Motor Programming in Apraxia of Speech and Aphasia

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Introduction

Apraxia of Speech (AOS) is a neurological disorder characterized by speech segmentation and schwa-insertion, speech sound distortions and prolongations, and dysprosody (Kent & Rosenbek, 1983; McNeil et al., 1997, 2000)**. AOS is considered a disorder of motor planning/programming** (Ballard et al., 2000; Darley et al., 1975; McNeil et al., 1997, 2000)**, based on observations of impairments in temporal coordination** (e.g., Ito et al., 1979; Kent & Rosenbek, 1983)**. Understanding the nature of the deficit in AOS is important for accurate differential diagnosis and ultimately for optimizing treatment.**

However, the underlying impairment remains unclear, because the nature of motor programming is underspecified theoretically and difficult to investigate using measures of speech output only. Recent models of motor programming delineate specific processing levels in skilled movements for unimpaired subjects (e.g., Klapp, 1995; Wright et al., 2004)**. As well, data from limb studies suggest that motor programming may be a central process in which particular effectors are specified as part of a movement pattern** (e.g., Keele et al., 1995; Park & Shea, 2003)**. Relative to AOS, one question is whether different motor programming processes can be selectively impaired. Another question is whether the motor programming deficit is confined to speech movements or whether a more central motor programming deficit is responsible for the speech disturbance in AOS.**

In recent years, a growing body of evidence has demonstrated that the impairment in AOS involves the processes that comprise motor programming. Current data also show that the deficit extends beyond speech to nonspeech oral and limb movements (e.g., Clark & Robin, 1998; Hageman et al., 1994; McNeil et al., 1995; Robin et al., subm.)**. Thus, one possibility is that AOS reflects the manifestation in speech of a general programming deficit of the temporal aspects of movements.**

The present study examined motor programming in AOS, by applying a modified reaction time (RT) paradigm using a recent two-process model of motor programming that focuses specifically on sequential movements (Klapp, 1995, 2003)**. We examined non-speech (finger) movements only, to test a strong version of the hypothesis that AOS involves a central programming deficit. A second aim was to determine whether different motor programming processes are differentially affected in AOS.**

The model that provides our theoretical background distinguishes two separate programming processes (Klapp, 1995, 2003; Wright et al., 2004)**. The first process, INT, organizes the internal structure of each unit contained in the sequential action, and it is assumed that this process can be preprogrammed (prepared prior to initiation). Complexity of a unit affects INT processing load and thus the time to complete this process. The second process, SEQ, organizes units into their correct serial order. SEQ cannot be preprogrammed, and is sensitive to the number of units in a given sequence.**

We hypothesize that AOS reflects an impairment of INT, not SEQ, based on hallmarks of AOS such as distortions (difficulty organizing the internal structure of units), segmentation and dysprosody (difficulty integrating units), and the absence of serial order errors (no difficulty with sequencing). To test this hypothesis, we examined INT and SEQ processing using the self-selection RT paradigm for individuals with AOS. To assess whether AOS involved a central degradation in INT we used finger movements rather than speech. Thus, the research question addressed here is: Is there evidence for a domain-general INT-deficit in AOS?

Methods

Participants

Five persons with AOS (with or without aphasia) and three persons with aphasia but without AOS have been tested thus far. However, 1 subject with AOS (AOS2) and 1 subject with aphasia (APH3) were unable to perform the task, and one additional subject with aphasia (APH1) only completed 8 out of 12 practice blocks. Two control participants (not included here) were also unable to perform the task. All patients suffered a left-hemisphere CVA.

Table 1. Participant information.

	Sex	Age	Native Language	Hand	Time post onset	Aphasia	AOS	Oral/Limb apraxia	Dysarthria
AOS1	M	68	English-Spanish	L	29 months	Mild nonfluent	Mild-moderate	None/None	Mild unilateral weakness
AOS2	M	75	English	R	18 months	Moderate-severe nonfluent	Severe	Moderate/ Severe	None
AOS3	F	67	English	R	31 months	Very mild fluent	Mild-moderate	None/None	None
AOS4	M	58	English	R	23 months	None	Mild	None/None	Mild unilateral weakness
AOS5	M	27	English	R	73 months	Mild-moderate nonfluent	Very mild	None/None	None
APH1	M	73	English	R	12 months	Mild-moderate fluent	None	Mild/None	None
APH2	M	54	English	L	72 months	Mild-moderate fluent	None	Mild/None	Mild unilateral weakness
APH3	M	66	English (British)	R	41 months	Moderate fluent	None	None/Mild	None
YCON n=18	13F 5M	m=23, range 19-41	16 English, 1 Spanish-English, 1 Tagalog-English	16R 2L					

Task

Using the self-selection paradigm (Immink & Wright, 2001; Wright et al., 2004)**, four different key-press responses were tested** (Table 2)**. The sequence of events on each trial is indicated in Figure 1. Presentation of the sequences was random and involved 12 blocks, and computer-generated feedback was provided (error messages on screen, auditory model of correct response) after each trial. Errors included incorrect total response duration, too long pauses between keypresses, premature responses (before go-signal), and late responses (RT > 1000). Incorrect responses were rerun at the end of each block until 4 correct responses had been collected for each of the four response patterns (thus, each block consisted of a minimum of 16 trials). The first block was considered practice and was excluded from analysis.**

Figure 1. Sequence of events for a trial in the self-selection paradigm (9). The word "READY" is presented for 500 ms in the center of the screen, immediately followed by a symbol indicating the required response (1S, 1L, 4S, or 4L). Participants prepare the required response and press the space bar when ready to respond. After a variable delay, the go-signal is presented for 300 ms. Participants execute the response by pressing the F-key on the computer keyboard with their left index finger as soon as possible after the go-signal, but within 1000 ms (longer RTs elicit an error message). Depression of the F-key produces a tone to indicate the duration of the key press.

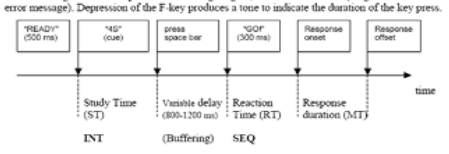


Table 2. Target responses.

Cue	Description	Temporal pattern	Duration
1S	Short (S)	150 ms	150 ms
1L	Long (L)	450 ms	450 ms
4S	Short-Long-Long-Short (SLLS)	150-450-450-150 (with 100 ms pauses)	1500 ms
4L	Long-Short-Short-Long (LSSL)	450-150-150-450 (with 100 ms pauses)	1500 ms

Predictions

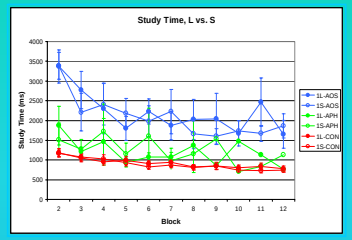
Dependent measures are ST and RT. The hypothesis that AOS reflects a deficit in INT but not in SEQ predicts

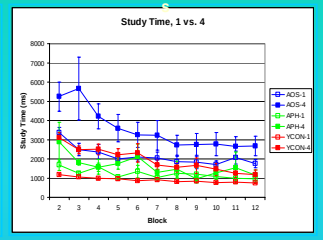
1) longer ST for the AOS-group compared to other groups due to an INT programming deficit.

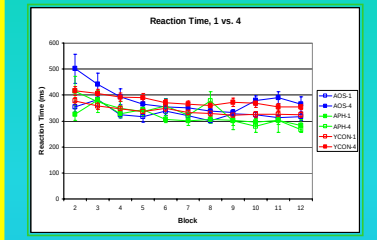
2) a larger ST-difference between simple and complex responses for the AOS-group than other groups (disproportionate effect of complexity on INT)

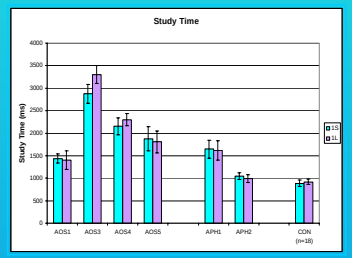
3) no group differences for RT (same overall RT, same RT-difference between 1-press vs. 4-presses), due to intact SEQ

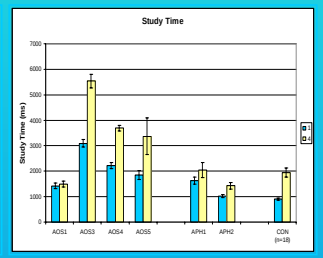
Results

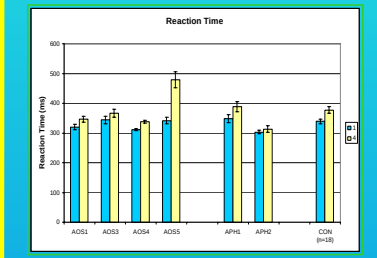












INT **SEQ**

Patients produced more errors (and thus trials) than control subjects (controls = 9% errors, AOS = 22% errors, APH = 44% errors).

- **Prediction 1 was confirmed: the AOS group has longer ST than the other two groups, both for single presses and for sequences.**
- **Prediction 2 could not be confirmed as we failed to find an effect of complexity (L vs. S) on ST for the control group. For single presses vs. sequences, the numerical differences between 1 and 4 were larger in the 3 of the 4 patients with AOS than in the control group and the patients with aphasia. However, the proportional differences (ST-4 / ST-1) did not differ between groups.**
- **Prediction 3 was confirmed: there were no differences between groups for RT values or patterns.**

Discussion

The present study examined two distinct motor programming processes in individuals with AOS, individuals with aphasia, and control participants, using a nonspeech movement task. Our questions were 1) Is the deficit in AOS restricted to speech production? and 2) Is there evidence for differential impairment of distinct motor programming processes?

• Regarding the first question, the results showed that subjects with AOS produced more errors than control subjects, suggesting that the deficit in AOS extends beyond speech production to other serial motor skills. However, the patients with aphasia also produced more errors than controls. It is not clear at this point why, but based on observations during the experiment we speculate that the auditory processing component of the task was the primary difficulty for the aphasic individuals.

• Regarding the second question, the results provide evidence for a deficit in motor programming that was localized to the INT process, as indicated by longer ST for the AOS group relative to both the control group and the two patients with aphasia. There were no differences between groups in RT, suggesting that the SEQ process is intact. The finding that the patients with AOS were as fast as the young adult controls argues against an explanation in terms generalized reductions in processing speed due to aging. In fact, data from older adults with the exact same task reveal that it is the SEQ process, not the INT process, that is sensitive to aging (Aranda & Wright, unpublished data). Furthermore, while both the AOS group and the patients with aphasia make more errors, only the AOS group shows increased INT processing load, suggesting that different impairments underlie the observed increased error rate in both patient groups.

Preliminary analyses of relative and absolute timing error measures (based on those responses accepted as correct by the computer program) suggest that these patients with AOS are more impaired on measures of relative timing (especially for the 4S sequences) than controls subjects, whereas absolute timing error appears to be within the normal range. If further substantiated, such findings may indicate that the formation, retrieval, or integrity of motor programs (presumably part of the INT process) is disrupted, whereas the temporal parameterization of these sequences is less impaired.

In conclusion, the present study, using a nonspeech (manual) task, adds to the growing body of evidence supporting the notion that AOS involves a central motor programming deficit, as opposed to a motor programming deficit specific to speech. Furthermore, our results suggest that this central motor programming deficit is localized to the INT process of motor programming, and does not extend to the SEQ process.

Future analyses of these data will include examination of relations between ST, RT, and various response characteristics, in order to further delineate the nature of the programming processes encompassed in INT and SEQ. Finally, studies applying this paradigm to speech are currently underway in our laboratory.

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Acknowledgements

We are grateful to all participants, without whom this study would not have been possible; to Elizabeth Lang and Shelby Gerson for their assistance in data collection; and to the Clinical Aphasiology Conference and NIDCD for a RSCA Student Fellowship awarded to the first author.