Effects of Feedback Frequency on Motor Learning in Individuals with Apraxia of Speech and Healthy Adults

It is well documented in limb motor learning literature that providing the optimal practice and feedback conditions is critical for the learning of new movements in healthy adults. However, it remains unclear if the conditions used for training limb movements can be directly applied to the speech motor system of healthy adults and individuals with acquired motor speech disorders. Collectively, these practice and feedback conditions are known as the Principles of Motor Learning (PML; Schmidt, 1988). These principles can be used to guide the structure of practice as well as the nature of feedback, and can have considerable implications for an individual's ability to learn, recall, and maintain skilled movements.

A small but growing body of literature suggests that the use of PML during speech treatment may improve the learning and retention of trained speech skills in healthy adults and individuals with acquired motor speech disorders (Maas et al., 2008). Of these principles, feedback frequency, the schedule in which feedback is provided, is the most widely investigated principle. Investigations of feedback frequency in healthy adults and individuals with Parkinson's disease have suggested that reduced feedback schedules are beneficial to speech motor learning (Adams & Page, 2000; Adams et al., 2002; Steinhauer & Grayhack, 2000). However, investigations of feedback frequency for the rehabilitation of individuals with apraxia of speech (AOS) have led to inconsistent findings (Hula et al., 2008, Katz et al., 2010). Thus, the primary aim of this study is to further investigate the effect of feedback frequency on speech motor learning in individuals with AOS. Specifically:

1. What is the effect of feedback frequency (e.g. feedback provided every trial or every 5th trial) on the learning, retention and transfer of a novel speech task (i.e., producing a sentence at a rate 2x and 3x slower than habitual rate) in participants with AOS and healthy adults?

2. Will speech motor learning differ from limb motor learning, as measured by a comparison of outcomes (e.g., retention and transfer of learned duration rates) for the novel speech task and a manual tracing task (i.e., moving a cursor from point A to point B, 2x and 3x slower than habitual rate) in participants with AOS and healthy adults?

METHODS

Participants: Ten participants with mild-moderate AOS and concomitant nonfluent aphasia have completed this study. Presence of AOS was determined using discriminatory diagnostic descriptors of AOS (Wambaugh et al., 2006). See Tables 1 and 2 for demographic information and results of standardized testing, respectively.

Results from 30 healthy adults that have completed the same protocol were used as a comparison. Healthy adults averaged 62 years of age (SD= 10.1) and 16.7 years of education (SD = 2.6).

Design: In the context of a randomized group design, motor learning was examined across two phases: retention of trained skills 2-4 days post training and transfer of trained skills to a related but novel task. Participants were randomly assigned to groups according to feedback schedule (every trial versus every 5th trial). Order of speech and manual tasks was counterbalanced.

Procedures: For the **speech task**, participants were first directed to say the target phrase ("Buy Bobby a poppy") at their habitual rate for 10 trials. Results were automatically calculated and plotted by MATLAB, in comparison to color-coded target lines that were 2x and 3x slower than the participant's habitual rate. The participant then received four practice trials to orient them to the graph and task.

Participants proceeded with 60 randomized **acquisition trials** where they attempted to match a target duration that was 2x or 3x slower than their habitual rate (30 trials per target duration). Plotted attempts were displayed after each trial or every 5th trial, depending on the feedback group, allowing participants to review their attempts relative to the target duration lines. Outcome measures were root mean squared error (RMSE) and accuracy of speech production. Motor speech errors such as phonemic substitutions, distortions, distorted substitutions and single sound omissions or additions were considered acceptable.

The **manual tracing task** was executed similarly to the speech task. The participant was asked to trace, with a mouse, a one cycle sine wave that was displayed on the computer monitor. A visual representation of the participant's movement trajectory was superimposed over the target pattern. All participants used their non-hemiparetic, non-dominant hand. Outcome measures were RMSE and the accuracy of the participant's tracing from the target waveform.

Following the acquisition phase, each group participated in a **transfer task**, where their skill at producing a different phrase and tracing target was measured. During the **speech transfer task** participants were asked to produce the phrase "Dye Didi a tutu". During the **manual transfer task** participants were asked to trace a one cycle vertical sine wave that had been rotated 180 degrees.

Participants returned 2-4 days after the initial session for retention testing (40 trials of the speech task [20 trials x 2 speech rates] and 40 trials of the manual task [20 trials x 2 tracing rates]), with no feedback regarding accuracy provided. Twenty trials of the transfer task were also performed for each task (speech and manual).

RESULTS

Question 1: Preliminary analysis suggests that participants with AOS who received *reduced feedback* were more accurate in reaching the speech duration target in the 3x slower condition only, as demonstrated by lower RMSE scores for both retention and transfer speech tasks (Table 3, Figures 1 and 2). In contrast, healthy adults who received feedback after *every* trial were more accurate in reaching the speech duration target in both the 2x and 3x slower conditions for the retention task. For the transfer task, no difference was observed in the 2x or 3x slower conditions, regardless of feedback frequency (Table 3, Figures 3 and 4).

Question 2: Contrary to the speech task, participants with AOS who received *less feedback* were more accurate in reaching the manual duration target in the 2x slower condition for the retention task only, whereas *more feedback* resulted in less error in the 3x condition for the retention and transfer tasks (Table 3, Figures 5 and 6). These results show an opposite effect from the speech task. Healthy adults who received reduced feedback were more accurate in reaching the manual duration target in the 2x slower condition for the retention and transfer task. Healthy adults who received more feedback demonstrated less error in the 3x slower condition for the transfer task only (Table 3, Figures 7 and 8).

DISCUSSION

Results suggest that feedback frequency affects speech motor learning and limb motor learning differently, both in participants with AOS and healthy adults. This finding is somewhat unexpected based on the extant speech motor learning literature (Maas et al., 2008) but consistent with the view of others (Grimme et al., 2011). Participants with AOS also responded differently to feedback schedule than the healthy controls. Specifically, during the speech task, participants with AOS appeared to benefit from reduced feedback during the 3x slower speech rate condition. In contrast, healthy adults only appeared to benefit from feedback provided after every trial. Finally, results suggest that limb motor learning may respond similarly to feedback frequency in both participants with AOS and healthy adults.

Table 1: Demographics for participants with AOS.

Participant Number	Feedback Schedule: Every Trial (1) vs. Every 5th (5)	Age (years)	Handedness	Education	Months post stroke onset	Gender
AOS1	1	57	R	12	30	F
AOS2	5	49	R	16	22	M
AOS3	5	66	R	16	105	M
AOS4	1	68	R	23	15	M
AOS6	5	28	R	13	18	M
AOS7	1	57	R	16	25	M
AOS9	5	70	R	16	12	M
AOS10	1	63	R	20	53	M
AOS11	5	61	R	16	26	M
AOS12	1	60	R	17	12	F
AVE (SD)	**Every Trial (5) Every 5th Trial (5)**	**56.0 (15.1)**	**10 Right**	**16.5 (3.1)**	**32.0 (28.4)**	**8 M 2 F**

Table 2: Results of standardized tests for participants with AOS: Western Aphasia Battery-AQ (WAB; Kertesz, 1982), Boston Naming Test (BNT; Kaplan et al., 1983), Standardized Assessment of Phonology in Aphasia (SAPA; Kendall et al., 2010), Discriminatory Diagnostic Descriptors of AOS (Wambaugh et al., 2006).

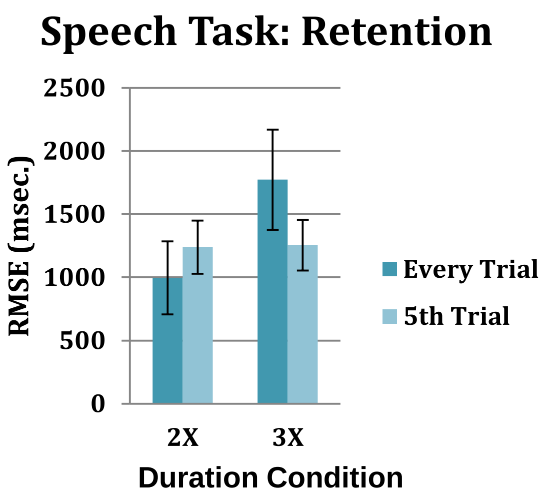
Participants with AOS	WAB Aphasia Quotient (out of100)	BNT (spontaneous correct out of 60)	SAPA (raw score out of 151)	Discriminatory Diagnostic Descriptors of AOS
AOS1	52.6	5	61	slowed rate: lengthened intersegment durations, sound distortions, sound substitutions, prosodic abnormalities
AOS2	88.6	42	106	sound distortions, sound substitutions
AOS3	85.7	57	119	slowed rate: lengthened segments, sound distortions and substitutions, distorted sound substitutions, prosodic abnormalities
AOS4	94.4	56	118	sound distortions, sound substitutions, prosodic abnormalities
AOS6	70.1	50	91	slowed rate: lengthened segments, slowed rate: lengthened intersegment durations, sound distortions, sound substitutions, prosodic abnormalities
AOS7	87.2	37	116	slowed rate: lengthened segments, sound distortions, sound substitutions, prosodic abnormalities
AOS9	94.7	35	114	slowed rate: lengthened segments, sound distortions, sound substitutions, prosodic abnormalities
AOS10	76.5	11	89	slowed rate: lengthened intersegment durations, sound distortions, sound substitutions, prosodic abnormalities
AOS11	96.1	57	115	slowed rate: lengthened segments, slowed rate: lengthened intersegment durations, sound substitutions, prosodic abnormalities
AOS12	95	53	110	slowed rate: lengthened segments, slowed rate: lengthened intersegment durations, sound distortions, sound substitutions, prosodic abnormalities
AVG (SD)	**84.1 (14.0)**	**40.3 (18.9)**	**104.0 (18.5)**	

Table 3: *Results of retention and transfer scores compared across feedback schedule and speech rate conditions for individuals with AOS and healthy adults.*

	AOS				Healthy Adults			
	Retention		Transfer		Retention		Transfer	
	2x	3x	2x	3x	2x	3x	2x	3x
Speech	1	5	1	5	1	1	=	=
Manual	5	1	=	1	5	=	5	1

1- feedback every trial resulted in less error
5- feedback every 5^{th} trial resulted in less error
= - no difference in error across feedback conditions

Figures 1- 2: Speech task retention and transfer scores compared across feedback schedule and speech duration conditions for participants with AOS. Error bars reflect the standard error of the mean.



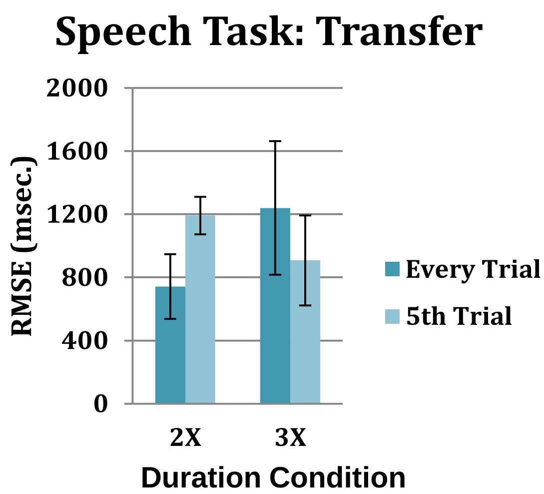
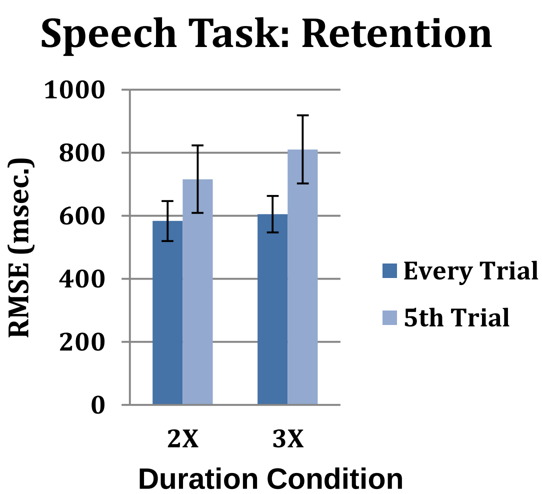


Figure 3-4: Speech task retention and transfer scores compared across feedback schedule and speech rate conditions for healthy adults. Error bars reflect the standard error of the mean.



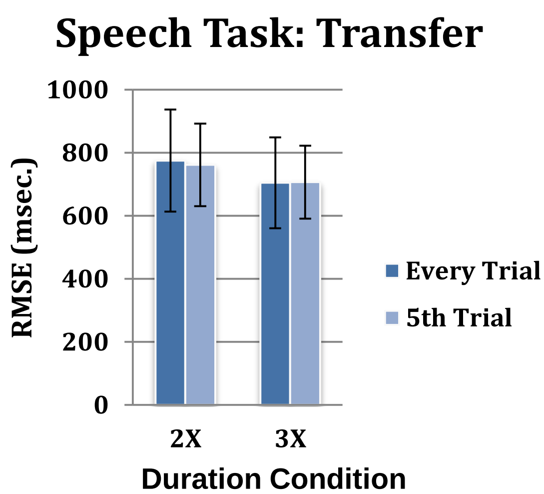
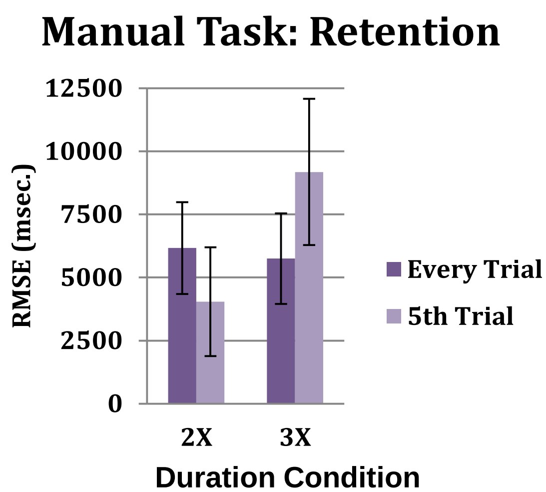


Figure 5-6: Manual task retention and transfer scores compared across feedback schedule and tracing rate conditions for participants with AOS. Error bars reflect the standard error of the mean.



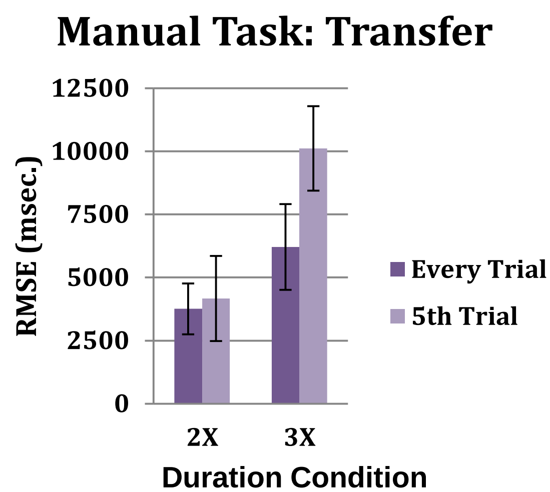
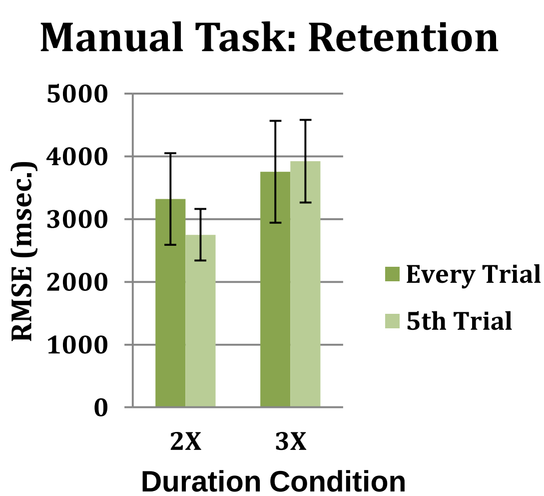
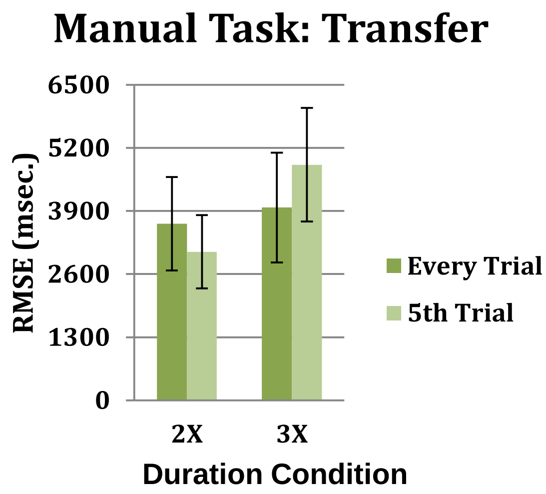


Figure 7: Manual task retention scores compared across feedback schedule and tracing rate conditions for healthy adults. Error bars reflect the standard error of the mean.





REFERENCES

Adams, S. G. and Page, A. D. (2000). Effects of selected practice and feedback variables on speech motor learning. Journal of Medical Speech-Language Pathology, 8(4), 215-220.

Dabul, B. L. (2000). Apraxia Battery for Adults—second edition. Austin: Pro-Ed. Inc.

Grimme, B., Fuchs, S., Perrier, P., Schoner, G. (2011). Limb versus speech motor control: a conceptual review. *Motor Control, 15*(1): 5-33.

Hula, S. N., Robin, D. A., Maas, E., Ballard, K. J., & Schmidt, R. A. (2008). Effects of Feedback Frequency and Timing on Acquisition, Retention, and Transfer of Speech Skills in Acquired Apraxia of Speech. *Journal of Speech Language and Hearing Research,* 51(5), 1088-1113. DOI: 10.1044/1092-4388(2008/06-0042).

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). The Boston Naming Test. Philadelphia:Lippincott Williams & Wilkins.

Katz, W. F., McNeil, M. R., & Garst, D.M. (2010). Treating apraxia of speech (AOS) with EMA-supplied visual augmented feedback. *Aphasiology,* 24(6-8), 826-837. DOI: 10.1080/02687030903518176.

Kendall, D., del Toro, C., Nadeau, S., Johnson, J., Rosenbek, J., Velozo, C. The development of a standardized assessment of phonology in aphasia. Clinical Aphasiology Conference. June 2010, Isle of Palm, SC.

Kertesz, A. (1982). The Western Aphasia Battery. New York: Psychological Corporation.

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J. & Schmidt, R. A. (2008). Principles of motor learning in treatment of motor speech disorders. *American Journal of Speech-Language Pathology,* 17(3), 277-298. DOI: 10.1044/1058-0360(2008/025).

Steinhauer, K. & Grayhack, J.P. (2000). The role of knowledge of results in performance and learning of a voice motor task. *Journal of Voice, 14, (2)*, 137-145.

Wambaugh, J. L., Duffy, J. R., McNeil, M. R., Robin, D. A., & Rogers, M. A. (2006).Treatment guidelines for acquired apraxia of speech: A synthesis and evaluation of the evidence. Journal of Medical Speech-Language Pathology, 14(2), xv-xxxiii. Retrieved from http://find.galegroup.com.offcampus.lib.washington.edu.