Effects of PROMPT therapy on speech motor function in a person with aphasia and apraxia of speech

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This research examined the effectiveness of PROMPT treatment, a tactile-kinesthetic speech motor treatment, on the acquisition and generalisation of precision and automaticity of speech movements in an individual with Broca’s aphasia and apraxia of speech. Using a single subject multiple probe design across behaviours, treatment effects and generalisation were examined for three linguistically different forms of sentences including imperatives, active declaratives, and interrogatives. Results indicated improved speech precision and sequencing of speech movements for trained and untrained sentences for imperative and active declarative forms only. There was no effect of treatment on the interrogatives. Findings are discussed in the context of motor facilitation and its relationship to the linguistic complexity of utterances. Furthermore, the relevance of the interface between motor-linguistic processes in individuals with aphasia and apraxia of speech and implications for resource allocation constructs are addressed.

The nature of the expressive deficit associated with Broca’s aphasia has been debated historically. In particular, the presence and functional effect of speech motor control impairments associated with aphasic syndrome have been the focus of the debate (see Square & Martin, 1994, for review). In the last decade, with improvements in the measurement of physical and physiological aspects of speech movements, it has progressively become clear that most individuals with aphasia, regardless of classification type, have some abnormalities of motor speech control. In fluent aphasia, the motor control impairments are often subtle and sub-clinical (Baum, Blumstein, Nasser, & Palumbo, 1990; Blumstein, 1998; Vijayan & Grandour, 1995). Typically, individuals with aphasia due to posterior brain damage demonstrate increased variability in the implementation of a number of phonetic parameters (Kent & McNeil, 1987; Ryalls, 1986), abnormal patterns in the temporal relations of segmental structure within and between words (Baum, 1992; Baum et al., 1990), and even difficulty in control of production of phonetic dimensions (e.g., voice-onset times in stop consonants, fricative duration as a cue to voicing) under different speaking rates (Baum, 1996; Baum & Ryan, 2001).
1993, Kent & McNeil, 1987). In individuals with non-fluent aphasia, especially Broca’s aphasia, the motor speech impairment is usually clearly observed and is characterised, in part, by perceptual features such as reduced articulatory agility, slow rate, speech errors including distortions, substitutions, and additions, articulatory groping, and abnormal prosodic patterns (Blumstein, 1990, 1998; McNeil & Kent, 1990). The classification schemas for aphasia recognise this dependency on the sensory and motor concomitants and characteristics of speech (Goodglass & Kaplan, 1983; McNeil & Kent, 1990). Thus, the presence or absence of motoric-level deficits has implicitly become an essential and integral part of the description of aphasic syndromes in general and non-fluent aphasia in particular (McNeil & Kent, 1990).

Indeed, by those who adhere to a motoric–linguistic explanation of aphasic verbal deficits, it has been estimated that 80% or more of individuals with Broca’s aphasia have apraxia of speech (AOS) (Wertz, LaPointe, & Rosenbek, 1984). Thus, it is probable that significant motoric deficits co-exist with language impairments, and probably account for at least part of the reduced verbal output and telegraphic language (Darley, 1982; McNeil & Kent, 1990), which is attributed to be principally linguistic in nature by others (e.g., Goodglass & Kaplan, 1983). The impact or the influence of a motor speech disorder on the verbal expressive abilities of individuals with Broca’s aphasia has not been systematically investigated in previous research. This paper will focus on Broca’s aphasia, the syndrome of aphasia most associated with accompanying motor speech impairments and the one in which there is likely to be the greatest interaction of motor speech and language formulation deficits affecting verbal output (Tonkovich & Peach, 1989).

The traditional treatment of Broca’s aphasia has focused largely on improving the linguistic abilities of the patients, with little consideration given to speech motor abilities except in cases of frank apraxia of speech. Even then, speech treatment for apraxia is frequently undertaken separately from treatment for aphasia rather than being integrated in a treatment paradigm that simultaneously facilitates both the motoric aspects and the linguistic formulation components of verbal expression. In other words, language facilitation in individuals with aphasia has generally been undertaken in the absence of facilitation of motoric aspects of verbal production. If it is true that the verbal expressive difficulties of individuals with aphasia, especially individuals with Broca’s aphasia, have both a motoric and a linguistic basis, therapies that focus only on improving linguistic formulation to enhance verbal expression (e.g., The Helm-Estabrooks Language Program for Syntax Stimulation, HELPSS, Helm-Estabrooks, 1981) may not provide enough support or opportunity for the patient to improve verbal production abilities. When treating individuals with aphasia, especially those with clinically significant speech motor control deficits, simultaneous motor treatment or support to the motor speech system should be integrated with strategies of language formulation in order to optimally facilitate the production of verbal expression.

Facilitation of the speech motor system could be provided in a variety of ways, including tactile and kinesthetic support (see Square, Martin, & Bose, 2001) or melodic and rhythmic methods (Sparks & Deck, 1986; Square, Roy, & Martin, 1997). The PROMPT system (Prompts for Restructuring Oral and Muscular Phonetic Targets) is a tactile–kinaesthetic based treatment method. This method was originally developed by Chumpeleik (1984) for the treatment of children with developmental motor speech disorders, and has subsequently been modified and effectively employed with adults having motor speech disorders (Square-Storer & Hayden, 1989). The prompts are targeted to guide the client through the temporal and spatial aspects of speech movements.
by heightening oro-facial kinaesthetic and tactile awareness for movement trajectories and sequences (Square et al., 2001; Square-Storer and Hayden, 1989). The tactile and kinesthetic cues are dynamic in nature and are designed to provide sensory input regarding the place of articulatory contact, extent of mandibular opening, presence and extent of labial rounding and retraction, voicing, muscle tension, timing of segments, manner of articulation, and/or coarticulation. PROMPT can be used to cue or prompt speech segments at the phoneme, word, or phrase level (Square-Storer & Hayden, 1989), or to facilitate only certain parameters of movement such as jaw opening, or the temporal flow of multi-syllabic utterances (see Square et al., 2001, for discussion).

In previous studies, PROMPT has been demonstrated to be an effective sensory motor treatment for helping individuals with Broca’s aphasia acquire functional utterances. The results of three existing studies on the treatment efficacy of the PROMPT system with adults with chronic apraxia and aphasia have been encouraging, but the studies themselves are problematic (Freed, Marshall, & Frazier, 1997; Square, Chumpetik, & Adams, 1985; Square, Chumpetik, Morningstar, & Adams, 1986). The two studies by Square et al. (1985, 1986) used an uncontrolled simultaneous treatment design to compare PROMPT treatment with integral stimulation (Rosenbek et al., 1973) and used a limited number of phoneme contrasts, target words, and phrases. The study by Freed et al. (1997) used PROMPT treatment but did not follow the PROMPT motor speech treatment hierarchy (Hayden & Square, 1994). Further, the treatment was applied over an extended number of sessions for motorically heterogeneous words and phrases. Thus, the previous research regarding efficacy of PROMPT treatment for individuals with aphasia was obtained through uncontrolled simultaneous treatment designs, without appropriate control measures for motor difficulty, and with limited consideration of the number of stimuli and sessions.

In addition to these methodological concerns of the previous studies, no study has investigated whether motor facilitation is affected by the linguistic complexity of utterances and sentence types. That is, does facilitation of verbal production that is provided by speech motor treatment depend on the linguistic nature of the utterances? In this study we attempted to extend our understanding of the effectiveness of PROMPT therapy for improving the speech motor control abilities in individuals with aphasia. In addition, we aimed to determine whether acquisition of movement precision is affected by sentence structure. The design of the experiment was primarily motivated by the speech production abilities demonstrated by the subject under investigation. The subject was a female speaker with co-occurring Broca’s aphasia and AOS. She demonstrated the ability to formulate the sentence types used as stimuli (imperatives, active declaratives, and interrogatives), but lacked the motor facility to support these productions. That is, the precision of speech movements and automaticity normally associated with the production of those utterances was seriously compromised.

The treatment chosen incorporated PROMPT cueing at the sentence or phrase level while the subject was attempting to produce the sentences chosen for treatment. No explicit attempt was made to improve or work on the syntactic or grammatical aspects of sentence production. Three different sets of sentences were chosen: imperatives, active declaratives, and interrogatives. The aim was not to directly improve the articulation of individual phonemes, but rather to facilitate the temporal and spatial movement parameters and the sequence of movement trajectories in the utterances. For example, if there was excessive lateral jaw side while producing an utterance, an attempt was made to normalise jaw movements in the midline; or if there was excessive retraction of the lips when targets should have been rounded, tactile prompting was delivered to facilitate lip
rounding at the appropriate point in the utterance. The primary purpose of the current investigation, therefore, was to determine the effectiveness of PROMPT treatment for improving the precision and automaticity of speech movements under different linguistic demands.

Although changing the grammatical correctness of the sentences was never the primary aim of the study, changes in grammatical correctness were observed and therefore further investigated. By grammatical correctness we mean whether the utterances produced were grammatically correct or incorrect irrespective of their speech motor accuracy. Therefore, the secondary purpose of this study was to determine the changes in linguistic correctness of utterances irrespective of motor performance as a result of supporting motor speech production in treatment.

METHOD

Participant

The subject, MS, was a 30-year-old female who was native speaker of American-English. She was highly educated and held a graduate degree in communication and film sciences. Pre-morbidly, she was right-handed. She experienced the sudden onset of a severe headache, quickly progressing to paralysis, coma, and right hemiplegia in August 1997, while she was shooting on a film set. She was later diagnosed as having suffered a left-hemisphere cerebrovascular accident (CVA) secondary to haemorrhage from the rupture of a congenital arteriovenous malformation. A large lesion occupying the left frontoparietal occipital region was evident on a CT scan done in September 1997. She was subsequently diagnosed as having a severe non-fluent aphasia with severe oral and verbal apraxia.

At the time of this investigation she was 13 months post-onset of the CVA and exhibited right hemiparesis. Before commencing the study, a detailed speech and language assessment was undertaken. The assessment protocol included both standardised and non-standardised measures of speech and language skills. The Western Aphasia Battery (WAB) (Kertesz, 1982) was given in order to estimate the severity of aphasia, and to determine a classification of aphasia. The Verbal Motor Production Assessment for Adults (VMPAA), (Hayden & Square, experimental edition) adapted from the Verbal Motor Production Assessment for Children (VMPAC) (Hayden & Square, 1999), was given to assess the neuromotor integrity of the speech systems, rule out the presence of significant dysarthria, and determine the level of speech motor disruption (i.e., global motor, oro-motor control, and sequencing). In addition to these tests, the Boston Naming Test (BNT), (Kaplan, Goodglass, & Weintraub, 1983), the Apraxia Battery for Adults (ABA), (Dabui, 1979), the Mayo Clinic motor speech examination protocol (unpublished, see Duffy, 1995), and the Neuropraxis Battery for Limb Apraxia (Roy, Square, Adams, & Friesen, 1985), were also administered. Pre-treatment assessment findings are presented in Table 1.

MS presented with both aphasia and AOS. The auditory comprehension portion of the WAB testing indicated mild comprehension deficits as evidenced in difficulties for longer and more complex sentences and sequential commands. Spontaneous speech was characterised by short phrases and simple sentences, and was essentially lacking in different and complex grammatical constructions. Problems in initiation along with perseveration of words were frequently noted. Her expressive language was also characterised by agrammatic errors. Repetition of phrases up to seven syllables closely approximated the target phrases. Only two or three words were attempted for longer phrases. MS experienced word-finding difficulties in the naming portion of the WAB and the BNT. Naming was characterised by circumlocutory responses, and both semantic and
TABLE 1
Pre-treatment assessment results

<table>
<thead>
<tr>
<th></th>
<th>Raw score/Total Possible</th>
<th>Score/Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Western Aphasia Battery (Kertesz, 1982)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spontaneous speech</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information content</td>
<td>9/10</td>
<td></td>
</tr>
<tr>
<td>Fluency</td>
<td>5/10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14/20</td>
<td>14</td>
</tr>
<tr>
<td>Auditory comprehension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes/No questions</td>
<td>60/60</td>
<td>176/200</td>
</tr>
<tr>
<td>Auditory word recognition</td>
<td>56/60</td>
<td>176/200</td>
</tr>
<tr>
<td>Sequential commands</td>
<td>60/80</td>
<td>176/200</td>
</tr>
<tr>
<td>Total</td>
<td>176/200</td>
<td>8.8</td>
</tr>
<tr>
<td>Repetition</td>
<td>52/100</td>
<td>5.2</td>
</tr>
<tr>
<td>Naming</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object naming</td>
<td>45/60</td>
<td></td>
</tr>
<tr>
<td>Word fluency</td>
<td>9/20</td>
<td></td>
</tr>
<tr>
<td>Sentence completion</td>
<td>19/10</td>
<td></td>
</tr>
<tr>
<td>Responsive speech</td>
<td>8/10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>72/108</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Aphasia quotient</strong></td>
<td></td>
<td>70.4</td>
</tr>
<tr>
<td><strong>Aphasia classification</strong></td>
<td></td>
<td>Broca’s aphasia</td>
</tr>
<tr>
<td><strong>Apraxia Battery for Adults (Dabul, 1979)</strong></td>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td>Severity rating</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boston Naming Test (Kaplan et al. 1983)</strong></td>
<td></td>
<td>Severe</td>
</tr>
<tr>
<td>Score</td>
<td>29/60</td>
<td></td>
</tr>
<tr>
<td><strong>Verbal Motor Production Assessment for Adults</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(Hayden &amp; Square, experimental version)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global motor control</td>
<td>14/15</td>
<td>93.3%</td>
</tr>
<tr>
<td>Oro-Motor control</td>
<td>35/69</td>
<td>50.7%</td>
</tr>
<tr>
<td>Oral and speech sequencing</td>
<td>23/38</td>
<td>60.5%</td>
</tr>
<tr>
<td>Interpretation</td>
<td></td>
<td>Oro-motor control more severely affected than sequencing</td>
</tr>
<tr>
<td><strong>Limb Apraxia Battery (unpublished)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>(Roy et al. 1985)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intransitive limb gestures</td>
<td>6/8</td>
<td></td>
</tr>
<tr>
<td>Transitive limb gestures</td>
<td>1/6</td>
<td></td>
</tr>
<tr>
<td>Complex axial gestures</td>
<td>2/12</td>
<td></td>
</tr>
<tr>
<td>Interpretation</td>
<td></td>
<td>Ideomotor limb and axial apraxia</td>
</tr>
</tbody>
</table>

Phonemic paraphasias, although phonemic paraphasias may have been confounded by AOS. As indicated in Table 1, the aphasia quotient (AQ) was 70.4, indicating moderate Broca’s aphasia. Her previous neuropsychological assessment indicated normal visual memory but mildly impaired verbal memory. Executive functions, reasoning, and problem solving, as well as attention, were normal. A mild deficit existed on a test of complex attention.

MS’s speech was characterised by difficulty in initiating speech, articulatory groping, visible and audible searching and self-rehearsals, phonemic perseverative errors,
anticipatory and transposition errors, vowel errors, consonant distortions and substitutions, difficulty in sequencing movements with increased utterance length, varied off-target attempts at words, and perceptually slow and laboured speech. She also exhibited less difficulty producing automatic versus volitional speech. Performance on the VMPAA indicated oro-motor control difficulties for both speech and non-speech posturing and impaired control of speech movement trajectories for the mandibular, labial, and lingual subsystems. Speech sequencing abilities were also impaired but less severely than the oro-motor control abilities of the mandibular, labial, and lingual subsystems. Motor speech examination revealed no significant abnormalities in muscle tone or strength or any classifiable dysarthrias as discussed by Darley, Aronson, and Brown (1975). It is important to mention here that even though MS had mild hemiparesis of the right side of the face, her speech errors could not be accounted for by this hemiparesis. Her overall speech characteristics were congruent with McNeil, Rovin, and Schmidt’s (1997) definition of AOS in which errors are assumed to be due to an inability to translate an accurately filled phonological frame to the kinematic parameters necessary for executing speech movements.

Prior to participating in the current investigation, MS had undergone nearly one year of in-patient and out-patient rehabilitation. She had attended speech-language therapy (four times a week) at a teaching-rehabilitation hospital. In the early stages of treatment, she completed the Prompting Aphasics’ Communicative Effectiveness program (PACE), (Davis & Wilcox, 1985). The Helm-Estabrooks Language Program for Syntax Stimulation (HELPSS) (Helm-Estabrooks, 1981) was also used. No specific or systematic speech motor therapy was administered during the course of in-patient and out-patient rehabilitation, although MS was encouraged to attempt to correct some of her speech errors during HELPSS training.

MS also attended physical therapy and occupational therapy for her right hemiplegia and physical weakness. She showed considerable recovery from hemiplegia and at the time of the study she had resumed bicycling and walking without any external aids. However, she continued to use her non-dominant (left) hand for writing. She demonstrated a significant ideomotor limb and axial apraxia on the Neuropraxis Battery for Limb Apraxia, using a plus–minus scoring system. She correctly performed 6 out of 8 intransitive gestures, 1 out of 6 transitive gestures and 2 out of 12 complex axial gestures.

Setting

The initial testing, probe sessions, and therapy sessions were undertaken in a treatment room of the University of Toronto Speech-Language Pathology clinic. The room contained a table and two chairs and was designed for individual adult treatment. It also contained a microphone and video camera.

Experimental stimuli

The stimuli consisted of 30 functionally and personally relevant short phrases grouped in three types of sentence constructions: imperatives, active declaratives, and interrogatives. This hierarchy of phrases was chosen based on the work of Helm-Estabrooks (1981), which demonstrated a similar order of difficulty (imperatives being the easiest and interrogatives the more difficult constructions) of sentence production for various sentence types for individuals with Broca’s aphasia. All the phrases were selected with the help of MS to ensure consistency with her style of language usage and her evaluation of functionality of the phrases in her daily life. Out of the 30 phrases, 15 were selected as
training phrases and 15 were used to probe generalisation. Thus each sentence type included five training phrases and five generalisation phrases. The phrases were randomly assigned to the training and generalisation conditions, and matched as closely as possible for syllable length and word length within each set of stimuli and across the stimuli sets. In order to maintain the functional relevance of the treatment programme for the subject, we were unable to equate the training phrases with generalisation phrases for phonetic similarity and prosodic characteristics. (See Appendix A for the stimuli.)

Definition of the dependent measure

The dependent measure was defined as the percentage of motorically precise and correct utterances. To be correct, the utterances were required to be free of the following articulation and fluency errors: false starts, repetition of individual sounds, syllables, and words, articulation errors including substitutions, omissions, distortions, and addition, phonemic metathesis, articulatory groping, perseveration, and anticipatory errors.

The percentage of correct phrases produced was determined as follows. Each phrase was considered as a whole unit for analysis. A 5-point categorical scale of 0–4 was used to evaluate two dimensions of motor production for each phrase, namely motor control and fluency–prosody. The dimension of motor control reflected the accuracy and precision of motor movements; the fluency–prosody dimension reflected the ability to fluently initiate and complete the phrases, and the prosodic characteristics of the phrases. The scoring system used in this investigation was based on visual and auditory perceptual characteristics of movements and speech accuracy, which is inferential regarding the nature of the actual motor movements. Linguistic errors were noted but not used for scoring the dependent variable.

Each phrase could have attained a maximum score of eight points, namely four based on movement precision and four based on fluency. Therefore, the total maximum score for each set of five phrases was 40 points (i.e., 8 points \( \times \) 5 phrases = 40). This total score obtained for each set of phrases was then converted into a percentage, which was derived from the sum of the raw scores for each probe divided by the maximum possible score, and then multiplied by 100. (See Appendix B for details on scoring methods.)

The percentage of correct phrase production was used to measure the effectiveness of treatment during baseline probes, treatment probes, and maintenance probes. The teaching criterion was a maximum of six therapy sessions for each set of sentences. That is, regardless of percentage of accurate speech motor production, training concluded on a particular set of training items after completion of six training sessions.

Observation and coding

All the probe sessions were recorded using a video camera that was focused perpendicular to the subject’s face in order to capture a clear and sharp picture of her speech movements. For the purpose of scoring, all probe sessions were randomised and then scored by two trained listeners who were speech-language pathologists. The judges were naive to the purpose of the study and were trained by the second author (PAS) of the study.

Experimental design

A multiple probe design (Horner & Baer, 1978; Kearns, 1986) across behaviours was employed to evaluate the effects of PROMPT on precision of production of short sentences. Specifically, the effects of PROMPT were evaluated for three different types
of sentences, namely imperatives, active declaratives, and interrogatives. The sequence of
the design was as follows. First, the target behaviours were base-rated for all three types
of sentences. Treatment was then applied to the first behaviour, i.e., imperatives.
Baselines were drawn periodically from the remaining two not yet treated behaviours,
active declaratives and interrogatives, while the first behaviour was in the training phase.
After reaching the teaching criterion for the first behaviour, treatment was applied to the
second behaviour, that is, active declaratives. The third behaviour was base-rated
periodically while the second behaviour received treatment. Again, after reaching the
teaching criterion for the second behaviour, the third behaviour, i.e., interrogatives, was
treated. Behaviours that had reached the teaching criterion were probed as a means
of monitoring maintenance.

This design allowed for the control of extraneous variables without the need for
discontinuing or withdrawing treatment, as would be necessary with other designs (e.g.,
ABAB design). By demonstrating that changes occur only once treatment is introduced
with a particular behaviour while the untreated baselines remain unchanged (until
 treatment is applied to them), this design permits us to attribute changes to the treatment
rather than extraneous variables such as history and maturation (Homer & Baer, 1978). A
multiple probe design was deemed more practical than a multiple baseline design (which
requires continuous data), because it avoids the unwanted learning effects by virtue of
repeated testing by using only periodic probing (Homer & Baer, 1978). As mentioned
earlier, once MS completed the maximum of six training sessions, i.e., the teaching
criterion, training began on the next behaviour.

Procedures

Baseline probes. Before introducing the treatment, initial baselines on all three
target behaviours were drawn during the first three sessions. During probes the phrases
were presented in random order. MS was given a small narration of a situation and was
encouraged to generate the phrase. Phrase generation was selected as the test mode
because it more closely parallels the processing required for expression in real life
communication than does sentence repetition (Benson & Ardilla, 1996; Berndt, 1988).
For example, the experimenter said, “Your friends want you to come out for a party but
you have a lot of work to do. So you say...”. The expected response from MS was “I am
busy today”. MS rarely had problems understanding the narration but when she did
experience difficulty, the narration was repeated only once.

No cues on the production of the phrases or feedback on the accuracy of the responses
were given during probes. In addition, no PROMPs were ever applied during
doing the probes. After completion of the probing of a stimulus, regardless of its
accuracy, the experimenter moved on to the following stimulus. There was an initial
concern that the subject would not produce the target phrase but instead produce a phrase
similar in content. Post-hoc examination of all responses revealed that the subject almost
always produced the target utterances.

Probes. Probes were collected on the dependent measure during the treatment phase
and the maintenance phase. During the treatment phase, probes were taken just prior to a
therapy session. The phrases were probed in a random order within and across sentence
types to minimize order effects. Maintenance probes were drawn for previously treated
behaviours. Instructional cues as well as response definition and consequences for correct
and incorrect responses were identical to baseline probes.
Definition of the treatment method/independent measure. The independent measure was defined as the application of appropriate PROMPTs by the experimenter in response to the subject's erroneous movement production for a phoneme, word, or phrase. The reader is referred to the PROMPT manual (Hayden, 1999) for the appropriate prompts for specified English phonemes. In this study, PROMPTS were principally delivered as surface and/or parameter PROMPT cues when necessary (see Square et al., 2001).

Surface PROMPTs are those that target prominent movements in a movement sequence. For instance, in the word "sensation", the key movements on the two /s/ and one /ʃ/ are delivered as lip retracted for /s/ and lips rounded for /ʃ/. Parameter PROMPTs are those that establish degrees of freedom and the boundaries of movements of the articulatory subsystems, jaw, lips, and tongue. Parameter PROMPTs can be thought of as the overall guiding principles for speech movements in each subsystem. Thus, on the word "mop", if the jaw opened too widely or slides laterally to the right or left on /a/, the clinician would limit jaw extension and/or horizontal sliding of the jaw by physically guiding the patient through correct boundaries and parameters of the movement. That is, physically limiting the excessive amplitude of jaw opening and/or providing tactile pressure to the side to which the jaw literalised.

Treatment session. MS attended individual treatment sessions three times a week. Each session was 50 minutes in duration and was conducted by the experimenter. This experimenter, a Level-I PROMPT-trained clinician (see Hayden, 1999), was also responsible for administering the baseline and daily probes.

The sequence of training of the target behaviours was as follows: imperatives, active declaratives, and interrogatives. During the treatment sessions the clinician verbally presented a target phrase from the training set, and MS attempted to repeat it. If correct, the next trial on that phrase was presented. If incorrect, the clinician immediately presented the PROMPT cues selected to reduce MS's movement errors. MS again attempted to produce the target phrase immediately after being PROMPTed. She was provided with written stimuli any time she encountered problems following verbal instruction. Approximately 10 trials of the five target phrases were completed randomly in each session, i.e., successive trials on the same phrase did not occur. Activities included role playing, discussing current events, and daily activities designed to include the target phrases. Discussion topics focused on activities involving the subject's recent daily life events and in most instances our subject helped to choose the topic of discussion or role-play. The target discussions and the role-play were similar but not identical. In these tasks, no attempt was made to improve the syntax, morphosyntax, or word order of the phrases, or lexical retrieval.

Maintenance probes. Maintenance probes were conducted on previously taught behaviours when MS finished six sessions of therapy for a sentence type. For example, when MS reached the teaching criterion for the third set of phrases (interrogatives), maintenance probes were gathered for the first (imperatives) and second (declarative) behaviours. Procedures were identical to baseline probes. Continuing to probe these parameters after ceasing direct treatment allowed the experimenter to evaluate the maintenance of therapeutic gains for the imperatives and declaratives.

Grammaticality analysis

The grammatical correctness analysis was done from the transcription data derived from the videotapes of each session for all the spoken sentences. An utterance was scored as grammatically correct and complete if it was identical or similar to the expected response.
with no syntactic errors. Utterances that were syntactically well formed but included minor semantic substitutions for target words yet which were contextually accurate were judged as grammatically well formed and complete. Grammatically incorrect formulation included “no responses” and “grammatically ill-formed” or “illegitimate English constructions”. The percentage of grammatically correct and incorrect formations was compared for each sentence type before and after the treatment. That is, the data reported here are those that were collapsed across all the probe sessions prior to therapy and all probe sessions following therapy.

Interobserver agreement

Interobserver agreement checks were undertaken for the dependent measure (speech motor performance) for 30% of the probes across all phases of the study. Point-to-point agreement for judgement of correctness of production of the target behaviour was determined. An agreement was recorded when the experimenter and the observer both recorded the same response. Interobserver agreement was calculated by taking the number of agreements plus disagreements and multiplying by 100. The judges were graduate students in speech-language pathology and were trained by the first and the second authors. The training criterion for the judges was 90% agreement between them.

RESULTS

Interobserver agreement

During probes (baseline, daily probes, maintenance probes), interobserver agreement checks were implemented during 30% of the probes. Mean interobserver agreements were 86% (range, 82–90%), 80% (range, 75–87%), and 82% (range, 78–84%) for baseline, daily probes, and maintenance probes, respectively.

Speech motor production

Acquisition and generalisation. Figure 1 illustrates the probe data representing the percentage of correct speech motor productions for the sentences from the baseline, treatment, and maintenance phases of the investigation. Data for each sentence type are depicted in separate graphs ordered from top to bottom according to the sequence in which treatment was administered. The diamonds represent the trained items and the unfilled circles represent the generalisation probes, that is, untrained items.

As can be observed in Figure 1, MS demonstrated a stable and low baseline across all sets of behaviours (i.e., low and poor speech motor performance prior to the treatment). Specifically, the baseline scores ranged from: (i) imperatives, 10–25% (mean 18%) for trained items and 7.5–25% (mean 17%) for untrained items; (ii) active declaratives, 0–30% (mean 15%) for trained items and 7.5–25% (mean 15%) for untrained items; (iii) interrogatives, 17.5–25% (mean 22.5%) for trained items and 15–27.5% (mean 20%) for untrained items.

1Grammatically incorrect or illegitimate constructions included errors that changed the syntactic interpretation of the sentence. To be grammatically incorrect an utterance should have one or more of the following features: incorrect word order (e.g., ride, I bike); incorrect S-V agreement (e.g., I wants small coffee); inappropriate verb morphology (e.g., Please, sitting down), or addition or omission of auxiliary verbs (e.g., I busy today).
With initiation of PROMPT treatment, the correctness of speech motor production improved for the trained items for imperatives and active declaratives. Correct production of the untrained items (generalisation items) also improved from their baseline performance, and acquisition closely followed their trained counterparts, although MS's performance was more variable on the untrained items. Correct production of imperatives increased from 17.5% to as high as 75% (mean 42%) for trained sentences and from 35% to 75% (mean 53%) for untrained items. Correct production of active declaratives increased from 37.5% to as high as 55% (mean 49%) for trained sentences and from 45% to 62.5% (mean 50%) for untrained items. Further for the active declaratives, there was a major shift in the level of performance from 10% in the last baseline probe prior to treatment to 35% in the first treatment probe. The performance on interrogatives did not
improve with the application of the PROMPT treatment. The correct production of trained interrogatives ranged from 15–40% (mean 24%) and for untrained items the correct production ranged from 17.5–30% (mean 24%). It can be seen in Figure 1 that the level of performance for the interrogatives in the treatment phase is comparable to the performance in the baseline.

Maintenance. Maintenance effects were observed for imperatives and active declaratives. For imperatives the maintenance effect was stronger for untrained items, whereas for active declaratives the maintenance effect was stronger and more stable for trained items. The mean performances during maintenance probes were 53% and 58%, for trained and untrained imperatives, respectively. For trained and untrained active declaratives the mean percentages were 60% and 40%, respectively. Maintenance probes were not collected for interrogatives.

Grammatical correctness

Figure 2 represents the grammaticality analyses for the different set of sentences before and after treatment. As seen in Figure 2 the percentage of correct grammatical utterances increased for imperatives and active declaratives compared to their baseline levels. The correct production of grammatically correct imperatives increased from 57% to as high as 85%, and for active declaratives from 37% to as high as 70%. The percentage of correct grammatical production for interrogatives remained identical pre and post treatment at the level of 37%.

![Graph showing percentage of grammatically correct utterances for different types of sentences](image)

**Figure 2.** Percentage of grammatically correct utterances produced before and after treatment for three different types of phrases: imperatives, active declaratives, and interrogatives.
DISCUSSION

The present investigation examined the effect of a motor speech treatment, specifically PROMPT therapy, on the acquisition of precision and automaticity of speech movements as related to the sentence structure and in the context of increasing language formulation demands. The results of this study indicated that PROMPT therapy induced positive changes in improving the precision and automaticity of speech movements for relatively simple sentence structures like imperatives and active declaratives. With the initiation of treatment the imperatives showed a steady increase from the baseline performance, particularly for the trained items. The generalisation items also showed positive, although more variable, effects. Similarly, for the active declarative sentences a positive change was observed with initiation of treatment. The generalisation items also showed similar improvement with treatment. Contrary to our expectations, there was no appreciable change or improvement for the interrogatives even after the treatment phase.

There could be several possible explanations for this latter finding. First, motor-based speech treatment methods like PROMPT are most effective and beneficial when the linguistic formulation demands on the individual are reduced to the level of the individual’s verbal production abilities. It has been demonstrated in previous research that linguistically, interrogatives are more complex forms of sentences for individuals with Broca’s aphasia to produce (Gleason et al., 1975; Helm-Estabrooks, 1981). In other words, when the linguistic formulation demands are high, as in interrogatives, it may be that the attentional resources or the processing capacities available for motor speech production become depleted (see McNeil, Odell, & Tseng, 1991; Murray, 1999, Murray, Holland, & Beeson, 1997, for discussion). That is, it is possible that the motor and the linguistic systems rely on a common reservoir of resources. While performing a complex task by one system (e.g., the formulation of interrogatives by the linguistic system) the resources available to the motor system may be extraordinarily taxed or drained. This reduction of available resources for the motor system might in turn result in decreased motor performance (see Van Lieshout, Hulstijn, & Peters, 1996, for a similar account to explain disfluencies in people who stutter). In the current study, our subject improved only for sentences that were simpler in structure and presumed to be within her processing capacity. When MS attempted to produce the more complex interrogatives, which probably required allocation of more processing resources than the other two types of sentences, the resources available for motor production may have been correspondingly less, resulting in poorer speech motor performance.

This study demonstrated that for this subject, higher linguistic task complexity compromised the ability of motor speech acquisition. These results may be indicative of the interactive nature of the linguistic and motor processes. This finding could be considered evidence for the claim by many researchers that the speech motor and the linguistic systems are highly interactive processes with the capacity to influence each other (Manner, Smith, & Grayson, 2000; Van Lieshout et al., 1995). This finding could also support the conclusion that the verbal expression deficit observed in Broca’s aphasia is indeed dependent on the processing demands on the speech motor system; in other words, the nature of expressive deficits associated with Broca’s aphasia is both linguistic and motoric.

It is also possible that the changes in the motor performance could have been due to the intrinsic differences in the prosodic structure of the utterances. However, only the “yes/no” interrogatives have different intonation contours from other types of sentence constructions. Our stimuli included “wh” interrogatives, which usually have similar
intonation contours to those of imperatives and active declaratives. This suggests that differences in prosodic characteristics are unlikely to be the cause of difference in speech motor performance in our subject. Further research is needed to determine the influence of prosodic characteristics on phrases and sentence acquisition.

It is also possible that the differences in performance between the interrogatives and other sentence types may have related to the use of different initial words for the target phrases in interrogatives. In contrast, all imperatives began with "Please", and all the declaratives began with "I". Even though "I" is used as a lexical item in the declarative sentences, the production complexity of "I" is simple and is equivalent to a vowel. However, the second lexical items following "I" in declaratives were all different. By using different lexical items as the initial word in the interrogatives, it is possible that the linguistic and/or motor processing demands are variable for different lexical access in the interrogatives, as opposed to more similar initial processing demands for imperatives and similar vowel for declaratives. Physiological studies of linguistic effects on motor production indicate that words in the initial position of a sentence are more demanding in terms of articulatory effort than words in sentence-final position for normal speakers and people who stutter (Van Lieshout et al., 1995). Individuals with apraxia of speech, like MS, characteristically demonstrate groping for initial sound or articulatory postures, indicating that the first motor stages of muscle tuning and/or initiation of postures for movement might be difficult. The increasing load of lexical access for interrogative production may have compromised motor speech accuracy.

MS's performance on the interrogatives may have improved if we had continued treating the behaviour for more sessions. However, our teaching criterion was a maximum of six sessions and the same criterion was applied for the other two sets of sentences. We provided equal amount of treatment for all the sentence types. The interesting point to note in this investigation is that interrogatives did not benefit as much as the other two sentence types. Thus, equal amount of training did not yield equal amount of benefit for the subject for the three sentence types, which is likely to be the result of an intrinsic difference between the sentence types. This finding is corroborated by the evidence from a study on individuals with agrammatism andaphasia who showed more impairment on wh-interrogatives than other forms of sentences (Maury, 1979). Clinically, our finding might indicate that stimuli chosen to train individuals with aphasia and apraxia should be selected with regard to the linguistic complexity of the utterances. Careful selection of the utterances could help individuals with severe aphasia-apraxia to acquire some functional phrases even in short-term rehabilitation.

The grammatical correctness analysis was included in this investigation as an attempt to study whether there was any change in the sentence/grammatical formulation strategies with motor-based treatment. The analysis revealed some interesting observations. Even though the treatment procedure did not attempt to change the grammatical correctness of sentences, improvement was noted on the following: correct word order, subject–verb agreement, completion of the utterances, and, in a few instances, better verb morphology, for two types of sentences, imperatives and active declaratives. This may imply that not just linguistic processes affect the motor system, but that changes in the motor system could potentially affect linguistic formulation. We can only speculate on the nature of the underlying mechanism. Let us suppose that MS needed extra processing resources to generate motor commands and to formulate sentence structure, in particular for the more complex interrogatives. We speculate that through PROMPT treatment MS gained better speech motor control and thus the resource demands by the motor system became less. This would result in increased resource capacity for the linguistic formulation processes,
which would benefit in particular the less complex imperatives and active declaratives, thus helping to improve their grammaticality. But for the more demanding interrogatives, this additional resource capacity did not have the same impact. Clearly, this speculation needs to be tested and verified in future research.

Finally, the findings of this study need to be viewed within the context of our subject’s reaction. She was an extremely motivated and willing participant. She welcomed the speech motor assistance given to her in the form of PROMPT cues. In addition, she showed no aversion reactions to the PROMPT cues. Thus, future research needs to determine whether the findings obtained would generalise to individuals who are less motivated or have difficulty tolerating the PROMPT cues.

In summary, this study represents an initial attempt to examine the effectiveness of motor-based PROMPT treatment for improving speech movements in utterances of varying linguistic complexity. It demonstrated that PROMPT treatment had positive effects for changing speech movements for relatively simple sentence structures, indicating that treatment for individuals with Broca’s aphasia should consider the linguistic demands posed on the individual. The PROMPT therapy was most effective and beneficial when the linguistic formulation demands on the individual are reduced to the level of the individual’s verbal production abilities. To fully understand the nature of aphasia, especially Broca’s aphasia, and to advance verbal production rehabilitation, continued research investigating the interaction of various linguistic and motor variables is necessary.

References


Dabul, B.L. (1979). Apraxia Battery for Adults. Austin, TX: Pro-Ed.


APPENDIX A: STIMULI

Bold items are the training stimuli.

Imperatives

1. Please, come here.  
   Please, sit down.
2. Please, go away.  
   Please, go home.
3. Please, help me.  
   Please, get it.
4. Please, open it.  
   Please, stop it.
5. Please, come out.  
   Please, watch out.

Active Declaratives

1. I want an appointment.  
   I want a big pizza.
2. I am busy today.  
   I want small coffee.
3. I want Semford. 
   I like chocolates.
4. I want to go out.  
   I want to ride bikes.
5. I like foreign films.  
   I like harbour front.

Interrogatives

1. Who is it?  
   Who is there?
2. What time is it?  
   What road is it?
3. What do you need?  
   What do you want?
4. Where do you live?  
   Where is the film?
5. How was the show?  
   How was your day?
APPENDIX B: SCORING METHOD

The scoring of the probe responses was undertaken along two parameters of production: motor control and fluency/prosody. Both parameters were scored using a 5-point categorical scale. The score categories were defined as follows:

4: adult normal production  
3: near normal but mildly impaired  
2: moderately impaired  
1: severely impaired  
0: no response.

Motor control

This parameter assessed the precision of the motor movements across a production. Motor patterns were judged by visually observing the movements of the jaw and lips. Lingual control was judged indirectly by perception of articulatory accuracy.

Jaw
- Movements are symmetrical and vertical (i.e., no jaw slide).  
- Movements are consistent with regard to grading (smoothness, coordination, and control).  
- Movements are consistent with regard to speed of movement.  
- Movements are consistent with regard to evenness of excursion.  
- Jaw excursion is not overextended (opening exaggerated) or severely limited.  
- There are no observed extraneous movements or dyskinesias of the jaw.

Labial/facial
- Sufficient and symmetrical rounding.  
- Complete closure.  
- Sufficient and symmetrical retraction.

Others
- No overflow of movement.  
- Movements are not augmented.  
- No involuntary movements or dyskinesias of the lip or bucco-facial muscles.

Fluency and prosody

- No difficulty in initiating the response.  
- No groping.  
- No audible or inaudible struggle.  
- No significant pausing.  
- No reattempt or self-correction.  
- No prolongation.  
- Rate is not significantly slow.  
- Completion of the phrase once initiated.

Scoring rules

1. Judge the entire phrase.  
2. Score the first response. Score the entire output prior to the second cues/facilitatory stimulation provided by the examiner.  
3. Carefully score motor control and fluency. The judge may listen to the sample to a maximum of three times for the purpose of assigning a score  
4. Score the response with regard to accuracy of form as follows:
   - Correct target. Target: "Please, go home." Response: "Please, go home."  
   - Correct linguistically acceptable substitution. Target: "Please go home." Response: "Please, go away."  
   - Error/irrelevant response. Target: "Please go home." Response: "I came home" or "Please get it."  
   - Score the response across two speech production parameters motor and fluency/prosody.  
   - Record exactly the response for which the scoring was undertaken. In the column marked "Notes" add other useful information such as perseveration.
Example of the scoring sheet:

<table>
<thead>
<tr>
<th>Phrase</th>
<th>Correct target: YES/NO</th>
<th>Correct linguistic substitution: YES/NO</th>
<th>Error Response: YES/NO</th>
<th>Motor control</th>
<th>Fluency and Prosody</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Please, go home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Who is it?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>