



Response generalization in apraxia of speech treatments: taking another look

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Abstract

The purpose of the present paper is to present a critical review and reanalysis of response generalization effects in studies of treatment efficacy in apraxia of speech (AOS). Response generalization takes two forms: generalization of treatment effects to untrained exemplars of trained behaviors and generalization to untrained (i.e., novel) behaviors. In the past, response generalization has not been extensive and typically has been restricted to untrained exemplars of trained behaviors. Reasons for these findings are discussed with reference to recent advances in our understanding of the nature of AOS and to theories of speech motor control and learning. The discussion focuses on the influence of the theoretical basis used to develop hypotheses and select behaviors to test predictions, the complexity of the treatment task/s, and patient characteristics. Suggestions for future directions in treatment efficacy research are offered. Learner outcomes: (1) An understanding of the nature of AOS, based on recent experimental analyses. (2) An understanding of the efficacy of current treatments for AOS in the area of response generalization. (3) An understanding of how theories of speech motor control might be applied to develop hypotheses for testing and increase effectiveness in treatment studies. (4) An understanding of how theories of speech motor control might guide selection of behaviors to test treatment effects and response generalization. © 2001 Elsevier Science Inc. All rights reserved.

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1. Introduction

Apraxia of speech (AOS) is a potentially devastating disorder that renders a person unable to use verbal communication effectively. Several treatment approaches have been developed to remediate this motor programming impairment (see Wambaugh & Doyle, 1994 for a review) but their success in terms of response generalization has been limited. Most treatment approaches have been motivated by the surface symptoms of AOS (Darley, Aronson, & Brown, 1975; Kent & Rosenbek, 1983) rather than by a theory of normal speech motor control or of its breakdown. In recent years, researchers have provided more objective descriptions of AOS and several theories of the underlying disorder. Furthermore, theories of normal speech motor control have become more sophisticated and more specified. As would be expected, treatment research is lagging behind. The present paper draws together reports on response generalization and reevaluates them in light of recent advances. A new perspective for facilitating response generalization is suggested.

In the field of speech and language pathology, AOS is typically referred to as a phonetic–motoric disorder rather than a linguistically based disorder (see Ballard, Granier, & Robin, 2000, Code, 1998; McNeil, Robin, & Schmidt, 1997 for reviews). McNeil et al. (1997) defined AOS as a disorder affecting the translation of an intact phonological representation of a message into the learned kinematic parameters for an intended movement. Code (1998) presented a slightly different perspective stating that AOS is a motoric disorder that manifests itself at both phonetic and phonological levels.

Although there is a range of treatment approaches for AOS, there are surprisingly few well-controlled treatment efficacy studies available in the literature. Thus, it is not always clear which approaches are effective, which are more effective than others, and whether certain patient characteristics might positively or negatively influence outcomes of a specific treatment approach. The standard measures used to judge treatment efficacy are the same across all disorder types. Essentially, acquisition of a trained behavior is important but long-term retention (i.e., maintenance) of that skill after all treatment has been completed is necessary. Also, it is preferable to demonstrate generalization of treatment effects to novel stimuli (i.e., stimulus generalization), to untrained exemplars of trained behaviors, and to untrained (i.e., novel) behaviors. Naturally, one does not expect generalization to occur to any novel behavior but rather only to those behaviors that are related, topographically or structurally, to the trained behavior/s (Thompson, 1989).

While maintenance of trained skills and generalization to novel stimuli are critical to determining a treatment's efficacy, the focus of the present paper will be on response generalization. First, there are more data available in the literature regarding response generalization and so a stronger statement can be made about what might or might not influence this process. Second, data on response generalization have the potential to inform theories of speech motor control in

terms of how different phonetic–motoric behaviors are related. This, in turn, will lead to generation of new hypotheses for future studies.

2. Review of treatment approaches

A number of treatment approaches have been advocated for AOS. These tend to fall into four broad categories being those that focus on temporal or prosodic features of speech (Dworkin & Abkarian, 1996; Dworkin, Abkarian, & Johns, 1988; Simmons, 1978; Sparks, Helm, & Albert, 1974; Wambaugh & Martinez, 2000; Wertz, LaPointe, & Rosenbek, 1984), articulatory kinematic aspects (Chumpelik, 1984; Deal & Florance, 1978; Hill, 1978; Rosenbek, Lemme, Ahern, Harris, & Wertz, 1973; Square, Chumpelik, & Adams, 1985; Square, Chumpelik, Morningstar, & Adams, 1986; Square-Storer, 1989; Van Riper & Irwin, 1958; Wambaugh, Kalinyak-Fliszar, West, & Doyle, 1998; Wambaugh, West, & Doyle, 1998), improving performance of articulatory gestures with biofeedback (Howard & Varley, 1995; Katz, Bharadwaj, & Carstens, 1999; McNeil, Prescott, & Lemme, 1976), and intersystemic reorganization via manual gestures (Code & Gaunt, 1986; Dowden, Marshall, & Tompkins, 1981; Raymer & Thompson, 1991; Rosenbek, Collins, & Wertz, 1976). These treatments aim to affect the behaviors characteristic of AOS such as (a) effortful groping for articulatory postures, (b) consonant phonemes more affected than vowels, (c) inconsistent, or variable, errors across productions, (d) errors that approximate the target within one to two features, (e) impaired coordination of voicing with movement of other articulators, (f) slowed speech rate, (g) prosodic disturbance, and (h) difficulty with initiation of utterances (Darley et al., 1975; Kent & Rosenbek, 1983). Typically, studies examining the efficacy of these treatments have focused on performance during the period when treatment is applied (see Wambaugh & Doyle, 1994 for a review). Few have considered long-term maintenance of treatment effects or generalization of trained behaviors to novel stimuli or responses. Those that have included such measures have reported varying results for generalization.

Essentially, in well-controlled treatment efficacy studies, we find that effects of treatment typically generalize to untrained exemplars of trained behaviors but not to novel behaviors. The ensuing discussion attempts to understand why the latter type of response generalization has not been forthcoming. It is argued that we might see more positive, or more extensive, results if a firm theory of speech motor control is applied to develop hypotheses and drive the selection of targeted behaviors. That is, behaviors that are fundamentally related by some motor control skill or group of skills should covary in treatment while behaviors that are not related in this way should remain stable.

The first group of treatments focuses on the temporal (e.g., overall rate) and prosodic (e.g., stress and intonation) disruptions in AOS. Such treatments have included pacing tasks using a metronome (Dworkin & Abkarian, 1996; Dworkin

et al., 1988; Wambaugh & Martinez, 2000) or finger-tapping (Simmons, 1978), contrastive stress drills (Dworkin et al., 1988; Wertz et al., 1984) and melodic intonation therapy (Sparks et al., 1974). Dworkin and Abkarian (1996) draw on several models of speech production to explain apraxia as a disruption in the rhythmic neural impulses that regulate speech. They argue that using a metronomic pacing method to enforce rhythm will facilitate relearning of specific speech motor control skills in apraxia. In this study with a single subject, they trained production of isolated vowels, then three vowel sequences, then voiced–voiceless alternates (vowel+/h/) at increasing rates. In all tasks, the basic skill being trained was control of onset and offset of voicing. They found some generalization within target type to faster production rates (this might be considered generalization of a trained response to a faster metronome stimulus), and across target types (this might be considered generalization of the trained response of onset/offset of voicing to untrained exemplars). Although they do not include specific results for speech intelligibility measures, they reported that intelligibility improved from pre- to posttreatment in their subject. This, presumably, was related to increased control of voicing and perhaps to the fitting of a palatal lift appliance pretreatment. These results are particularly impressive as the individual demonstrated a chronic apraxia that had been resistant to articulation-based treatments.

In an earlier study, Dworkin et al. (1988) utilized their metronomic pacing approach and examined generalization of treatment effects to untrained responses in a multiple baseline across behaviors design. In this case, results were not as positive. One individual with a primary impairment underwent a series of treatment tasks including nonspeech tongue movements, then alternating syllable productions, multisyllabic words, and finally sentence productions. Each set of behaviors was practiced at increasing speech rates (metronome beats per minute). The primary dependent variable was correct articulation of target behaviors at a given rate. The findings of this study are difficult to compare with Dworkin and Abkarian (1996) as no basic underlying speech motor skill (e.g., onset and offset of voicing) was being treated. The authors noted that there was "... no evidence to suggest that successful performance at an earlier step in the treatment regimen generalized to later, ostensibly more complex, speech control activities." (p. 287). For example, treatment on nonspeech oral motor tasks did not result in generalization to speech tasks, nor treatment on nonstressed sentences to stressed sentences. This type of response generalization (i.e., transfer of skills to untrained responses) tends not to occur from less to more complex behaviors (Ballard & Thompson 1999; Gierut 1998; Plaut, 1996; Thompson, Ballard, & Shapiro, 1998; see the Task Complexity section). Second, generalization is usually only expected to occur between behaviors that are related theoretically. Although pacing facilitated relearning of treated behaviors, the lack of any fundamentally unifying motor control skill/s across the different behavior targets may have precluded generalization.

These preceding arguments perhaps gain some support from Simmons (1978) and Wambaugh and Martinez (2000). Simmons (1978) used finger counting to pace sentence production and so improve intelligibility in a single subject. Simmons noted generalization with improved verbal scores on the Porch Index of Communicative Ability (PICA; Porch, 1967). By treating at the level of sentence production, the subject was presumably practicing control of several articulatory skills in a range of contexts (i.e., a relatively complex level), at least some of which were also represented in the verbal subtests of the PICA. Similarly, Wambaugh and Martinez used metronomic pacing to facilitate articulation of two sets of three syllabic words and noted modest improvements in production of untrained three syllable and four syllable words. Results from both studies potentially are explained by what Wambaugh and Martinez refer to as a generalized improvement in facility of production of syllable sequences.

A second approach to treatment has been to target articulatory kinematic aspects of speech production by using articulatory placement cues, modeling, and minimal contrasts (Chumpelik, 1984; Deal & Florance, 1978; Hill, 1978; Rosenbek et al., 1973; Square et al., 1985, 1986; Square-Storer, 1989; Van Riper & Irwin, 1958; Wambaugh, Kalinyak-Fliszar, et al., 1998). Studies using these techniques have typically focused on training production of specific phonemes and have trained one behavior or a small set at a time (but see Knock, Ballard, Robin, & Schmidt, 2000; Wambaugh, West, et al., 1998). Most studies have reported acquisition of treated behaviors and maintenance above baseline levels a month or more posttreatment. In a series of studies applying sound production treatment, Wambaugh and Cort (1998), Wambaugh, Kalinyak-Fliszar, et al. (1998), Wambaugh, West, et al. (1998), and Wambaugh, Martinez, McNeil, and Rogers (1999) reported successful generalization of treatment effects to untrained exemplars of treated sounds. However, generalization to untreated sounds has been limited or nonexistent and varies across sounds and speakers (Wambaugh et al., 1999). When treatment effects do generalize to untrained responses, it is typically to sounds that are related by manner or place of production (Square et al., 1986: Subject 3) or by error type, such as devoicing of plosives (Wambaugh & Cort, 1998; Wambaugh, Kalinyak-Fliszar, et al., 1998). That is, the sounds are related by some spatial or temporal phonetic–motoric features.

A third set of treatment approaches advocates use of biofeedback in stimulating improved performance of articulatory gestures. Forms of biofeedback include electromyography (McNeil et al., 1976), electropalatography (Howard & Varley, 1995), and electromagnetic articulography (Katz et al., 1999). These treatments have typically provided biofeedback for a single articulator (e.g., tongue body and tip: Howard & Varley, 1995; tongue tip position: Katz et al., 1999) on the movement underlying production of a specific minimal contrast pair (e.g., /d/ and /l/: Howard & Varley, 1995; /s/ and /ʃ/: Katz et al., 1999). The gesture is usually practiced in isolation in a nonspeech (i.e., silent) task and finally in phoneme

sequences such as CV or VCV. To the author's knowledge, biofeedback methods have not, as yet, been used to facilitate interarticulatory coordination or coarticulation. These studies have reported improvements in trained behaviors. Although they have not directly examined response generalization, treatment at earlier stages (e.g., nonspeech tasks) has not resulted in change at higher levels (e.g., phoneme or phoneme sequence production).

Finally, some treatments (Code & Gaunt, 1986; Dowden et al., 1981; Raymer & Thompson, 1991; Rosenbek et al., 1976) have attempted to stimulate intersystemic reorganization (Luria, 1970) by facilitating re-access to speech via manual gestures (Rosenbek et al., 1976; Skelly, Schinsky, Smith, & Fust, 1974). These approaches have met with success in stimulating production of treated speech behaviors but response generalization, when tested, has been limited. Dowden et al. (1981) trained gestures only and found no change from pre- to posttreatment in verbal scores on the PICA. Raymer and Thompson (1991) and Code and Gaunt (1986) both applied a verbal plus gestural paradigm in single subjects. Raymer and Thomson trained production of words initiated by /s, f, t, l/. They observed weak generalization to production of untrained exemplars and some generalization from treatment for /l/ words to production of untrained /n/ words. No clear generalization effect was observed for production of untrained /z/ or /v/ initial words. Code and Gaunt trained production of words with functional significance in the individual's daily life. They tested generalization to untrained words and found minimal improvement (i.e., from zero words produced correctly pretreatment to one to two produced posttreatment).

In the following sections, I reexamine the response generalization findings from several of the studies presented above. I discuss some factors that appear to influence generalization of treatment effects to untrained exemplars of trained behaviors and to novel behaviors. These factors form three major categories: the theoretical basis used to generate predictions, task complexity, and patient characteristics.

3. Factors influencing generalization

There appears to be some consensus that the common characteristics of AOS involve spatio-temporal disruptions with articulatory discoordination (manifesting as impaired spatial targeting, reduced coarticulation, and reduced control of voice onset time (VOT)), protracted segment and intersegment durations, and increased variability on durational measures over repeated trials (see Ballard et al., 2000; Code, 1998; McNeil et al., 1997 for reviews). These characteristics reflect impairments of intraarticulator control, interarticulatory coordination within and between gestures, and transitioning between articulatory gestures. They are likely to underlie the behaviors classically associated with AOS (Darley et al., 1975; Kent & Rosenbek, 1983).

3.1. *Theoretical bases*

Gesture theories of speech production provide one possible basis from which to interpret the common characteristics of AOS and readdress the issue of treatment (Bell-Berti, Krakow, Gelfer, & Boyce, 1995; Boyce, Krakow, Bell-Berti, & Gelfer, 1990; Browman & Goldstein 1986, 1995; Saltzman & Munhall, 1989; Weismer, Tjaden, & Kent, 1995). In gesture theory, each segment is represented by an articulatory gesture that comprises a set of control structures for realization of features. Gestures are relatively stable across segmental context and stretch beyond the time where their effects are manifest in the acoustic signal. Under this model, coarticulation results when adjacent gestures interact locally and overlap. In a series of studies, it has been demonstrated that individual gestures are more likely to emerge as distinct entities (i.e., with less overlap) (a) in stressed syllables, which have increased duration (Krakow, 1993), (b) when neutral segments are added (Bell-Berti & Krakow, 1990), and (c) when speaking rate is reduced (Bell-Berti & Krakow, 1990; Munhall & Löfqvist, 1990). It is interesting to note that the speech of individuals with AOS typically features reduced coarticulation (i.e., reduced gestural overlap), reduced stress contrasts, protracted segmental durations, schwa insertion, and reduced rate. One hypothesis might predict that the ability to produce overlapping gestures (i.e., perform precise spatio-temporal manipulations of multiple gestures) is impaired and results in surface characters such as rate and stress changes. Furthermore, the observation that individuals with AOS have poor control of VOT suggests disintegration of articulatory gestures such that the core structures are no longer produced as a cohesive unit.

The above hypotheses would motivate treatment approaches that focus on relearning control of articulators within and across gestures. Such an approach would advocate training across broad groups of phonemes, rather than training production of specific phonemes, and training individual gestures in a range of phonetic–motoric contexts. It perhaps addresses the problem of AOS from the perspective of the motor system rather than the linguistic system. Folkins and Bliede (1990) and Saltzman (1986) have commented that the motor system is not necessarily organized around presumed units of language or speech. As Saltzman (1986, p. 129) comments, “. . . actions are performed by effector systems that are indifferent to the goals of would-be performers.” Therefore, perhaps the damaged system should be retrained in performing movements that are highly coordinated in the spatio-temporal domain rather than be trained to produce specific phonemes or syllables. Although the latter approach has been the dominant one in treatments for AOS, the alternative might give us a useful framework to interpret findings of positive generalization to untrained exemplars of trained behaviors (Dworkin & Abkarian, 1996; Raymer & Thompson, 1991; Wambaugh & Cort, 1998; Wambaugh, Kalinyak-Fliszar, et al., 1998; Wambaugh et al., 1999). Most of these studies have involved treatment for a small set of phonemes or consonant clusters at the word level. For example,

when initial /p/ is trained using a set of 10 real words, generalization to untrained initial /p/ words is typically observed. It could be argued that training 10 different /p/ words specifically promotes controlled flexibility in transitioning from the articulatory gesture for /p/. Training 10 different transitions provides enough experience and practice to facilitate generalization to untrained transitions.¹ Whether or not coarticulation (i.e., the ability to *overlap* gestures) has been improved is not clear from these studies, as specific measures of coarticulation have not been performed.

For another example of the application of gesture theories of speech production to designing treatments for AOS and developing hypotheses about response generalization, consider VOT. Control of VOT presents particular difficulty for individuals with AOS. Producing a perceptually accurate token of, for example, the voiceless stop consonant /p/ involves coordination of closing and opening gestures for the mandible and lips, elevation of the velum to seal the velopharyngeal port, widening of the glottis, increased longitudinal tension of the vocal folds to avert vibrations, and finally temporal coordination of stop release with onset of voicing for a subsequent vowel. Furthermore, the velocity and size of glottal opening differ across phoneme classes (i.e., stops and fricatives) (Gracco & Löfqvist, 1994; Löfqvist & Yoshioka, 1981; Munhall & Ostry, 1983). To retrain the ability to manipulate VOT for voiced versus voiceless phonemes at the syllable or word level, it would seem necessary to provide multiple contrasts along this dimension. That is, therapy would involve training control of the relative timing of control structures within gestures to produce accurate voiced/voiceless distinctions within and across phoneme class. In terms of generalization, one might expect that intensive training on multiple consonant targets should increase the likelihood of generalization to improved production of voiced/voiceless contrasts in untrained consonants and that this transfer might only occur to consonants that are of lesser phonetic complexity (Dinnsen, Chin, Elbert, & Powell, 1990; Tyler & Figurski, 1994; also see the Task Complexity section). Thus, the initial hypothesis derived from a theory of motor control provides predictions regarding where treatment should be focused and, potentially, where response generalization should be seen.

Of note, this approach argues for training a single motor control skill in a range of phonetic–motoric contexts to facilitate generalization of that skill to untrained exemplars. Thus, treatment effects may generalize to untreated speech sounds if they entail the trained motor skill. In this case, these sounds would not be considered novel behaviors. This approach does not necessarily predict that generalization will occur to untrained motor control skills. For example, treatment for control of VOT would not be expected to generalize to increased control

¹ The distinction between the two types of response generalization discussed in this paper at times becomes unclear. The example presented here could represent generalization of the trained behavior — transitioning between gestures — to untrained exemplars or generalization of the trained behaviors (10 specific transitions) to novel responses (10 novel transitions).

of coarticulation across a range of contexts as these two classes of motor skill are unlikely to be fundamentally related along spatial or temporal parameters. One involves control of timing between articulators within a segment and the other transitioning from one gesture or segment to the next.

One potential criticism of the VOT treatment suggested here might come from the observation that individuals with AOS typically do not demonstrate perceptually inaccurate production of all VOT contrasts. Two approaches could be tested in this case. In one, a detailed inventory could be taken to determine which contrasts are problematic and which are intact. Only those judged as problematic would be candidates for treatment. It would be important, however, to make these judgments based on acoustic analyses as it has been noted previously that perceptual judgments of sound productions in AOS speakers may not identify underlying abnormalities in control of VOT (Wambaugh, West, & Doyle, 1997). The alternative approach would include intact and impaired phoneme contrasts in treatment. This might be justified given the results of Wambaugh and Cort (1998). These researchers studied a single subject who produced voiced stop consonants incorrectly. Errors were typically perceived as the voiceless cognate. They used sound production treatment, which includes production of minimal pair contrasts, and noted change from pre- to posttreatment in production of both voiced and voiceless sounds. Notably, perceptual accuracy of the voiceless sounds declined, with VOT shifting toward the voiced distribution. A related effect was noted by Wambaugh et al. (1999) when treatment for one sound (/s/) appeared to interfere with production of sounds not currently in treatment (/p, k/). Therefore, targeting intact VOT contrasts at the same time as impaired contrasts might facilitate maintenance of intact skills while also providing a vehicle for the AOS speaker to evaluate their performance through comparisons.

By structuring treatment and generalization goals around phonetic–motoric characteristics of production, I am not suggesting that we can separate these stages from phonology. On the contrary, the ultimate goal is a perceptually accurate token of a speech segment, syllable, or word. Kelso, Saltzman, and Tuller (1986) suggested that motor and linguistic components of speech production might not be separable. Further, it is clear that as a given speech movement pattern unfolds it is being monitored and corrected for deviations from that perceptual goal (Baars, Motley, & MacKay, 1975; Levelt, 1989; Ohala, 1981). Ohala (1990) quite convincingly argues that phonology and phonetics interact extensively and attempts to consider them as autonomous systems that communicate through some “interface” are futile and perhaps misleading. I merely suggest that individuals with AOS may demonstrate greater gains in treatment if goals are designed to tackle the motor control impairment, rather than the perceptual consequences of that impairment, but the ultimate goal is naturally to improve communication.

Finally, this approach would not require us to abandon previous approaches to treatment of AOS but rather complement them. It is likely that we will always use

techniques such as phonetic placement and the suggestions for treatment proposed above certainly support the methods used in minimal pair or contrastive approaches. Perhaps the greatest benefit of using such a theory is not to dictate how behaviors are elicited but to provide a framework for *selecting* behaviors for treatment and testing generalization.

3.2. *Task complexity*

Baer (1981) provided arguments that would seem to support the novel treatment approach and hypotheses presented above (see the Theoretical Bases section). Baer noted that a common reason for lack of treatment generalization is that insufficient exemplars of a behavior or rule are trained. Including multiple exemplars in training will increase the difficulty of the learning experience initially, but should result in greater generalization (Kearns, 1989). However, selecting the best exemplars to use in treatment is a difficult issue. Wertz et al. (1984) recommended introducing multiple target behaviors into treatment simultaneously and focusing on contrasts such as minimal pairs (i.e., distinctive feature contrasts) or varied stress patterns to prevent perseveration. However, they did not provide guidelines on selecting specific behaviors to facilitate learning and generalization. Keller and Schoenfeld (1950) noted that, when responses with a given “topography” are reinforced, those responses as well as responses with similar topographies increase in frequency. In learning motor skills, they suggested that topography might reflect characteristics such as force, speed, and duration.

More recently, several lines of research have provided concrete guidance on the issue of selecting behaviors for treatment across a number of domains. In summary, much evidence speaks against employing the traditional hierarchy of working from less to more complex behaviors (Dworkin et al., 1988; Howard & Varley, 1995; Katz et al., 1999; Rosenbek et al., 1973; but see Dworkin & Abkarian, 1996 for stimulus generalization). When more complex behaviors are selected, the treatment becomes more difficult but response generalization is more likely to occur to related behaviors that are of similar or lesser complexity. This phenomenon has been demonstrated in treatments for phonological disorders (see Gierut 1998 for a review) and syntactic impairments (Ballard & Thompson, 1999; Thompson et al., 1998) and in learning semantic categories (Plaut, 1996).

The concepts of training multiple exemplars and increasing the difficulty (or complexity) of the training context gain further support from a large body of literature examining learning of motor skills. Such studies were aimed at testing the application of several “principles of motor learning” that emerged from research on the schema theory of motor control (Schmidt, 1975; Schmidt & Lee, 1999). These principles have been tested primarily in learning of novel limb movements by normal children and adults. According to these studies, the development of flexible and skilful actions is influenced by the structure of practice and the nature of feedback (see Schmidt & Lee, 1999 for an extensive

review). For example, practicing several motor skills in random order during a session (e.g., A B B A C B C C A), without frequent modeling, promotes greater long-term retention and generalization than practicing them in a blocked order (e.g., BBB AAA CCC). Providing feedback on success of performance (i.e., knowledge of results feedback) with low frequency (i.e., on 30–60% of trials) also results in greater retention and generalization than providing feedback on 100% of trials. Furthermore, providing a higher number of trials (> 100 per session) is more beneficial than a low number of trials (≤ 20).

It is easy to see how performing several skills in random order with a high number of trials would promote retention and generalization. Such conditions might represent a more realistic learning context that promotes emergence of stable movement patterns and development of controlled flexibility in switching between movement patterns and adjusting to changes in initial conditions. Furthermore, these principles combined with an intermittent and unpredictable reinforcement schedule would encourage the learner to become independent in “recall” of movement patterns and self-evaluation of accuracy.

It follows then that these principles are not compatible with a treatment approach for motor speech disorders that uses imitation, solely or primarily, to elicit targeted behaviors. While individuals with AOS may initially require substantial support to produce target behaviors (e.g., through modeling, cueing, and a high rate of feedback to shape behaviors), it is likely that treatment and generalization effects will be greatest if the above principles are introduced into therapy as early as possible. Currently, there is little empirical evidence to support the use of these principles of motor learning in the motor speech system. A few specific principles, such as performing a high number of trials (Chumpelik, 1984; Dworkin & Abkarian, 1996; Hill, 1978; Rosenbek et al., 1973; Sparks et al., 1974; Square et al., 1985; Wambaugh, Kalinyak-Fliszar, et al., 1998) or practicing skills in random order (Hill, 1978; Sparks et al., 1974) have been adopted without direct testing. Knock et al. (2000) recently presented support for the effectiveness of random practice order versus blocked order in facilitating long-term retention of trained syllable and word production in severe AOS. They utilized the common treatment approach of phonetic placement therapy. Additional evidence for training multiple speech targets in parallel, rather than sequentially, is provided by Wambaugh et al. (1999) and Wambaugh, West, et al. (1998) in studies using sound production treatment. Thus, combining principles of motor learning with treatment approaches that are firmly based on theories of speech motor control (e.g., gesture theories, see the Theoretical Bases section) and provide specific predictions regarding response generalization might prove fruitful.

3.3. Patient characteristics

A relatively consistent observation in studies of treatment efficacy is that acquisition, maintenance, and generalization results vary across individuals. This

is assumed to result from heterogeneity in patient characteristics such as extent and profile of impairment. Wertz et al. (1984) noted that being greater than 1 month post-onset or having a concurrent aphasia or anomia indicate a poorer prognosis for improvement in AOS. Note, however, that changes due to spontaneous recovery have confounded many evaluations of the influence of time post-onset on treatment outcomes. Further, individuals who are in the chronic phase of AOS clearly still are able to benefit from intervention (see Wambaugh & Doyle, 1994).

Marshall, Tompkins, and Phillips (1982) studied prognostic factors in 110 individuals who had aphasia subsequent to a single left hemisphere infarct. They found that individuals with a poorer prognosis tended to be older, to have an etiology of thrombo-embolic stroke, have poor comprehension skills, and be more severely impaired at commencement of treatment. It was noted that age, etiology, and general health factors are not independent.

Considering severity, it appears that more severe impairments are more resistant to remediation or require more intensive treatment to demonstrate substantial improvement (Ballard & Thompson, 1999; Marshall et al., 1982; Wambaugh et al., 1999). Ballard and Thompson (1999) and Wambaugh et al. (1999) noted that individuals with more severe impairments tend to demonstrate overgeneralization of treatment effects to untrained behaviors rather than generalization. It is not possible to undertake a detailed analysis of the influence of impairment severity on generalization or overgeneralization in the extant AOS treatment literature for two reasons. First, available studies typically do not contain detailed error analyses so it is not possible to determine whether overgeneralization occurred. Second, at present, severity is judged subjectively and reliability across studies appears to be poor. Of several studies claiming to include individuals with severe AOS, the behaviors used as an index of treatment effect suggest a considerable range in what is identified as severe: simple sentence production (Deal & Florance 1978), mean length of utterance in spontaneous speech (Florance, Rabidoux, & McCauslin, 1980), phrases or word pairs (Square et al., 1985, 1986; Square-Storer & Hayden, 1989), single word production (Knock et al., 2000; Lane & Samples, 1981; LaPointe, 1984; Raymer & Thompson, 1991), and CV and VC syllables (Knock et al., 2000).

This discrepancy in subject severity ratings across studies of treatment efficacy calls for a more standard rating measure and more detailed descriptions of patient characteristics. Wertz et al. (1984) suggested use of a seven-point scale developed by Rosenbek and Merson (1971). Although this scale still relies on examiner ratings or judgments, it has demonstrated reasonable correlations with total number of articulatory (e.g., substitutions, distortions, repetitions, etc.) and nonphonemic (pauses, groping, unintelligible productions, etc.) errors (Rosenbek & Merson, 1971). However, in addition to reporting a severity “score,” cross-study comparisons would be facilitated by detailed subject descriptions of performance on a range of clinical measures. For example,

performance on measures such as the following might be included: (a) an identification of level of spontaneous production (e.g., MLU), (b) naming ability and effect of cueing on naming, (c) ability to repeat at the sound, syllable, word, phrase, and sentence levels, (d) quantitative data on the presence and frequency of classical behavioral characteristics (Dabul, 1979; Darley et al., 1975), (e) speech rate, (f) when available, acoustic and kinematic measures of speech production, and (g) presence of concomitant disorders, such as aphasia, along with quantitative data on the presence and frequency of the classical characteristics of these. When available, lesion data might also be informative. Such detailed information on patients would have benefits beyond understanding treatment outcomes and facilitating cross-study comparisons. A large database of patient characteristics might serve to facilitate a more accurate definition of the disorder, aid identification of potential subtypes of AOS, and contribute to testing the several available theories as to the underlying nature of the disorder. While the space limitations imposed by journals might preclude such detail, this problem has been overcome in other fields of study by developing databases on the World Wide Web (<http://www.ncbi.nlm.nih.gov/Genbank/GenbankOverview.html>).

4. Summary and conclusions

Although a number of treatment approaches have been developed for AOS, research on treatment efficacy has been limited. In the few studies where authors have reported on response generalization, the results have not been ideal. The present paper attempts to evaluate and explain findings on response generalization and provide some directions for future treatment efficacy studies. Specifically, recent advances in our understanding of normal and disordered speech motor control need to be incorporated into treatment approaches. Theories of motor control should be more rigorously applied in developing hypotheses and selecting behaviors to examine generalization effects. The influence of factors such as task complexity and specific patient characteristics on maintenance and generalization of treatment effects needs to be directly examined. Finally, well-controlled studies comparing different treatment approaches would lead to enhanced service delivery.

Appendix A. Continuing education

1. Detailed analyses of AOS have shown that it is primarily characterized by
 - (a) articulatory groping
 - (b) substitution of phonemes
 - (c) difficulty initiating speech

- (d) spatial and temporal incoordination within and between articulators
 - (e) weakness of the oral musculature
2. Studies of treatment efficacy in AOS have demonstrated that
 - (a) generalization to untrained (i.e., novel) behaviors typically occurs
 - (b) generalization to untrained exemplars of trained behaviors typically occurs
 - (c) both types of response generalization typically occur
 - (d) response generalization is usually not forthcoming
 - (e) theory predicts that response generalization should not occur
 3. In well controlled treatment efficacy studies, the best index/indices of efficacy (aside from social validation) is/are
 - (a) long-term maintenance of treated behaviors and generalization across stimuli and responses
 - (b) generalization of treatment effects to novel behaviors
 - (c) acquisition of treated behaviors
 - (d) acquisition of treated behaviors and stimulus generalization
 - (e) demonstration of a reversal of behavior when treatment is withdrawn
 4. It is critical to base treatment on well established theory for which reason/s
 - (a) to develop well justified and testable hypotheses of treatment effects a priori
 - (b) to increase the likelihood of positive treatment effects such as generalization across stimuli and responses
 - (c) to have a framework from which to interpret positive and negative treatment effects and so develop a logical sequence of goals in treatment
 - (d) to demonstrate accountability to the client, their family, and third party payers
 - (e) all of the above
 5. Individuals with more severe AOS
 - (a) are more likely to demonstrate generalization of treatment effects rather than overgeneralization
 - (b) are more likely to need intensive treatment over a longer time period to demonstrate positive treatment effects
 - (c) should not participate in impairment-based treatment programs
 - (d) typically have an etiology of hemorrhagic cerebrovascular accident
 - (e) always have intact automatic speech

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