speech production improvement may be greater for more people. While the hope is that there will be greater benefits, to date the research is showing mixed results (Litovsky et al., 2006).

Visual feedback technology has been shown to be a useful adjunct to speech therapy for people with a hearing loss (Bacsfalvi, Bernhardt & Gick, 2007; Bernhardt, Gick, Bacsfalvi & Ashdown, 2003; Dagenais, 1992; Fletcher, Dagenais, & Critz-Crosby, 1991). Ultrasound, in particular, is good for showing tongue shapes and movement (Bernhardt, Bacsfalvi, Gick, Radanov & Williams, 2005). When an ultrasound probe is situated under the chin during speech, sound waves are reflected back from air just above the tongue back into the probe. The resulting waves are translated into images, which are presented on a computer screen, and show the outline of the tongue during speech production. Ultrasound has been shown to be helpful in remediation of long-term persistent speech errors, such as /r/, in teenagers and young adults with normal hearing (Adler-Bock, Bernhardt, Gick & Bacsfalvi, 2007) and Down syndrome (Fawcett, Bacsfalvi & Bernhardt, 2008). The lingual components of North American /r/ that are visible on ultrasound include: tongue root retraction (into the pharynx), tongue tip retroflexion/curling or tongue blade bunching and tongue midline grooving (see Figure 1).

Because our preliminary research with ultrasound revealed that it was useful in remediating North American English /r/ (Adler-Bock et al., 2007; Bacsfalvi, Adler-Bock, Bernhardt, & Gick, 2004; Bacsfalvi, Bernhardt & Gick, 2001; Bernhardt et al., 2003), a study was initiated with three recently implanted CI users with long-term speech production difficulties who did not yet produce /r/. Given that participants were all in their late teens and had received therapy for /r/ previously, this was considered to be a viable target. This paper brings forward a model of phonological therapy/speech habilitation that addresses the interaction of phonetic and phonological development through motor learning with auditory-visual feedback and a cognitive component that emphasises the functioning of the speech production mechanism. The objectives of the current study were to introduce the lingual components of /r/ through use of ultrasound to the three speakers. Based on previous research, establishing the components of /r/ leads to its production (Bacsfalvi et al., 2004; Gick, Iskarous, Whalen and Goldstein (2003). This suggests that targets are articulatory and that /r/ has several constrictions that are essential for production of an acoustically accurate /r/. Without audition, typically, a person cannot learn the necessary constrictions.

A single-participant design approach was used to evaluate the effectiveness of the ultrasound technology for teaching the components of /r/. Single participant research uses an approach that repeatedly and continuously measures the dependent variable from individual participants (Morgan & Morgan, 2001). "…The characteristics of single-subject and small-N approaches that may be found in the literature …lend themselves to investigations of treatment efficacy while remaining true to …the purposes of scientific research: replication, the discovery of causal relationships, the establishment of the generality of relationships, the discovery of new knowledge, and the use of formal codified knowledge as the basis for research" (p. 758, Attanasio, 1994). Predictions were that the students would attain the lingual gestures of /r/ during the treatment program, with the possibility that they might produce accurate /r/s after treatment. (It was recognised that further practice and speech therapy would probably be needed for accuracy in all positions in words, sentences and conversation, a process which was beyond the scope of the current project [Bernhardt et al., 2005; Bernhardt et al., 2003; Ruscello, 1984].)

Methodology

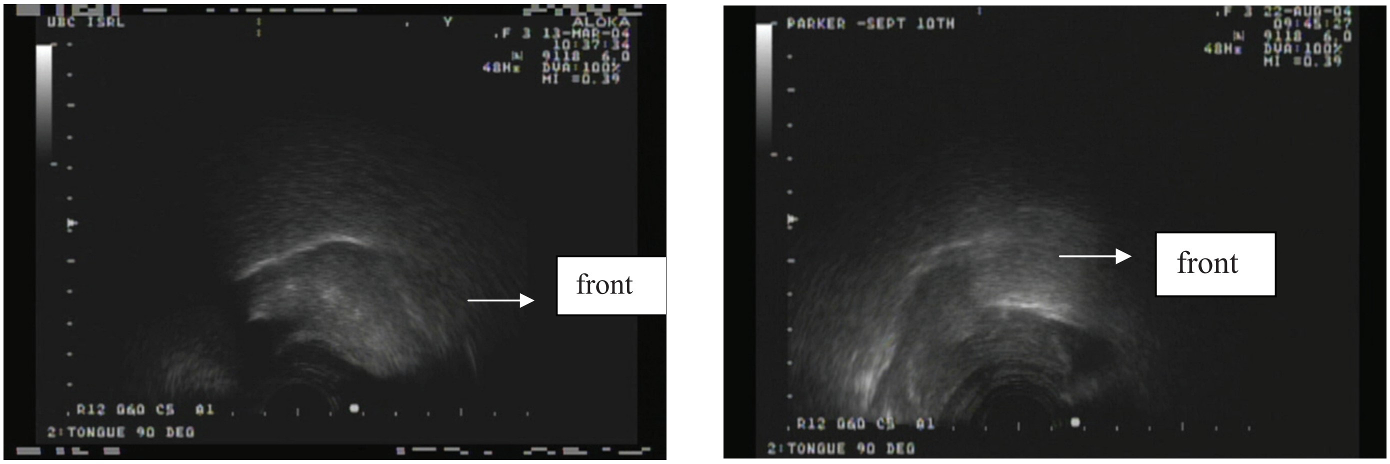
Participants

Three adolescents participated in this study. They all met the following criteria: (a) severe-to-profound bilateral sensorineural hearing loss; (b) congenital or early onset of hearing loss (< 3 years of age); (c) use of a CI unilaterally for more than three months (to allow mapping to be set and time for some auditory perceptual training), and consistent use of the CI; (d) the desire and motivation to improve speech productions; (e) past or current enrolment in an educational environment with an emphasis on an oral approach; and (f) access to speech therapy. All three students wore a hearing aid in their other ear for potential stimulation of the auditory nerve.

The participants had received years of speech therapy and had had varying degrees of success with traditional approaches. While many phonemes were accurately produced, these students were interested in a new approach to speech therapy for remediation of the long-standing speech errors that had not been successfully treated with traditional methods. All participants used oral language on a daily basis to meet their communication needs. Speech intelligibility levels of participants were judged by two listeners, both practicing speech-language pathologists (S-LPs) familiar with speech of the hearing impaired.

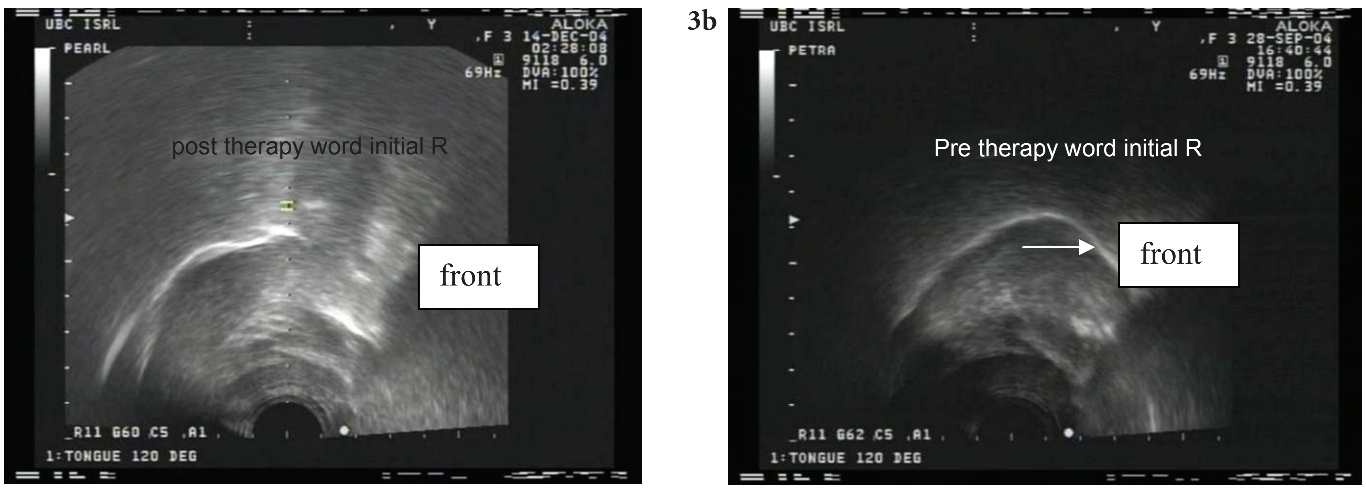
Participant 1 (pseudonym: Parker) was 15 years of age and presented with CHARGE syndrome. In this syndrome, tissues in various structures of the body do not develop completely. (CHARGE Syndrome Canada, 2010). Parker had a 3G Cochlear Nucleus behind-the-ear processor, which he had been using for 9 months when he joined the therapy project. His speech could be described as intelligible with careful listening, as judged by S-LP listeners. He had been in a signing program for most of his life and

Figure 2: Parker's productions of /r/ pre-treatment in word-initial position and post-treatment in isolation. Notice the tongue root retractions and tongue blade retraction in the post-therapy token.



Figures 3a and 3b: Pearl's productions of /r/ pre (3a) and post-therapy (3b) in word-initial position. Notice the tongue root retractions and tongue tip curl in the post therapy token.

3a **3b**



communicated at school and with his peers and mother predominantly in sign language. Communication with his father, brother, family and neighbourhood friends was in spoken or written language.

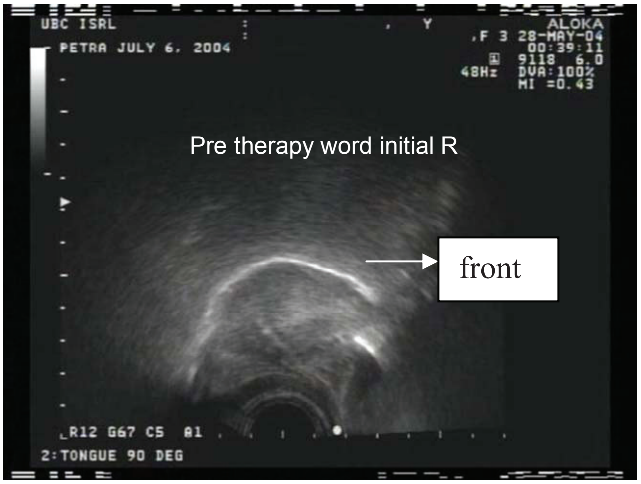
Prior audiology reports indicated a profound sensorineural hearing loss in the left ear and a moderate to severe sensorineural hearing loss in the right ear since birth. Parker was fitted with a unilateral hearing aid in the right ear at 1.5 years of age. At the age of 12, Parker's hearing began to degenerate and by 14 he had a profound sensorineural hearing loss bilaterally. At that time he appeared to receive no benefit from his hearing aids, and seldom wore them.

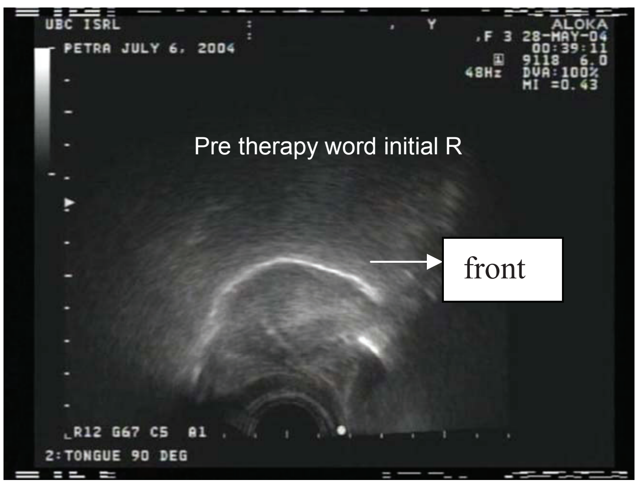
Initial speech evaluation with ultrasound, using a word list developed for ultrasound assessments at the speech laboratory (see Appendix 1), revealed some difficulty with the production of velars and none of the lingual components of /r/. For motivation, the participants were encouraged to add a couple of words they wanted to learn to the word list, which is why the lists were somewhat different. Parker had never used ultrasound technology and was unfamiliar with it. Figure 2a provides an example of Parker's /r/ attempt in word-initial position before intervention.

Participant 2 (pseudonym Pearl) was 15 years of age. Pearl had a 3G Cochlear Nucleus behind-the-ear processor, which she had been using for 3 months when she joined the therapy project. Her speech was described as unintelligible. She had been in oral programs her whole life, but communicated using a combination of written, oral and sign languages (with both English and Cantonese as input languages). Prior audiology reports indicated a profound sensorineural hearing loss in both ears since birth. Pearl had been fitted with binaural hearing aids at 3 months of age. Audiology reports also indicated that the hearing aids were not providing Pearl with the auditory information that she needed. Aided response to warble tones revealed the range of moderate to severe hearing loss from 250-4000 Hz in the right ear. The left ear showed a moderate to moderately severe hearing loss from 250-1500 Hz with no response at 2000 or 4000 Hz.

Initial speech evaluation by the author revealed difficulty with the production of several consonants and

Figure 4: Petra's productions of /r/ pre and post therapy in word-initial position. Notice the tongue root retractions and tongue tip curl in the post-therapy token.





vowels, including /r/ (the /r/ portion of the word list is in Appendix 1). Pearl indicated that she wanted to focus on /r/ at the time of the study. Ultrasound images of her /r/ attempts pre-treatment showed none of the lingual components of /r/ (Figure 3a). Pearl had participated previously in therapy pilot work with ultrasound and was familiar with the equipment and the therapy process with visual feedback technology. She had previously acquired velars /k/ and /g/ using ultrasound.

Participant 3 (pseudonym Petra) was 18 years of age. She and Pearl are siblings. Petra used a 3G Cochlear Nucleus behind-the-ear processor, which she had also had for three months when she joined the therapy project. Her speech could be described as intelligible but with a quality typical of people with severe hearing impairment. She had been in oral programs throughout her schooling, and communicated predominantly in spoken English and was just starting to speak limited Cantonese at home with her family. She did use signing with some friends and acquaintances from the deaf community but used oral and sign communication at home and at school. Prior audiology reports indicated a severe to profound sensorineural hearing loss in both ears since birth. Audiology reports also indicated that hearing aids (Phonak PPCL4 BTEs) provided adequate gain up to 1000 Hz but not above that frequency. Petra had also participated in a pilot study with ultrasound and was familiar with the equipment. She had previously been introduced to the lingual components of /r/ and was able to produce all of the gestural components some of the time at the end of that pilot study before receiving her CI. Therapy research had been stopped to allow her time to adjust to the CI and the initial stages of learning to listen. Petra participated in the current study in order to re-learn the components of /r/ with her new and different auditory feedback. Figure 4a provides an example of Petra's /r/ attempt in word-initial position before intervention in the current study.

Research Design

A non-concurrent multiple baseline across participants was employed in this single subject design study, with a changing criterion design for each participant. The design allowed for a sensitive assessment of developing repertoires, which is critical to clinical research (Gliner, Morgan & Harmon, 2000; Morgan & Morgan, 2001). Due to past success with this approach, a componential approach to teaching /r/ was used (Bacsfalvi, Adler-Bock, Bernhardt, & Gick, 2004). As each lingual component was established, the next one was added. The design had three major phases: (a) baseline, (b) intervention, and (c) follow-up. The functional relationship between the independent variable and dependent variable was documented through a step-wise improvement in lingual component productions.

When a stable baseline was established, training was initiated. Training began for each speaker with tongue root retraction because this is a critical element of /r/ and one that is easy to demonstrate with this visual feedback tool. A componential approach allowed the establishment of each lingual component before the next one was learned. Each component or gesture was learned first in isolation and, once maintained, then combined with others. (See further details below on the intervention process.)

The dependent variables were the lingual components of /r/: tongue root retraction, tongue tip elevation or tongue blade bunching, midline grooving of the tongue, and lip rounding (see Figure 1). Accuracy of tongue components was measured two-thirds of the way through each session, after the client "warmed-up" and before fatigue began. When the participant produced 7 out of 10 accurate productions for a gesture in three consecutive sessions, the criterion was met and we moved on to the next component. A gestural component was considered established when the speaker could produce the gesture without prompts or cues from the clinician-researcher.

Equipment

An Aloka Pro-Sound SSD-5000 ultrasound machine with a 6 MHz transducer series M00196 was used for assessment and treatment, and a portable Sonosite 180 Plus ultrasound machine with a Sonosite C15/4-2 MHz

Table 1
Listener judgments pre and post therapy

Speaker	Listener	Percent 'yes'[a] pre-intervention	Percent 'yes' post-intervention	Percent change
Parker	Listener 1	43.14%	73.33%	30.20%
	Listener 2	61.22%	88.14%	26.91%
	Listener 3	4.17%	44.07%	39.90%
Pearl	Listener 1	27.78%	24.49%	-3.29%
	Listener 2	26.32%	30.61%	4.30%
	Listener 3	8.57%	10.64%	2.07%
Petra	Listener 1	34.78%	51.35%	16.57%
	Listener 2	39.13%	36.11%	-3.02%
	Listener 3	17.39%	25%	7.61%

[a]A "yes" judgment indicates perceptible /r/-quality, and includes accurate /r/s and tokens with /r/-quality.

MCX transducer was used only for treatment. Clarity of the image was enhanced on all machines by adjusting the range and gain (e.g. range of 11, gain of 60 on the Aloka Pro-Sound) and coating the transducer with water-soluble ultrasound gel. Two machines were used because one was portable and one was not. The portable machine allowed the speech-language pathologist (S-LP, author) to work with the participants in the home or other rooms at the university when the need arose. All participants had equal time with both machines. Both machines provided the same level of detail to participants.

Intervention process

All students attended 45 minute weekly sessions to learn the lingual components of /r/, and to subsequently attempt /r/ in isolation and at the word level. Intervention sessions took place in privacy in the lab at the university or in the student's home with the portable ultrasound machine. Tongue root retraction was demonstrated by the author, with an explanation that the tongue was being pulled back and kept low in the mouth. Tongue tip retroflexion was also demonstrated with the explanation that the end of the tongue is curling up and back. The tongue tip retroflexion (see Figure 1d) was introduced as a backwards curl, but the students were also shown how the S-LP used a bunched tongue blade, rather than a curled tip. They were instructed to try whichever one they found easier to learn. All three of the students began with the tongue tip curl as they found this easier to understand. Once these individual components had been established and the students could combine the components, voicing was added to attempt an [r]. Once a student was able to produce /r/ in isolation, /r/ was incorporated into syllables and words in word-initial, -medial and -final positions as a singleton and in consonant clusters (e.g., /gr/, as in *green*).

Target contexts for /r/ were decided in part with the students because they had words they wanted to learn to say accurately. Therefore, contexts reflected these personal goals for each student. Attempts were made to target words where /r/ occurred initially and finally with front, back, high and low vowels. Treatment sessions were typically 45 minutes long.

Evaluation of lingual components and speech samples

Evaluation of the treatment programme focused primarily on the lingual components of /r/. In addition, three speech-language pathologist listeners were asked to evaluate the /r/ sound files collected during assessments to evaluate whether change towards /r/ accuracy was underway. All three listeners had previous experience in clinical research and practice with ultrasound, to evaluate North American /r/.

The participants' lingual gestures were evaluated qualitatively by the author, with criteria developed in previous projects (Bacsfalvi et al., 2004; Adler-Bock et al., 2007) as in Figures 1a-1d). The gestures were recorded on DV tape with a Sony Mini DV Handycam (connected to the ultrasound, US) and/or recorded in a log-book after visual inspection of the frozen images. The hand entries were done either to shorten probe time for the speakers, or due to occasional equipment malfunctions during recording. For the computerized versions, the US recordings were transferred to a computer using Adobe Premiere 1.0 (2004) for video editing, and stored on the hard drive.

Independent observer agreement

Reliability measures were conducted by a speech-language pathology graduate student who was experienced in evaluating ultrasound images. She was blind to the chronological order of the ultrasound images and the identity of speakers. She viewed 10% of the ultrasound images of the /r/ gestures across sessions on video-tapes. The criterion for inter-observer agreement was 80% for gestural components accuracy, with the actual agreement between observers being 95% for all three participants.

To determine if generalization to the word level was occurring, short single word speech probes were taken every 2-3 weeks for evaluation of /r/ development. The sound files attached to the ultrasound recordings were extracted from the DV tapes and transferred onto a laptop computer in a PowerPoint format (Microsoft 2003), with stimuli organized in random order across evaluation points. Three S-LP listeners with normal hearing in the speech spectrum were invited to evaluate the /r/ productions. All three had worked with students who are deaf or hard of hearing in the past, and were experienced using ultrasound for therapy with /r/. Stimuli were presented through Kenwood Open Air Headphones KPM-110 and listeners rated between 75 and 100 tokens per speaker. To measure progress beyond the componential level, listeners were asked to rate the tokens as having some or no rhotic quality (yes-no judgments), i.e., where a 'yes' rating did not necessarily indicate an accurate /r/, but an attempt that included /r/-quality. There are different ways to measure (rate) outcomes. We chose rhotic quality as a factor to measure /r/ in isolation or at the word level. This type of rating provides the best opportunity to show changes in speech production, even if the participant has not yet completely mastered the target sound. This perspective followed that of Ertmer and Maki's (2000) speech habilitation study of children with hearing impairment; they state that there is an intermediate phase along the progress trajectory as the individual is learning. This phase can precede production of fully acceptable variants of the target (Ertmer & Maki, 2000). Mean intra-rater reliability for the three S-LP listeners was 92% (range 80% to 100% agreement). Inter-observer reliability was calculated for participants across all three listeners item by item (see Table 1).

Listener 1 was in agreement with listeners 2 (72%) and 3 (63%) for Parker. However, listeners 2 and 3 had a low level of agreement (48%) with each other for individual items in Parker's data. Although listener agreement was more divergent for Parker in absolute values, all three listeners agreed that he had improved in 'r' production by about 30%. Listeners had higher agreement levels for Petra (75%) and Pearl (69%). A greater range of inter-rater reliability agreements are acceptable when making judgments on speech production of people with a hearing loss, with the average agreements between 64% to 74% (Blamey et al., 2001; Shriberg & Lof, 1991).

A Chi Square analysis was used (alpha levels from .05 to .001) to determine if there were any significant differences between the pre- and post-treatment listener judgments for each participant (see results).

Results

Results are discussed within speaker because of the single subject design of the study. Results for the components of /r/ (the primary focus of the study) are presented in Figure 5.

In addition, ultrasound images of pre- and post-treatment /r/ attempts are shown in Figures 2-4. The listener evaluations of the /r/ word samples are presented in Table 1.

Participant 1: Parker

Three baseline measurements of /r/ production confirmed (Figures 2, 5) that Parker did not produce any of the gestural components of /r/: tongue retraction, grooving or tongue tip curling/bunching. Parker quickly learned tongue root retraction, maintained it during intervention, and continued to produce this gesture at follow-up with 100% accuracy. The tongue tip curl was introduced next. Parker was able to produce this by the end of the first session accurately, and was able to maintain this over the rest of intervention and at follow-up with 100% accuracy. The final tongue gesture taught was the tongue groove. Midline grooving proved to be more difficult for Parker and he took three therapy sessions to reach accuracy. Once again Parker was able to achieve accuracy during intervention and maintain this accuracy at follow-up. By the end of the intervention period Parker was able to produce all the components of /r/ in combination at the word level. Table 1 shows that listeners judged Parker's post-treatment samples to have significantly more /r/-like tokens (Chi Square Continuity Correction of 32.144, $p<.001$).

Participant 2: Pearl

Five baseline measurements of /r/ production confirmed that Pearl did not produce any of the gestural components of /r/ pre-treatment (Figures 3, 5). During the baseline period, speech therapy continued for Pearl with the author, including listening therapy, review of velars, and some attempts at /r/ without ultrasound. Once a stable baseline level was achieved for /r/ components, the introduction of one gestural component of /r/ began. Pearl quickly learned tongue root retraction and maintained it throughout intervention, producing it at follow-up with 100% accuracy. The tongue tip curl was introduced next. Pearl was able to produce this by the end of the second session accurately, and was able to maintain this over the rest of intervention and at follow-up with 100% accuracy. The final component taught was the tongue groove. Midline grooving was learned over two sessions. Once again Pearl was able to achieve accuracy during intervention and maintain this accuracy at follow-up. Listener ratings showed no significant difference in pre-post treatment word samples for /r/-like quality.

Participant 3: Petra

Petra produced the retraction and tongue tip gestures accurately when provided with visual feedback, but five baseline measurements of /r/ production confirmed that she did not produce the midline grooving component of /r/ (Figures 4, 5). Once a stable baseline level was achieved with the mid-line grooving component of /r/, the training for that final gestural component began. Petra learned tongue grooving over four therapy sessions, maintained it during the remainder of intervention, and continued to produce this gesture, as well as the others, at follow-up with 100% accuracy. Listener ratings for /r/ in words showed no significant change at this time.

Discussion

Overall Results

All three students made improvements in production of the gestural components of /r/. It is important to keep in mind that the goal of this study was to establish the components of /r/. Once the components of /r/ are established and voicing added, typically several weeks of therapy and practice are needed `to produce

/r/ at the word level, because the /r/ components need to be integrated both with each other and with surrounding segments (Bernhardt, Bacsfalvi, et al., 2005, Bernhardt, Gick, et al, 2005). All participants were successful in producing /r/-like segments post-treatment to varying degrees. Significant changes in /r/ production at the word level were seen only for Parker at this time, which was a desirable if not expected outcome (given the relatively short duration of the study).

Within-Participant Factors

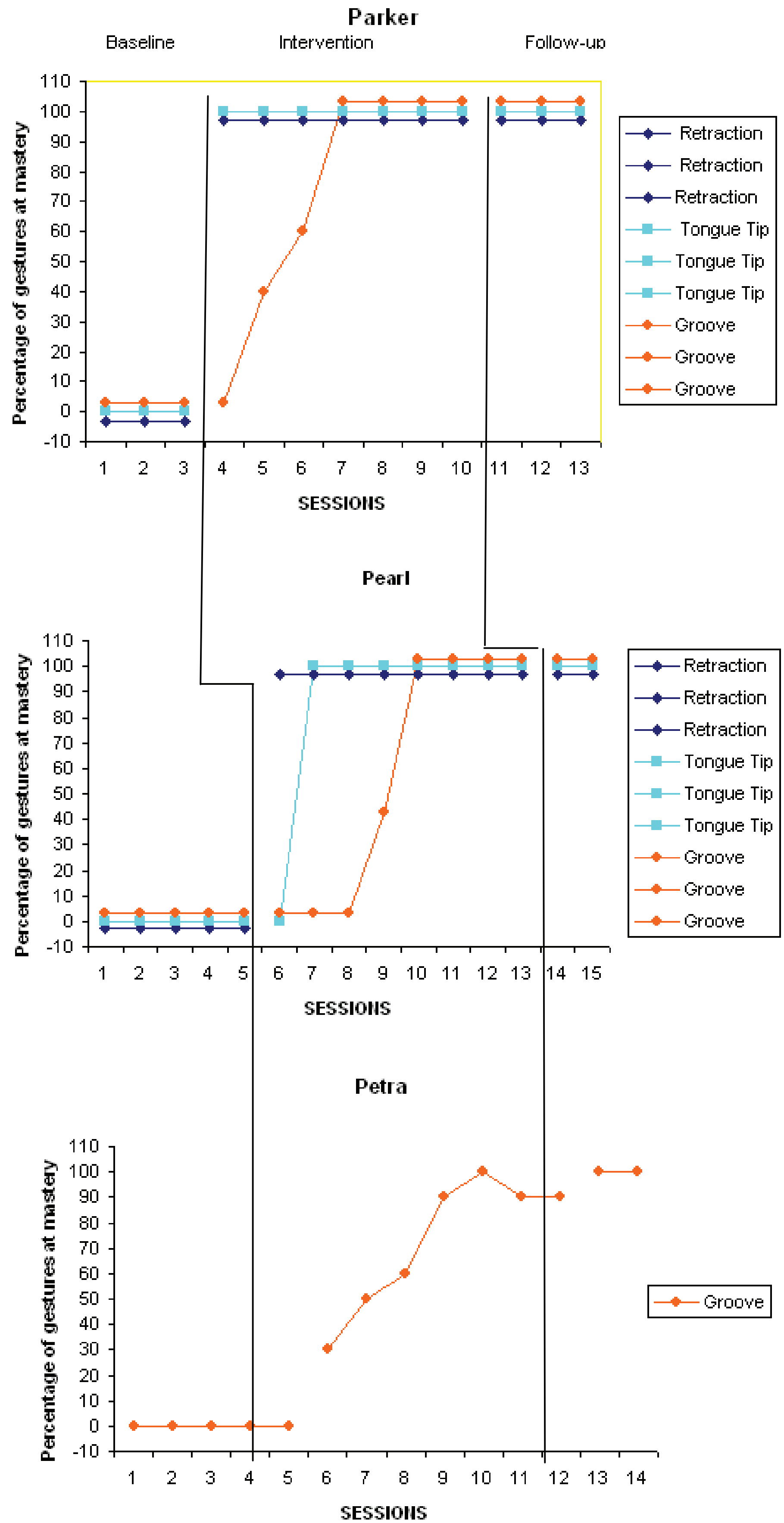
In evaluation of results, given a single-subject design, it is important to look at factors affecting varying outcomes for individuals in the study. Individual factors that can affect outcomes in speech intervention are motivation, practice opportunities, and for persons with CIs, auditory perception (McLeod & Bleile, (2004); Wie, Falkenberg, Tvete, & Tomblin, 2007). The following discussion describes the possible impact of those factors for each of the participants.

Participant 1: Parker

The main settings for Parker's habilitation were the home and the university. Parker was interested in learning speech and was very interested in and motivated by the ultrasound technology. Parker was always accompanied by his mother (a teacher) during the therapy sessions. In addition, Parker and his mother worked very hard on practicing and following through every step of the way during our ultrasound therapy project.

Prior to receiving his CI, Parker's audiogram had indicated a profound bilateral hearing loss. However, when we began therapy nine months post-implant, Parker was able to hear and identify most speech sounds, although he still presented with some r-w confusions. All of these factors may have facilitated his outcomes for the study, which included more /r/-like words in addition to mastery of the lingual components of /r/ within words.

Figure 5: Baseline, intervention and follow-up gestural /r/ components for Parker, Petra and Pearl.



Participant 2: Pearl

The main setting for Pearl's habilitation was the university. Prior to receiving her CI, she was minimally interested in speech practice and homework, but was more motivated upon receiving her new CI. Pearl did not have opportunity at home for consistent practice with English /r/ models (given the Cantonese/ESL home environment), although some of the time Petra would practice with her. Although her oral interpreter did attempt to provide some opportunities for her to practice at school, the curriculum was not designed to address her need to have scheduled practice sessions.

Prior to receiving her CI, Pearl's audiogram indicated a profound bilateral sensorineural hearing loss with very little benefit from amplification. However, while her audiogram looked similar to her sister's, her functional hearing was much lower. Pearl struggled to listen with her hearing aids. As a result, she had a greater challenge in learning to listen and reduced speech intelligibility when she received her CI. After three months of auditory perceptual training, she was still unable to hear all English consonants and vowels. The /r/ was still confused with /w/ some of the time.

Participant 3: Petra

The main setting for Petra's habilitation was the university and her community college. Petra had been diligent with schoolwork in high school and her first year of college. She had the opportunity to practice her speech occasionally with an educational audiologist at the community college she was attending. However, she too, due to family circumstances, did not have the necessary support for consistent practice and feedback in the home. Nevertheless, Petra worked on her own because she was very self-motivated.

Prior to receiving her CI, Petra's audiogram indicated a severe-to-profound bilateral sensorineural hearing loss. However, functionally Petra listened well in conversational contexts, and used compensatory strategies very well. Within a few months of learning to listen Petra was able to hear all the high frequency consonants she had not been able to before (/s/, /ʃ/ and /k/). She could also differentiate most of the English sound system by place and manner. However, she still had some difficulty discriminating between /r/ and /w/.

Qualitative commentary

Reports from participants and their families and friends add to the social validity of intervention research. Because of not wanting to place further demands on participants and their families, a formal study evaluation questionnaire was not used post-treatment. Instead, verbal comments volunteered by the participants are indicated here. All participants indicated that they believed they could produce /r/ more accurately and were better understood by family and friends. In addition, parents reported they were happy with the improvements during the course of the project, and all reported that participants were more intelligible.

Long-term follow-up

A follow-up evaluation of the ultrasound in treatment was completed 1.5 years later (Bacsfalvi, 2007), using perceptual judgments by trained listeners of randomized pre-post speech samples. All participants either maintained or improved their productions of target /r/ in the long term. All participants had access to traditional therapy for a couple of months post project.

Conclusion

This type of clinical research suggests the potential clinical usefulness of ultrasound as an adjunct to therapy, with a possibility of reducing the costs (years of therapy versus months) and time requirements for both the client and S-LP, and lessening the frustration for the client. The main objective of this study was to learn the gestural components of /r/. All three participants met this objective (Figures 2 to 5), with one moving beyond the objective to make a notable gain in production of /r/ or /r/-like segments as indicated by perceptual judgment (the other two also produced some /r/-like or /r/ segments during treatment, but showed no pre-post gain). All participants and the people in their lives reported that they were producing the /r/ with more rhotic quality by the end of this study. According to the International Classification of functioning, disability and health (WHO, 2001) a reduction in speech patterns that are unusual (e.g., no movement of the tongue for production of the /r/ sound) suggests that this study was successful (McLeod & Bleile, 2004). This study was only the first step in the speech habilitation process, and looked at change in production predominantly at the level of the articulatory gesture. To facilitate production of accurate /r/ in conversation, continuing speech therapy with an S-LP experienced with acoustic phonetics, CIs and ultrasound was needed, with a generalization plan and sufficient practice opportunities. The longer-term outcomes evaluation (Bacsfalvi, 2007) showed either maintenance or continuing improvement.

The study shows that perceptual and gestural components may not change at exactly the same time, or the early changes may not be perceptible. These well-known examples of speech productions that cannot be recovered by transcription alone have been called covert contrasts. Productive knowledge of covert contrasts has been viewed as a positive prognostic sign to facilitate learning of sounds in treatment (Gibbon, Stewart, Hardcastle, & Crampin, 1999). As a result, gestural components can be compared to these covert contrasts as positive prognostic signs in the process of learning /r/. This research reflects how /r/ has several constrictions that are essential for production of an acoustically accurate /r/, suggesting the necessity of learning these articulatory targets.

Further research is needed, with larger numbers of participants of different ages and disorder types, and over longer periods of time to determine the optimal type of benefit of the technology and the course of change, as perceptual and gestural changes align.

Acknowledgments

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Author Note

Correspondence concerning this article should be addressed to Penelope Bacsfalvi PhD, CCC-SLP(C), Department of Linguistics, University of British Columbia, Totem Field Studios, 2613 West Mall, Vancouver, British Columbia V6T 1Z4. Email: penbacs@interchange.ubc.ca.

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Appendix 1

Word and syllable probe lists for all participants

Parker	Pearl	Petra
raw	row	row
re	roo	roo
recycle	ree	ree
retire	or	or
ear	ear	ear
are		har
far		road
red		
bar		
car		

Appendix 2

Speech Therapy Techniques with Ultrasound Biofeedback

The following appendix provides a short illustration how ultrasound biofeedback may be used to facilitate articulation therapy.

1. In the first step, we have found it useful to start with a verbal description of the anatomy of the tongue. We facilitate understanding by using as many means of illustration as possible. The following items may be helpful:

Anatomical drawings or pencil drawings of the midsagittal tongue and vocal tract are useful to orient the patient to the structures. Especially when working with pediatric patients, it is important to minimize distraction by choosing a drawing that is visually plain and clear.

EPG prints and clay models of the hard palate can be used to illustrate where and how the tongue touches the palate.

Mirrors can be used to help the patient relate the information from the drawing to his or her own mouth.

Tongue depressors can be used to provide the patient with gentle tactile feedback about the location of different intraoral structures.

Finally, pliable mouth models, often used by clinicians, or hand puppets with movable tongues can help to engage a child to learn in a play activity.

2. Following this, we provide a demonstration and verbal description of speech production with the ultrasound machine. The clinician demonstrates the midsagittal ultrasound image and demonstrates how the tongue attains different positions during the production of different speech sounds. We have found it useful to start the demonstration with the vowels /a/, /i/ and /u/, which are usually differentiated in the ultrasound image. The plosive sounds /t/ and /k/ produced in an /ata, aka/ sequence are useful to demonstrate front and back raising of the tongue for English. Depending on the therapy goals for the patient, a coronal ultrasound view may be used to illustrate grooving of the tongue. Here, it is useful to obtain a coronal scan of the posterior third of the tongue and to produce a sequence of /i/ and /u/, which will demonstrate an alternation of concave and convex tongue shapes in most speakers. The therapist should become familiar with the ultrasound image of his or her own tongue before attempting a demonstration to the patient.

3. We have found it beneficial to start tongue positions (gestures) without sound. These gestures must be stable and consistent before introducing sound. Each component of this oral motor work is underlying the exact movement needed in a speech sound. A componential approach to intervention is recommended.

4. Before giving homework, make sure the patient can do the movement without looking at the ultrasound display. The patient should practice the target tongue movement and speech sounds at least twice a day.

5. When using the ultrasound biofeedback, be mindful of patient fatigue and provide frequent breaks. While ultrasound is considered to be biological safe, it is prudent to limit the exposure duration in a session. Whenever the ultrasound display is not actively used in therapy, the machine should be put into the freeze mode.

How to teach velars

Suggested sequence for the differentiation and isolation of movements:

1. Place the transducer under the chin in the sagittal position.
2. Start with /u/ to demonstrate the high back tongue position and to ascertain that the patient can move his or her tongue towards the velum.
3. Ask the patient to push the tongue up against in the palate in the /u/ position (without voicing).
4. The clinician demonstrates the difference between /t/ and /k/ on the ultrasound.
5. Merge 'stopping' with /u/.
6. Begin with isolated productions. For example, you can move from /uku/ to other vowel contexts, and then to words.

Acknowledgements:

This appendix was developed by Dr. P. Bacsfalvi with input from the Vancouver School Board Speech Language Pathologists (SLP) spring 2010. For more information see:

Bacsfalvi, P., Bernhardt, B., Gick, B. (2007). Electropalatography and ultrasound in vowel remediation for adolescents with hearing impairment. *Advances in Speech Language Pathology, 9(1), 36-45.*

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Book Reviews/ Évaluation des livres

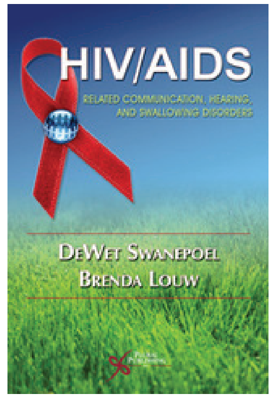
HIV/AIDS: Related communication, hearing and swallowing disorders

Author: De Wet Swanepoel and Brenda Louw
Publisher: Plural Publishing Inc.
Cost: $55.50
Reviewer: Caroline Menezes
Affiliation: University of Toledo

In this book, the editors Swanepoel and Louw shine a torch at an area long shrouded by shame, taboo and ignorance. Since the initial reports of auto immunodeficiency syndrome (AIDS) in the early 1980s, the medical world has made huge strides in understanding the cause and treatment of the disease. Developments in medicine have improved the survival rate of people infected with HIV (carriers of the human immunodeficiency virus). As the authors point out, this changes the treatment focus for persons with a chronic HIV condition from survival to quality of life. The book highlights the HIV/ AIDS-associated disorders that are particularly relevant to a speech-language pathologist. These may pertain to communication, hearing, balance, swallowing, and feeding.

The edited book assembles chapters written by various experts from around the world, organized into four sections. The authors include medical doctors, nurses, researchers, audiologists, and speech-language pathologists. Section One lays out necessary background information on HIV/ AIDS including prevalence, pathology, diagnosis, management, infection control, psycho-social impact and ethical challenges in research and clinical care. In the chapter dealing with pathology, the reader is introduced to the human immunodeficiency virus, its life cycle, and the corresponding progression of clinical symptoms and relevant treatments. In Chapter 3, Dr. Bekker details the various tests used to diagnose the syndrome. Towards the later part of the chapter, she discusses the clinical and pharmacological management of the virus. This information is extremely relevant to a clinician who will come in direct contact with the patient. The chapter on infection control is very specific to clinicians dealing with communication disorders in this population and clearly outlines various hygiene protocols that need to be adopted.

Section Two contains two separate chapters that discuss communication disorders in children and adults. By dealing with children and adults separately in the text, the authors reinforce the inherent differences in the course of the disease between these two populations and the resulting consequent differences in the assessment and treatment of communication disorders. Section Three deals with



auditory and balance disorders associated with AIDS. There are three chapters in this section specifically addressing etiology, diagnosis and management of conductive hearing loss, sensorineural hearing loss and associated balance disorders. The chapter on associated balance disorders also gives a but brief but clear explanation of the vestibular system and ways to test it. Finally, Section Four discusses the swallowing and feeding disorders that may affect pediatric and adult populations with HIV/ AIDS. The possibility of HIV transmission through breast milk makes feeding a point of concern for management and control of AIDS. The book discusses risk assessment and ways in which the risk of transmission from mother to child can be reduced. It expounds methods of identification, evaluation, monitoring, and management of patients with swallowing disorders related to AIDS.

The book is well-organized and has a nice flow. It starts by giving the reader an understanding of the problem and then offers enough tools to make accurate assessments and provide appropriate treatment. Each chapter ends with a short summary that reinforces the take-home messagesto for the reader. The depth and quality of information makes the book an easy guide for both neophytes and the seasoned speech-language pathologists treating communication disorders in the HIV/ AIDS patient population. In my opinion, this book lives up to the aspirations of the editors "to offer a unique and useful resource and training tool for professionals," with the hope that "the people who will benefit most from this are those living with HIV/AIDS."

■ ■ ■

Aphasia Couples Therapy (ACT) Workbook

Author: Larry Boles, PhD
Publisher: Plural Publishing Inc.
Cost: $51.95
Reviewer: Riva Sorin-Peters, PhD, Reg CASLPO, SLP (c), CCC(Sp)
Affiliation: Regional Stroke Program – North & East Greater Toronto Area; Assistive Technology Clinic, Sunnybrook Health Sciences Centre, Toronto

Conversational training programs, in keeping with a social model of aphasia, are a means of increasing communicative effectiveness between people with aphasia and their communication partners (Turner & Whitworth, 2006). The training process is designed to adjust the expectations and perceptions of both partners and to expand the opportunities for communication (Simmons-Mackie, 2001). Turner and Whitworth (2006) identified three broad approaches: (a) conversation analysis-motivated therapy (e.g., Booth & Swabey, 1999; Lessar & Algar, 1995), (b) *Supported Conversation for Adults with Aphasia* (Kagan, 1998), and (c) *Conversation Coaching* (Hopper, Holland, & Rewega, 2002).

Boles has developed a program called *Aphasia Couples Therapy* (ACT) which is a hybrid of *Conversation Coaching* (Hopper et al., 2002), *Supported Conversation* (Kagan, 1998), *Communication Partners* (Lyon et al., 1997), *Authentic Social Perspective* (Simmons-Mackie & Damico, 1996), and the author's own clinical and research experience (Boles, 1997; 1998; 2006). ACT includes "therapeutic" conversations between the person with aphasia and his or her significant other. The person with aphasia, the speech-language pathologist and the spouse all participate. The treatment represents a social approach to aphasia treatment (Simmons-Mackie, 1998). The speech-language pathologist's role is that of a coach who offers constructive criticism. Sessions include a review of homework, a discussion of session goals, a free conversation and feedback from the speech-language pathologist, followed by new homework. Couples are encouraged to establish a routine to work on conversation at home. Boles (2006; 2007) has reported on the success of ACT and on the success of solution-focused aphasia therapy (Boles & Lewis, 2000; Boles & Lewis, 2003).

As an adjunct to ACT, the primary objective of the *Aphasia Couples Therapy Workbook* is to provide the speech-language pathologist with functional conversation activities. The workbook's intended audience includes speech-language pathologists and significant others (SOs) of people with aphasia (i.e., spouses, family and friends). The intent is for the speech-language pathologist to use the activities in therapy sessions and then guide dyads in the use of the activities as therapeutic home practice.

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The Workbook includes 26 activities that address *how* to get significant others involved with therapeutic communication activities. Each activity includes a description of background, written materials to support the conversation, and an evaluation of the activity for the survivor and the significant other. Some of the activities are "role play" activities where the SO assumes the role of a service worker or physician. There is a short preface addressing the speech-language pathologist, significant other and couple with aphasia, outlining each of their roles in conversation with the person with aphasia. At the end of the conversation, a 10-point scale is used to evaluate the person with aphasia's and the SO's satisfaction with the conversation. There are no pictographic resources accompanying the activities.

The publication serves as a well-needed resource for speech-language pathologists who are including SOs in therapy sessions. It provides specific activities in clear and simple language. It encourages the couple to actively reflect on and evaluate the conversation.

In terms of the organization of the book, it would have been nice if pages that are meant to be used in the couple's actual conversation had been printed separately on individual pages to make it easier to photocopy them. In terms of content, more information from the author's publications about the pre-training speech-language assessment and the post-training evaluation of conversation practice should have been included in the preface to the speech-language pathologist. The author does not outline whether this workbook is intended for patients with a specific type or severity of aphasia, what level of commitment is required to ensure success, and whether modifications would be necessary to accommodate cultural differences.

In addition, more guidance to the speech-language pathologist, significant other and couple with aphasia would have been beneficial in the preface. There is no hierarchy of difficulty in terms of the order in which the 26 activities are presented to the couple (e.g., grocery shopping in activity 4 may be easier than a three-minute conversation in activity 1). Guidance could also have been offered about how the speech-language pathologist can encourage successful conversation practice by the couple at home (e.g., determining a comfortable environment for home practice, deciding the best time of day for practice, and the appropriate amount of time for practice for a specific couple, etc.).

A speech-language pathologist working according to the ACT approach based on this book may wish to supplement the book with additional materials and activities. For example, the SO could be encouraged to keep a diary, as suggested by Davidson, Worrall, and Hickson (2008), to identify real-life communication situations that were successful or that were challenging for the patient and SO. Aphasia-friendly information should also be created and included for the person with aphasia to explain the purpose and format for conversation practice. Although Boles stipulates that no materials are required for ACT, a speech-language pathologist may wish to develop a repository of possible resources, such as pictographs and diagrams to accompany each of the activities. Written multiple choice options in the workbook should probably be enlarged for use with the person with aphasia. The therapy session could be supplemented with strategies such as *Supportive Conversation for Aphasia* (SCA; Kagan, 1998), which would not be incompatible with ACT. The speech-language pathologist using this workbook could also benefit from knowledge about adult learning techniques and ways to modify workbook activities to accommodate differences in couples' learning styles (Sorin-Peters, 2004).

The *Aphasia Couples Therapy Workbook* is a useful and welcome resource for speech-language pathologists, significant others, and couples with aphasia in their pursuit of improved quality of couple conversation. If used in conjunction with additional materials, it can serve to increase communicative effectiveness of individuals with aphasia and their communicative partners.

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Dysphagia Post Trauma

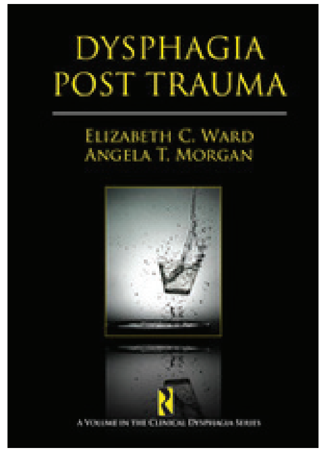
Author: Elizabeth Ward and Angela Morgan
Publisher: Plural Publishing Inc.
Cost: $76.95
Reviewer: Catriona M. Steele, Ph.D. S-LP(C), CCC-SLP, BRS-S, Reg. CASLPO
Affiliation:

This is a welcome new text book, part of the new Clinical Dysphagia Series edited by Drs. Jay Rosenbek and Harrison Jones. In this book, Ward and Morgan, together with a team of their Australian colleagues as chapter authors, cover a topic that has received very little attention in the dysphagia literature before: namely, dysphagia following traumatic injury. The book begins with a general overview chapter, which reviews swallowing physiology and general principles of dysphagia assessment and intervention in the context of trauma. This is followed by a helpful overview of traumatic brain injury (TBI), a topic that has received secondary attention in our literature to stroke but which deserves equal attention because patients with TBI often suffer serious dysphagia. Here, Morgan's expertise in the management of TBI-related dysphagia shines. This chapter would be a good introduction to the TBI population for any clinician.

These introductory chapters are followed by three chapters that delve into several other kinds of traumatic injury – perhaps topics that one would not immediately expect to find in this book. First, Maura Solley and Ward cover the topic of dysphagia following traumatic spinal cord injury (SCI). As with Morgan's chapter on TBI, this chapter includes a thorough and helpful review of SCI, the details of which may be unfamiliar to many speech-language pathologists. The chapter includes extensive discussion of respiratory issues in this population, a review of different types of braces worn by patients with SCI, and different surgical management approaches. Unlike the majority of the sparse literature on dysphagia following SCI, this chapter contains a detailed and thorough consideration of the topic, emphasizing the wide-spread consequences and the importance of multi-disciplinary team management.

Chapter 4 is another highlight on a topic that has received too little attention in our literature: dysphagia following burn injuries. Here, we are treated to Anna Rumbach's superb work in the area. Different types of burn injuries are described thoroughly, followed by a detailed discussion of the physiological response that occurs following burn-related tissue damage. Surgical approaches to burn intervention are described as well as the management of dysphagia in this population.

Chapter 5 covers the topics of multiple traumas and iatrogenic trauma, led by authors Jane Crombie and Ann-Louise Spurgin. Here, in addition to a description of the different types of skeletal and tissue injury that can occur, we



find discussion of different surgical reconstruction techniques. Nerve damage through trauma or as an iatrogenic consequence of surgery in the head, neck and thorax is covered.

What was missing? Although not technically trauma, it was unfortunate that there was no discussion of anoxic brain injury resulting from non-traumatic causes like cardiac events. These patients often present with similar problems and follow similar trajectories to those with traumatic brain injury, and this is a topic upon which very little has been written. Similarly, it was unfortunate that there was no specific discussion of pediatrics, since Morgan is known for her work in this area. The book is oriented to management of adult dysphagia in all populations, and special considerations for pediatric patients are missing.

Despite these omissions, this is a welcome addition to the available textbooks on dysphagia. The book is written in user-friendly language, with excellent illustrations, and will prove a useful resource to any clinicians working in this area.

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Tim Bressmann, PhD
Editor in Chief
Canadian Journal of Speech-Language Pathology and Audiology
Department of Speech-Language Pathology
University of Toronto
160 - 500 University Avenue
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Title Page: This page should include the full title of the manuscript, the full names of the author(s) with academic degrees and affiliations, and a complete mailing address and email address for the contact author.

Abstract: On a separate sheet of paper, a brief yet informative abstract that does not exceed one page is required. The abstract should include the purpose of the work along with pertinent information relative to the specific manuscript category for which it was submitted.

Key Words: Following the abstract and on the same page, the author(s) should supply a list of key words for indexing purposes.

Tables: Each table included in the manuscript must be typewritten and double-spaced on a separate sheet of paper. Tables should be numbered consecutively beginning with Table 1. Each table must have a descriptive caption. Tables should serve to expand the information provided in the text of the manuscript, not to duplicate information.

Illustrations: All illustrations for the manuscript must be appended to each copy of the manuscript. All manuscripts must have clear copies of all illustrations for the review process. High resolution (at least 300 dpi) files in any of the following formats must be submitted for each graphic and image: JPEG, TIFF, AI, PSD, GIF, EPS or PDF. For other types of computerized illustrations, it is recommended that CJSLPA production staff be consulted prior to preparation and submission of the manuscript and associated figures/illustrations.

Legends for Illustrations: Legends for all figures and illustrations should be typewritten (double-spaced) on a separate sheet of paper with numbers corresponding to the order in which figures/illustrations appear in the manuscript.

Page Numbering and Running Head: The text of the manuscript should be prepared with each page numbered, including tables, figures/illustrations, references, and appendices. A short (30 characters or less) descriptive running title should appear at the top right hand margin of each page of the manuscript.

Acknowledgments: Acknowledgments should be typewritten (double-spaced) on a separate page. Appropriate acknowledgment for any type of sponsorship, donations, grants, technical assistance, and to professional colleagues who contributed to the work but are not listed as authors, should be noted.

References: References are to be listed consecutively in alphabetical order, then chronologically for each author. Authors should consult the APA publication manual (6th Edition) for methods of citing varied sources of information. Journal names and appropriate volume number should be spelled out and italicized. All literature, tests and assessment tools, and standards (ANSI and ISO) must be listed in the references. All references should be double-spaced.

Potential Conflicts of Interest and Dual Commitment

As part of the submission process, the author(s) must explicitly identify if any potential conflict of interest or dual commitment exists relative to the manuscript and its author(s). Such disclosure is requested so as to inform CJSLPA that the author or authors have the potential to benefit from publication of the manuscript. Such benefits may be either direct or indirect and may involve financial and/or other nonfinancial benefit(s) to the author(s). Disclosure of potential conflicts of interest or dual commitment may be provided to editorial consultants if it is believed that such a conflict of interest or dual commitment may have had the potential to influence the information provided in the submission or compromise the design, conduct, data collection or analysis, and/or interpretation of the data obtained and reported in the manuscript submitted for review. If the manuscript is accepted for publication, editorial acknowledgement of such potential conflict of interest or dual commitment may occur within the publication.

Participants in Research Humans and Animals

Each manuscript submitted to CJSLPA for peer-review that is based on work conducted with humans or animals must acknowledge appropriate ethical approval. In instances where humans or animals have been used for research, a statement indicating that the research was approved by an institutional review board or other appropriate ethical evaluation body or agency must clearly appear along with the name and affiliation of the research ethics and the ethical approval number. The review process will not begin until this information is formally provided to the Editor.

Similar to research involving human participants, CJSLPA requires that work conducted with animals state that such work has met with ethical evaluation and approval. This includes identification of the name and affiliation of the research ethics evaluation body or agency and the ethical approval number. A statement that all research animals were used and cared for in an established and ethically approved manner is also required. The review process will not begin until this information is formally provided to the Editor.

Renseignements à l'intention des collaborateurs

La Revue canadienne d'orthophonie et d'audiologie (RCOA) est heureuse de se voir soumettre des manuscrits de recherche portant sur la communication humaine et sur les troubles qui s'y rapportent, dans leur sens large. Cela comprend les manuscrits portant sur les processus normaux et désordonnés de la parole, du langage et de l'audition. Nous recherchons des manuscrits qui n'ont jamais été publiés, en français ou en anglais. Les manuscrits peuvent être tutoriels, théoriques, synthétiques, pratiques, pédagogiques ou empiriques. Tous les manuscrits seront évalués en fonction de leur signification, de leur opportunité et de leur applicabilité aux intérêts de l'orthophonie et de l'audiologie comme professions, et aux sciences et aux troubles de la communication en tant que disciplines. Par conséquent, tous les manuscrits sont évalués en fonction de leur incidence possible sur l'amélioration de notre compréhension de la communication humaine et des troubles qui s'y rapportent. Peu importe la catégorie, tous les manuscrits présentés seront soumis à une révision par des collègues afin de déterminer s'ils peuvent être publiés dans la RCOA. La Revue a établi plusieurs catégories de manuscrits afin de permettre la meilleure diffusion possible de l'information portant sur la communication humaine et les troubles s'y rapportant. Les catégories de manuscrits comprennent :

Tutoriels : Rapports de synthèse, traités ou exposés de position portant sur un sujet particulier dans un cadre théorique ou clinique.

Articles : Manuscrits conventionnels traitant de recherche appliquée ou expérimentale de base sur les questions se rapportant à la parole, au langage ou à l'audition et faisant intervenir des participants humains ou animaux.

Comptes rendus cliniques : Comptes rendus de nouvelles procédures ou méthodes ou de nouveaux protocoles cliniques portant particulièrement sur une application directe par rapport aux questions d'identification, d'évaluation et de traitement relativement à la parole, au langage et à l'audition.

Comptes rendus sommaires : Semblables aux notes de recherche, brèves communications portant sur des conclusions préliminaires, soit cliniques soit expérimentales (appliquées ou fondamentales), pouvant mener à une étude plus poussée dans l'avenir. Ces comptes rendus se fondent typiquement sur des études à petit « *n* » ou pilotes et doivent traiter de populations désordonnées.

Notes de recherche : Brèves communications traitant spécifiquement de travaux expérimentaux menés en laboratoire. Ces comptes rendus portent typiquement sur des questions de méthodologie ou des modifications apportées à des outils existants utilisés auprès de populations normales ou désordonnées.

Comptes rendus d'expérience : Comptes rendus décrivant sommairement la prestation de services offerts en situations uniques, atypiques ou particulières; les manuscrits de cette catégorie peuvent comprendre des comptes rendus de dépistage, d'évaluation ou de traitement.

Courrier des lecteurs : Forum de présentation de divergences de vues scientifiques ou cliniques concernant des ouvrages déjà publiés dans la Revue. Le courrier des lecteurs peut avoir un effet sur notre façon de penser par rapport aux facteurs de conception, aux confusions méthodologiques, à l'analyse ou l'interprétation des données, etc. Comme c'est le cas pour d'autres catégories de présentation, ce forum de communication est soumis à une révision par des collègues. Cependant, contrairement aux autres catégories, on recherchera la réaction des auteurs sur acceptation d'une lettre.

Présentation de manuscrits

Pour soumettre un article, les auteurs doivent utiliser le système de soumission électronique de l'ACOA à l'adresse http://cjslpa.coverpage.ca. Si vous ne pouvez pas utiliser le système électronique, veuillez envoyer par courriel un fichier Word ou WordPerfect contenant le manuscrit, y compris tous les tableaux, les figures ou illustrations et la bibliographie. Adressez le courriel au rédacteur en chef à l'adresse tim.bressmann@utoronto.ca. Vous pouvez aussi soumettre cinq (5) exemplaires sur papier à :

Tim Bressmann, PhD
Rédacteur en chef
Revue canadienne d'orthophonie et d'audiologie
Department of Speech-Language Pathology
University of Toronto
160 - 500 University Avenue
Toronto, Ontario M5G 1V7

On doit joindre aux exemplaires du manuscrit une lettre d'envoi qui indiquera que le manuscrit est présenté en vue de sa publication. La lettre d'envoi doit préciser que le manuscrit est une œuvre originale, qu'il n'a pas déjà été publié et qu'il ne fait pas actuellement l'objet d'un autre examen en vue d'être publié. Les manuscrits sont reçus et examinés sur acceptation de ces conditions. L'auteur (les auteurs) doit (doivent) aussi fournir une attestation en bonne et due forme que toute recherche impliquant des êtres humains ou des animaux a fait l'objet de l'agrément d'un comité de révision déontologique. L'absence d'un tel agrément retardera le processus de révision. Enfin, la lettre d'envoi doit également préciser la catégorie de la présentation (i.e. tutoriel, rapport clinique, etc.). Si l'équipe d'examen juge que le manuscrit devrait passer sous une autre catégorie, l'auteur-contact en sera avisé.

Toutes les présentations doivent se conformer aux lignes de conduite présentées dans le publication *Manual of the American Psychological Association (APA)*, 6e Édition. Un accusé de réception de chaque manuscrit sera envoyé à l'auteur-contact avant la distribution des exemplaires en vue de la révision. La *RCOA* cherche à effectuer cette révision et à informer les auteurs des résultats de cette révision dans les 90 jours de la réception. Lorsqu'on juge que le manuscrit convient à la RCOA, on donnera 30 jours aux auteurs pour effectuer les changements nécessaires avant l'examen secondaire.

L'auteur est responsable de toutes les affirmations formulées dans son manuscrit, y compris toutes les modifications effectuées par les rédacteurs et réviseurs. Sur acceptation définitive du manuscrit et immédiatement avant sa publication, on donnera l'occasion à l'auteur-contact de revoir les épreuves et il devra signifier la vérification du contenu dans les 72 heures suivant réception de ces épreuves.

Organisation du manuscrit

Tous les textes doivent être dactylographiés à double interligne, en caractère standard (police de caractères 12 points, non comprimée) et sur papier 8 ½" X 11" de qualité. Toutes les marges doivent être d'au moins un (1) pouce. L'original et quatre (4) copies du manuscrit doivent être présentés directement au rédacteur en chef. L'identification de l'auteur est facultative pour le processus d'examen : si l'auteur souhaite ne pas être identifié à ce stade, il devra préparer trois (3) copies d'un manuscrit dont la page couverture et les remerciements seront voilés. Seuls les auteurs sont responsables de retirer toute information identificatrice éventuelle. Tous les manuscrits doivent être rédigés en conformité aux lignes de conduite de l'APA. Ce manuel est disponible dans la plupart des librairies universitaires et peut être commandé chez les libraires commerciaux. En général, les sections qui suivent doivent être présentées dans l'ordre chronologique précisé.

Page titre : Cette page doit contenir le titre complet du manuscrit, les noms complets des auteurs, y compris les diplômes et affiliations, l'adresse complète de l'auteur-contact et l'adresse de courriel de l'auteur contact.

Abrégé : Sur une page distincte, produire un abrégé bref mais informateur ne dépassant pas une page. L'abrégé doit indiquer l'objet du travail ainsi que toute information pertinente portant sur la catégorie du manuscrit.

Mots clés : Immédiatement suivant l'abrégé et sur la même page, les auteurs doivent présenter une liste de mots clés aux fins de constitution d'un index.

Tableaux : Tous les tableaux compris dans un même manuscrit doivent être dactylographiés à double interligne sur une page distincte. Les tableaux doivent être numérotés consécutivement, en commençant par le Tableau 1. Chaque tableau doit être accompagné d'une légende et doit servir à compléter les renseignements fournis dans le texte du manuscrit plutôt qu'à reprendre l'information contenue dans le texte ou dans les tableaux.

Illustrations : Toutes les illustrations faisant partie du manuscrit doivent être incluses avec chaque exemplaire du manuscrit. Chaque manuscrit doit contenir des copies claires de toutes les illustrations pour le processus de révision. Il faut envoyer un fichier électronique pour chaque image et graphique en format JPEG, TIFF, AI, PSD, GIF, EPS ou PDF, compression minimale 300 ppp. Pour les autres types d'illustrations informatisées, il est recommandé de consulter le personnel de production de la RCOA avant la préparation et la présentation du manuscrit et des figures et illustrations s'y rattachant.

Légendes des illustrations : Les légendes accompagnant chaque figure et illustration doivent être dactylographiées à double interligne sur une feuille distincte et identifiées à l'aide d'un numéro qui correspond à la séquence de parution des figures et illustrations dans le manuscrit.

Numérotation des pages et titre courant : Chaque page du manuscrit doit être numérotée, y compris les tableaux, figures, illustrations, références et, le cas échéant, les annexes. Un bref (30 caractères ou moins) titre courant descriptif doit apparaître dans la marge supérieure droite de chaque page du manuscrit.

Remerciements : Les remerciements doivent être dactylographiés à double interligne sur une feuille distincte. L'auteur doit reconnaître toute forme de parrainage, don, bourse ou d'aide technique, ainsi que tout collègue professionnel qui ont contribué à l'ouvrage mais qui n'est pas cité à titre d'auteur.

Références : Les références sont énumérées les unes après les autres, en ordre alphabétique, suivi de l'ordre chronologique sous le nom de chaque auteur. Les auteurs doivent consulter le manuel de l'APA (6e Édition) pour obtenir la façon exacte de rédiger une citation. Les noms de revues scientifiques et autres doivent être rédigés au long et imprimés en italiques. Tous les ouvrages, outils d'essais et d'évaluation ainsi que les normes (ANSI et ISO) doivent figurer dans la liste de références. Les références doivent être dactylographiées à double interligne.

Conflits d'intérêts possibles et engagement double

Dans le processus de présentation, les auteurs doivent déclarer clairement l'existence de tout conflit d'intérêts possibles ou engagement double relativement au manuscrit et de ses auteurs. Cette déclaration est nécessaire afin d'informer la RCOA que l'auteur ou les auteurs peuvent tirer avantage de la publication du manuscrit. Ces avantages pour les auteurs, directs ou indirects, peuvent être de nature financière ou non financière. La déclaration de conflit d'intérêts possibles ou d'engagement double peut être transmise à des conseillers en matière de publication lorsqu'on estime qu'un tel conflit d'intérêts ou engagement double aurait pu influencer l'information fournie dans la présentation ou compromettre la conception, la conduite, la collecte ou l'analyse des données, ou l'interprétation des données recueillies et présentées dans le manuscrit soumis à l'examen. Si le manuscrit est accepté en vue de sa publication, la rédaction se réserve le droit de reconnaître l'existence possible d'un tel conflit d'intérêts ou engagement double.

Participants à la recherche – êtres humains et animaux

Chaque manuscrit présenté à la RCOA en vue d'un examen par des pairs et qui se fonde sur une recherche effectuée avec la participation d'être humains ou d'animaux doit faire état d'un agrément déontologique approprié. Dans les cas où des êtres humains ou des animaux ont servi à des fins de recherche, on doit joindre une attestation indiquant que la recherche a été approuvée par un comité d'examen reconnu ou par tout autre organisme d'évaluation déontologique, comportant le nom et l'affiliation de l'éthique de recherche ainsi que le numéro de l'approbation. Le processus d'examen ne sera pas amorcé avant que cette information ne soit formellement fournie au rédacteur en chef.

Tout comme pour la recherche effectuée avec la participation d'êtres humains, la RCOA exige que toute recherche effectuée avec des animaux soit accompagnée d'une attestation à l'effet que cette recherche a été évaluée et approuvée par les autorités déontologiques compétentes. Cela comporte le nom et l'affiliation de l'organisme d'évaluation de l'éthique en recherche ainsi que le numéro de l'approbation correspondante. On exige également une attestation à l'effet que tous les animaux de recherche ont été utilisés et soignés d'une manière reconnue et éthique. Le processus d'examen ne sera pas amorcé avant que cette information ne soit formellement fournie au rédacteur en chef.

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