

Self-correction in apraxia of speech: The effect of treatment

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Abstract

Background: Overt attempts at self-correction of speech errors reflect conscious monitoring of speech output. The ability to monitor speech reveals something about the dynamics of motor control. Speakers with apraxia of speech (AOS) attempt to self-correct speech, but systematic analyses of self-correction in AOS have rarely been done.

Aims: The aims of the study were to determine the effect of treatment on the number of overt attempted self-corrections during the course of treatment, on the number of overt attempted self-corrections as a percentage of the total number of incorrect productions, and on successful self-corrections as a percentage of the total number of self-corrections.

Methods & Procedures: One speaker with AOS was treated for a period of 18 months. Self-corrections were noted during three repetitions of 110 words and 110 nonwords. Three pre-treatment baseline probes and four subsequent probes, spanning the treatment period, were performed.

Outcomes & Results: The number of attempted self-corrections decreased and the percentage of successful self-corrections increased during treatment. However, attempted self-corrections as a percentage of the total number of incorrect productions remained fairly stable during treatment.

Conclusions: The results indicate that success of overt self-corrections improved during treatment. However, the almost unchanged number of self-corrections as a percentage of the total number of incorrect productions suggests that the process of internal predictive control remained dysfunctional. The inadvertent occurrence of speech errors points towards a loss or dysfunction of volitional control of speech production. Mental practice as a complementary treatment technique may need to be considered. A continuum of volitional control of speech is presented to explain AOS.

Speakers can monitor almost any aspect of their own communication (Levelt, 1995), and speech monitoring can reveal something about the dynamics of speech motor control. Overt attempts at self-correction of incorrect speech production reflect conscious monitoring of speech output and an awareness of overt speech errors. Speakers with apraxia of speech (AOS) attempt to self-correct speech errors (Duffy, 2005; McNeil, Robin, & Schmidt, 1997; Wertz, LaPointe, & Rosenbek, 1984), but very little is known about the nature of these self-corrections and which variables may influence the ability to

monitor speech output. An analysis of changes in the pattern of self-correction during a period of treatment may elucidate speech monitoring processes in speakers with AOS.

Systematic analyses of the prediction and attempts at self-correction of apraxic speech errors have rarely been done. Deal and Darley (1972) examined the ability to predict speech errors in AOS and found that these speakers were able to predict upcoming errors, but that more errors occurred than were predicted. The speakers who participated in their study were able to point out the errors they had made, and thus displayed an awareness of speech errors after output. Duffy (2005) also reports that patients can predict errors, that some speak slowly to prevent errors, that some recognise errors that were made, and that some are surprised by unpredicted errors that occurred in otherwise fluent speech.

Van der Merwe, Uys, Loots, and Grimbeek (1988) studied successful and unsuccessful self-correction of speech errors in five speakers with speech apraxia. Four speakers met the diagnostic criteria for AOS as suggested by McNeil et al (1997), and the fifth was a child with childhood apraxia of speech. The participants had all received treatment with the Speech Motor Learning Program (Van der Merwe, 1985) (which will be described under Method), but for different lengths of time and from different clinicians. The data were based on a nonword repetition task in which the speakers with speech apraxia had to repeat 40 nonwords, six times consecutively. The nonwords varied in consonant (C) and vowel (V) structure (CVCV, CVC, CVCVC, and CVCVCVC) but conformed to the phonotactic rules of the first language of the speakers (English or Afrikaans). The type of errors that the speakers attempted to self-correct was also noted. A total of 19 successful self-corrections and 13 unsuccessful self-corrections occurred. Of the total of 32 attempted self-corrections, 9 were on CVCV nonwords, 1 on a CVC nonword, and 22 on CVCVC and CVCVCVC nonwords. The majority of self-corrections therefore occurred on the longer utterances, which by nature provide a greater opportunity for more errors. Self-correction of phoneme substitutions and distorted substitutions were observed, but not distortions, slow rate, syllable segregation, or segmental lengthening, even though these errors were in the majority (214 substitutions and distorted substitutions versus 2021 motor-level errors). The lack of motor-level attempted self-corrections (all errors other than phoneme substitutions and distorted substitutions) by the participants in that study may indicate a lack of awareness of these errors or the perception that motor-level errors are not amenable to self-correction.

Self-correction of linguistic errors has been analysed by several researchers, and theoretical models for linguistic monitoring have been proposed (Levelt, 1995; Oomen & Postma, 2001). Natural and experimentally induced “slips” are analysed to explore the nature of linguistic monitoring (Baars, 1992; Oomen & Postma, 2001). The perceptual loop theory proposed by Levelt (1995) is widely accepted as an explanatory model (Oomen & Postma, 2001) that accounts for linguistic, including phonological, self-monitoring of speech output. According to this theory the phonetic plan (internal speech according to Levelt) and overt speech are relayed to a speech *comprehension* system via an internal and external loop. Levelt (1995) uses the words “speech” comprehension system and “language” comprehension system alternatively, but indicates the intended meaning by stating that this comprehension system can “detect deviations from linguistic standards” (Levelt, 1995, p. 470). It seems logical to assume that a language comprehension system can detect linguistic (e.g., phonological, syntactic, morphological)

errors, but not errors in articulatory precision, rate, fluency, and voicing characteristics. Clarification of the monitoring of motor speech output could more logically be found in speech production models.

The Four Level Framework of speech sensorimotor control (Van der Merwe, 1997) offers some clarification of the nature of speech monitoring. According to this framework the outcome of production can be monitored by means of response-produced feedback of tactile-kinaesthetic and auditory stimuli. This type of feedback may result in overt self-correction of speech errors. However, self-correction may also occur before speech is executed. During speech motor planning the speaker can centrally monitor the efference (reference) copy of the planned utterance through internal feedback. For accurate production of the speech sound, a comparison with an internal model of the motor plan in the sensorimotor memory may take place (Van der Merwe, 1997). Internal feedback and internal predictive control may perform an error-correction function before speech is produced (Kawato & Gomi, 1992; Keele, 1982; Kelso, 1982; Van der Merwe, 1997).

The questions addressed in the current study relate to changes in self-monitoring during a period of treatment that resulted in improved speech production ability in a speaker with AOS (Van der Merwe, 1998; Van der Merwe, Tesner, Groenewald & Moore, 1998). The specific aims of the current study were to determine the effect of treatment on the *number* of overt attempted self-corrections during the course of treatment, on the number of overt attempted self-corrections as a *percentage* of the total number of incorrect productions, and on *successful* self-corrections as a percentage of the total number of self-corrections. It was predicted that the number of attempted self-corrections would decrease and the percentage of successful self-corrections would increase as speech improved (total number of incorrect productions decline) during treatment. It was also predicted that the number of overt attempted self-corrections as a percentage of the total number of errors would decrease during treatment. A decrease in the percentage of overt attempted self-corrections may indicate a shift from externally manifested (overt) self-corrections based on response-produced feedback to error correction of upcoming speech errors based on internal feedback. If internal predictive control (Kawato & Gomi, 1992; Keele, 1982; Kelso, 1982; Van der Merwe, 1997) improves, the percentage of overt attempted self-corrections may decline. Answers to these questions may contribute to a better understanding of speech monitoring and speech motor control in AOS.

METHOD

The current study was part of a larger study on the outcomes of the Speech Motor Learning (SML) Program (Van der Merwe, 1985). The SML Program targets speech sound treatment in nonwords and words and incorporates motor learning principles such as variability in practice, augmented feedback on some productions, and blocked and random practice. Production drill of series of nonwords is continued until utterances become 80% correct, speech rate approaches normal, and no start-restart and groping behaviours occur. Data from the larger study showed that the number of incorrect productions and the number of perceptual errors decreased during treatment of the same speaker with AOS who participated in this study. The number of incorrect productions was determined by two independent raters. A total of 5940 productions of words and

nonwords were analysed and a point-to-point agreement score of 89% was reached (Van der Merwe, 1998; Van der Merwe et al., 1998). In the current study the data were further analysed with regard to self-corrections.

Participant

The participant was a university trained, bilingual, right-handed male who suffered an embolic stroke at the age of 52 years. The study started 30 months post-onset. The Boston Diagnostic Aphasia Examination (an informally translated Afrikaans version) showed no problems other than in fluency. The participant had normal hearing, normal voice quality and resonance, and no facial or tongue weakness. He was not hemiplegic, but did show tactile agnosia of the right hand. Radiological reports (MRI and CT) revealed small lesions near Broca's area and the left parietal-occipital and right occipital areas of the brain. He displayed slow speech rate, lengthened segmental duration, lengthened intersegment durations, sound distortions, substitutions, distorted substitutions, articulatory groping, awareness of errors, and increasing errors with increasing word length. The diagnosis was consistent with AOS without aphasia. At the start of treatment his speech was very slow, struggling, and highly unintelligible. At the time Probe 4 was administered his speech had become much more fluent and not as slow as previously. He used words that he knew he could produce well for communication, and therefore he was much more intelligible. He had once again become independent in all aspects of his life.

The participant had signed informed consent to take part in the study, and for the data collected during the three baseline and four following probes to be used at scientific meetings and in scientific publications. He was free to withdraw from the study at any stage. He continued treatment for 18 months and then withdrew from the study.

Procedures

The SML Program (Van der Merwe, 1985) was applied for 18 months. The treatment was provided twice a week for an hour by the author. Three baseline probes (B1 to B3) were completed before treatment commenced. Throughout the course of treatment, multiple probes were administered. The data for four of these probes, spanning the treatment period, were analysed in the present study. Each word or nonword was printed on a separate card and presented to the participant one at a time. All responses were read. The clinician did not pace the three responses, and no time restriction was imposed. The instruction was to repeat each word and nonword three times consecutively. This procedure differed from that followed during scoring of the total number of incorrect productions (Van der Merwe, 1998; Van der Merwe et al., 1998) where only a single utterance of the target was allowed. The three repetitions were requested to foster attempted self-correction. The environment and procedures followed were similar for all baseline and subsequent probes.

Materials

The probe stimuli consisted of 110 Afrikaans words and 110 nonwords that complied with the phonological rules of Afrikaans. Afrikaans was the native language of the participant. Three repetitions of each of the 220 target utterances were scored for each baseline and each subsequent probe. Probe stimuli were not part of the treatment stimuli but were representative of the type of material used during treatment. The probe stimuli were identical for all probes. The probe stimuli contained 15 different consonants (C), 10 vowels (V), and eight consonant clusters in CVCV, CVC, CVCVC, and CVCVCVC (or initial CC) syllable structures. The speech sounds represented easy and difficult sounds as perceived by the participant. All sounds except the consonant clusters had been treated.

Attempted self-corrections were judged perceptually by the author. These data were scored from tape recordings. The production of words and nonwords was regarded as incorrect when distortion, substitution, or distorted substitution of any speech sound occurred. The three repetitions of a target word or nonword were scored as a *single opportunity* to self-correct production. To differentiate between audible trial-and-error groping (Duffy, 2005) and attempted self-correction, attempted self-correction was identified as such only if the client had produced the entire word or nonword (incorrectly) and then displayed a pause or start-restart behaviour and attempted to change the utterance. The total number of times a word or nonword was said also guided the decision that attempted self-correction had been displayed.

Production of a target utterance was scored as *one* of the following: (1) Three correct repetitions of the target utterance. (2) Incorrect with no attempt to self-correct when *one or more* of the three repetitions were produced incorrectly with no pauses or start-restart behaviour and no attempt to change production. (3) Successful self-correction when the *incorrect production of the target word or nonword was followed* by a successful attempt to correct a sound substitution, a sound distortion, or a distorted substitution; if a successful self-correction was followed by an error on the same target utterance during a next repetition, it was still accepted as an instance of successful self-correction. (4) Unsuccessful self-correction under same circumstances as successful.

Reliability

The rating system developed by the author was verified by a second rater. Data from the first baseline (B1) were analysed by consensus to refine the formulation of the different ratings. The judgements made by consensus were then compared point-to-point to the ratings of the first rater. An agreement score of 85% was reached. The data of B1 were re-analysed by the first rater and an intra-rater point-to-point agreement score of 87% was achieved.

RESULTS

The total number of incorrect productions of words and nonwords as determined in the larger study (Van der Merwe, 1998; Van der Merwe et al., 1998) is displayed in figure [1](#) to provide an indication of the nature of speech changes during the period that was

analysed with regard to self-corrections. The data show that the total number of incorrect productions declined across the 18-month treatment period. The number of incorrect productions demonstrated some improvement during the baseline probes, and improvement continued during treatment but subsequently seemed to reach a plateau.

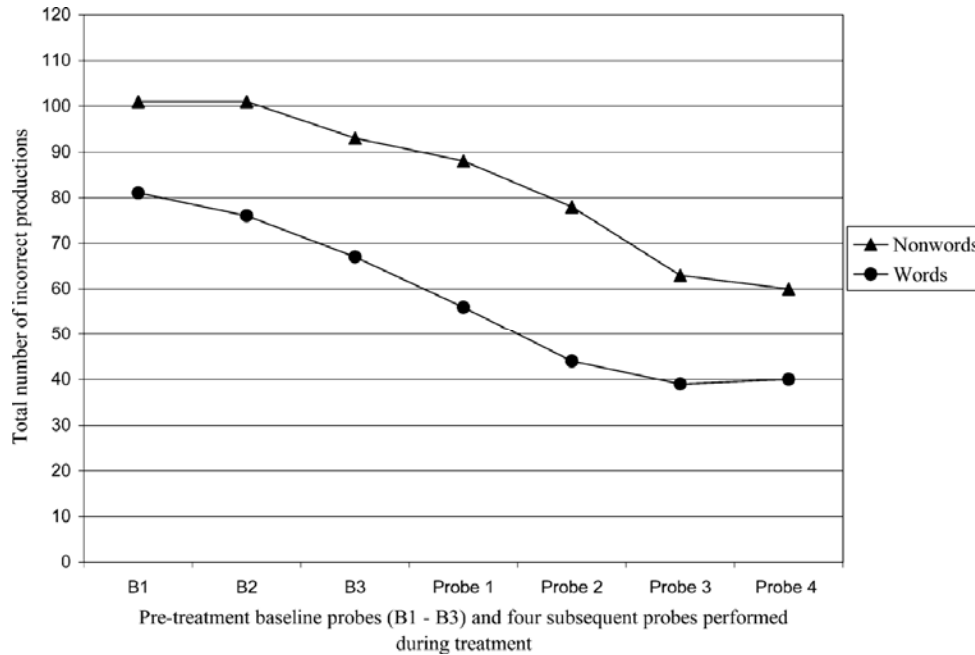


Figure 1. Total number of incorrect productions of nonwords and words.

The number of attempted self-corrections showed no improvement during the baseline probes but then decreased during treatment and then also reached a plateau (see figure 2). Self-corrections as a percentage of the total number of incorrect productions remained fairly stable during treatment (see figure 3). There is some improvement displayed during Probe 2 for words and Probe 3 for nonwords, but thereafter the percentage appears to remain relatively stable. The percentage of successful self-corrections for both words and nonwords (see figure 4) increased across time. A plateau was not reached in this regard. Nonwords followed the same trend as words, but not as pronounced. A greater number of successful self-corrections occurred on words than on nonwords.

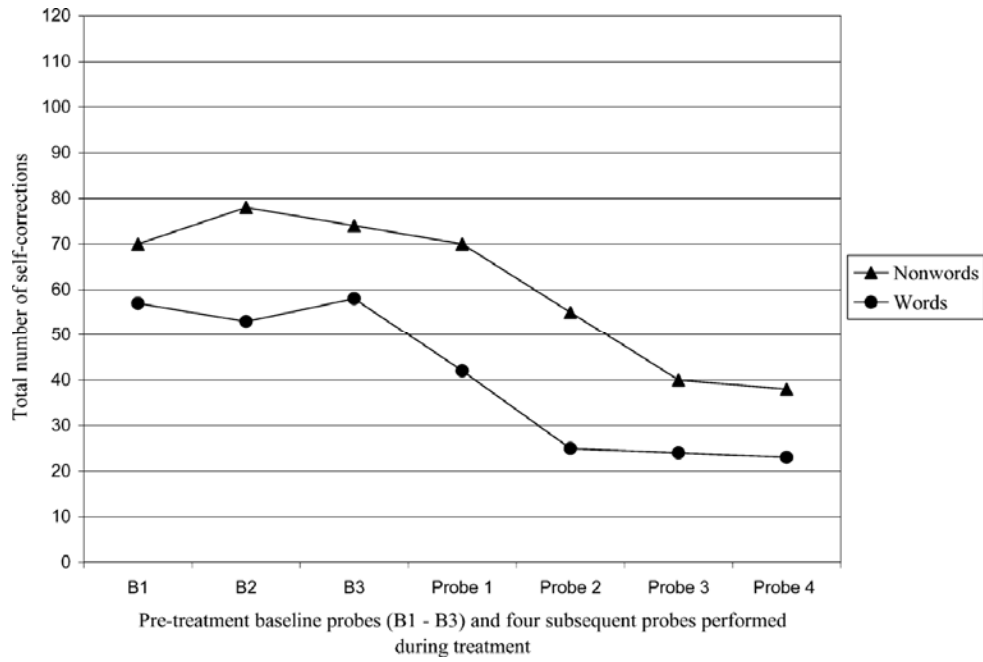


Figure 2. Total number of attempted self-corrections of nonwords and words.

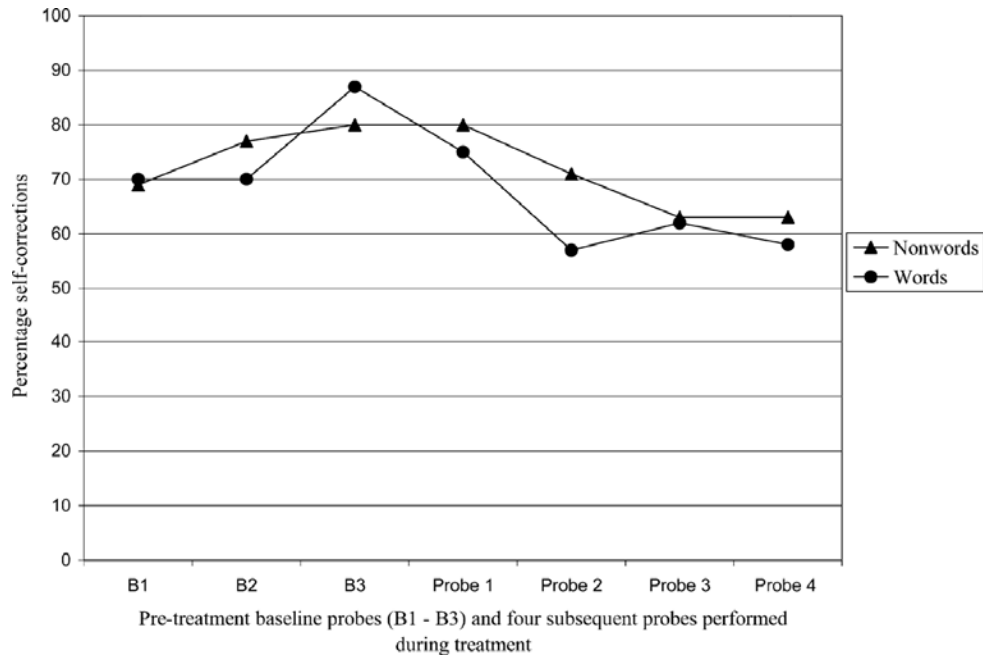


Figure 3. Attempted self-corrections as a percentage of the total number of incorrect productions.

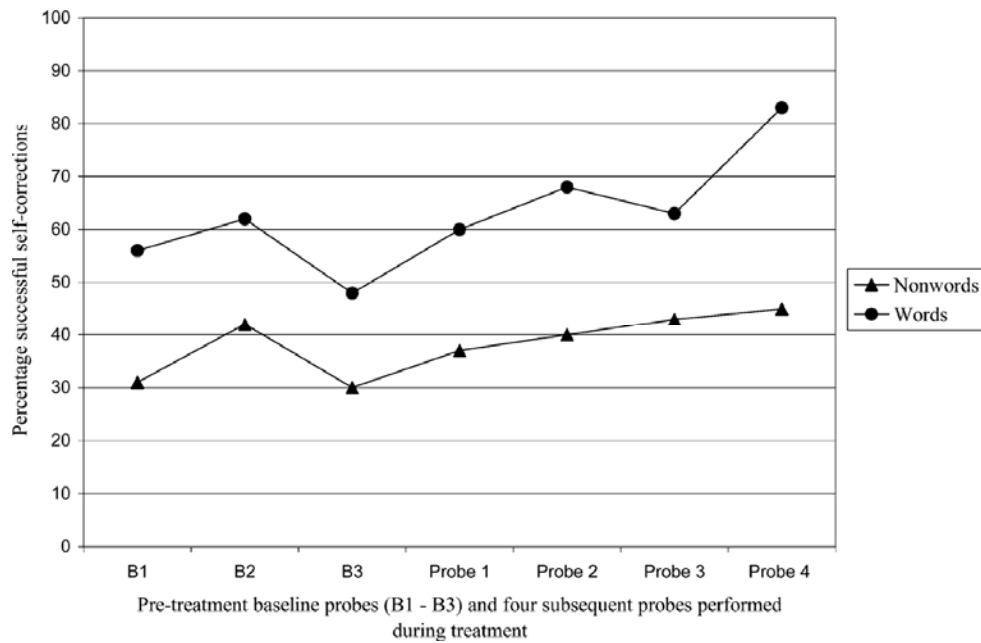


Figure 4. Successful self-corrections of nonwords and words as a percentage of the total number of self-corrections.

DISCUSSION

The decrease in number of incorrect productions and number of overt attempted self-corrections together with the increase in the percentage of successful self-corrections seem to suggest that this client's speech production ability and his ability to monitor speech through overt self-corrections improved during treatment. As the participant's speech improved, the need for self-correction declined, and therefore the percentage of self-corrections declined. However, the almost unchanged number of attempted self-corrections as a percentage of total number of incorrect productions suggests that prediction of upcoming errors and the ability to prevent these errors did not improve. Speech errors continued to occur inadvertently, and the mode of speech motor monitoring seems unchanged. This result suggests that the process of internal predictive control remained dysfunctional in this speaker with AOS. These findings are supported by Van der Merwe and Grimbeek (2006), who noted inadvertent errors in a study of five speakers with speech apraxia. In that study the variability of voice onset time of the speakers with speech apraxia was found to be less variable than that of the control speakers. Despite the smaller range of variability and mostly correct voice onset times, occasional voice onset time errors occurred during six consecutive repetitions of nonwords. These results concur with the observation of unpredicted speech errors by patients with AOS as cited by Duffy (2005).

The inadvertent occurrence of speech errors that are not amenable to internal predictive control reveals something about the underlying nature of speech motor control in AOS. Inadvertent speech errors may be comparable to linguistic (e.g., morphological and phonological) "slips" that occur in normal communication. "Slips" reflect a momentary loss of volitional control and are "in essence a mismatch between intention and

performance” (Baars, 1992, p. 4). The loss of volitional control of speech production has traditionally been integral to early definitions of AOS (Wertz et al., 1984). Later conceptualisations of AOS place greater emphasis on the nature of the breakdown in speech motor planning and/or programming (McNeil et al., 1997; Van der Merwe, 1997). The integration of a theory of volitional control of speech production with a comprehensive conceptualisation of the nature of breakdown in speech motor planning (or programming) (Van der Merwe, 1997) may contribute to a more comprehensive definition of this intriguing and not well understood disorder.

In table 1 a continuum of volitional control of speech motor output is presented. This continuum may elucidate the underlying nature of some speech errors in AOS, including unpredicted errors that are not prevented by internal predictive control. The continuum portrays speech motor control as being mediated along a continuum ranging from highly controlled processing to a mode of automatic processing. The hypothesised continuum is in accord with current theories of motor control of movement and of speech output (Duffy, 2005; Schmidt & Lee, 1999). During highly controlled processing, speech monitoring occurs via response feedback. As processing becomes more automatic, internal predictive control becomes operational. Fully automatised utterances are probably produced without reliance on internal feedback cues. Automatic processing is “faster and many processes can be done in parallel” (Schmidt & Lee, 1999, p. 69), and control may be mediated by progressively “lower” levels (Schmidt & Lee, 1999, p. 374) in the central nervous system. Motor planning and programming of speech movements (Van der Merwe, 1997) is probably imbedded within a volitional control system with different levels of conscious processing—highly controlled to automatic. Execution and even phonological planning are probably also under volitional control, but the current focus is on planning and programming, as these are probably the stages in speech motor control which are dysfunctional in AOS.

Different speech utterances might be controlled at different levels of controlled processing in the adult speaker. The contextual factors as portrayed in the Four Level Framework (Van der Merwe, 1997) may clarify the nature of speech utterances that are controlled consciously or automatically. The contextual factors are hypothesised to be the level of automaticity of the utterance (volitional versus automatised), motor complexity of the utterance, syllable structure of the utterance, length of the utterance, familiarity with the utterance (novel versus well known), and the required rate of production. It is hypothesised in the framework that contextual factors influence the mode of coalition of neural structures and the skill required from the planning, programming, and execution mechanisms. Motorically complex, long, novel utterances and an increase in speech rate may require more attention and controlled processing during production.

Signs of disorders along the continuum of volitional control will probably differ (see table 1). A loss of volitional control and/or lost volitional access to the sensorimotor memory and/or a loss of previously automatic processing, may cause a speaker to divert to *highly conscious processing* and reliance on response-produced feedback for speech monitoring. Such a disorder may result in severe apraxia of speech of all utterances, or it may affect certain speech sounds, syllable structures, words, longer utterances, or speech in second/third languages. Groping and trial-and-error articulation may be evident. Groping may reflect the underlying disorder and/or attempts to monitor speech. Predicted

and unpredicted errors may occur. A less severe disorder in volitional control may lead to *controlled processing*. Some measure of automatic processing and internal predictive control is possible. A disorder at this point in the continuum may result in moderate AOS or may affect certain speech sounds, syllable structures, words, a second/third language, or long utterances that the speaker finds motorically complex. Predicted and unpredicted errors may occur. A loss of *automatic processing* of speech motor planning and programming may be momentary and inadvertent. Unpredicted spatial, temporal, and inter-articulatory synchronisation errors may occur and result in speech sound distortion and disrupted fluency. In the speaker with AOS a loss of automatic processing and/or (momentary) reliance on automatic processing that is no longer operational may lead to inadvertent speech errors. Even in normal speakers such momentary loss of automatised motor control may occur. Motor-based “slips” are traditionally not the focus of study. However, analyses of such phenomena may contribute to a better understanding of speech motor control.

The automatised processing of speech utterances and the prevention of unpredicted speech errors in speakers with speech apraxia should be addressed in clinical practice. Overlearning of movement sequences enhances automaticity (Schmidt & Lee, 1999), while mental practice or mental imagery (i.e., imagining the movements without any overt actions) turn the attention of the learner to the predicted outcomes and the possible avoidance of errors (Schmidt & Lee, 1999). In the SML Program overlearning and delayed responses with mental preparation of production during the delay period are two of the techniques that are applied. However, it may be necessary to place more emphasis on mental imagery during treatment and to direct the attention of the learner to the prevention of errors. The point in time during which this motor learning principle is applied will have to be considered carefully. It is also important to bear in mind that mental imagery can in no instance replace the value of rehearsal of overt speech production.

In conclusion the present study suggests that internal predictive control of speech and the ability to prevent speech errors did not improve in this particular speaker with AOS even though his success in repairing these errors did improve over the course of treatment. The inadvertent occurrence of speech errors points towards a loss or dysfunction of volitional control of speech production. A comprehensive definition of the nature of AOS may need to incorporate the loss or dysfunction in volitional control of speech.

TABLE 1
Continuum of volitional control of speech motor planning and programming: A guide to understanding apraxia of speech

	Highly controlled processing	Controlled processing	Automatic processing
Continuum of volitional motor control	Speech is produced with attention and volitional monitoring. May occur during motor learning of novel utterances and during production of long and/or phonetically complex utterances. Monitoring may occur via response feedback and closed loop control is operational. Utilisation of internal feedback cues and predictive control is not yet effective. The mode of coalition of neural structures that control speech output is adapted to accommodate highly controlled processing (Van der Merwe, 1997).	Speech motor planning and programming is more automatic and the speaker becomes more skilled at utilisation of internal feedback cues and therefore more capable of predictive motor control. Open loop control becomes operational. Utilisation of internal feedback cues and predictive control becomes more effective. The mode of coalition of neural structures that control speech output is adapted to accommodate controlled processing (Van der Merwe, 1997).	Speech motor planning and programming is mediated via automatic processing where open loop control is operational and there is little reliance on internal feedback and predictive control. Such processing is "faster and many processes can be done in parallel" (Schmidt & Lee, 1999, p. 69) and control may be mediated by progressively "lower" levels (p. 374) in the central nervous system. This mode of control is operational during production of frequently used words, phrases, syllables, and automatised utterances such as counting.
Disorder in volitional motor control	A disorder in volitional motor control may result in a loss of, or dysfunction in, volitional speech motor planning and programming, or in ineffective volitional access to motor plans in the sensorimotor memory. A disorder may affect all speech utterances and cause severe apraxia of speech or it may affect certain speech sounds, syllable structures, words, a second/third language or long utterances that the apraxic speaker finds motorically complex. Predicted and unpredicted errors may occur and articulation is slow and groping. Groping may reflect the underlying disorder and/or attempts to monitor speech.	A disorder in volitional motor control may result in a dysfunction in volitional speech motor planning and programming, or in ineffective volitional access to motor plans in the sensorimotor memory. A disorder may cause moderate apraxia of speech of most utterances or may affect certain speech sounds, syllable structures, words, a second/third language or long utterances that the apraxic speaker finds motorically complex to produce. Predicted and unpredicted errors may occur and articulation is slow and groping. Normal speakers who produce novel or difficult utterances may show slow careful articulation.	A loss of automatised control of speech motor planning and programming may be momentary and inadvertent. Unpredicted spatial, temporal and inter-articulatory synchronisation errors may occur resulting in speech sound distortion and disrupted fluency. In the apraxic speaker a loss of automatised control and/or reliance on automatised control that is no longer operational, may lead to unpredicted errors. Even in the normal speaker a momentary loss of automatised motor control may occur.

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