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Practice and retention of nonwords in adults who stutter

Jayanthi Sasisekaran[a,*], Sanford Weisberg[b]

[a] Department of Speech, Language, Hearing Sciences, University of Minnesota, United States
[b] School of Statistics, University of Minnesota, United States

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ABSTRACT

Purpose: We investigated short-term practice and retention of nonwords in 10 adults who stutter (*Mean* age = 30.7 years, *SD* = 15.1) and age and sex-matched 10 control participants (*Mean* age = 30.8 years, *SD* = 14.9).
Methods: Participants were required to repeat nonwords varying in length (3, 4, and 6 syllables), phonotactic constraint (PC *vs.* NPC, on 3-syllable nonwords only), and complexity (simple, complex). They were tested twice with 1 h gap between sessions.
Results: Logistic mixed model of speech accuracy revealed that the AWS showed a significantly lower probability of correct responses with increasing length and complexity. Analysis of speech kinematics revealed practice effects within Session 1 in AWS seen as a reduction in movement variability for the 3-syllable nonwords; the control group was performing at ceiling at this length. For the 4-syllable nonwords, the control group showed a significant reduction in movement variability with practice, and retained this reduction in Session 2, while the AWS group did not show practice or retention. Group differences were not evident at the 6-syllable level.
Conclusions: Group differences in speech accuracy suggest differences in phonemic encoding and/or speech motor processes. Group differences in changes in movement variability within and between sessions suggest reduced practice and retention in AWS. Relevance of the combined use of both behavioral and kinematic measures to interpret the nature of the skill acquisition deficit in persons who stutter is discussed.

Educational objectives: At the end of this activity the reader will be able to: (a) summarize the process of skill acquisition; (b) discuss the literature on skill acquisition deficits in adults who stutter, (c) summarize the differences between AWS and control participants in speech accuracy and speech kinematics with short-term practice and retention of nonwords, (d) discuss potential research directions in the area of skill acquisition in AWS.

Stuttering is a developmental speech disorder characterized by the presence of repetition, prolongations, and blocks in speech. Several theories have been proposed to account for stuttering as a deficit in sensorimotor processes (Kalvaram, 2001; Max, Guenther, Gracco, Gosh, & Wallace, 2004; Neilson & Neilson, 1991; Smith & Kelly, 1997). The investigation of such processes has been undertaken using both speech and non-speech tasks and the findings allude to a deficit in skill acquisition (Bauerly & De Nil, 2011; Namasivayam & Van Lieshout, 2008; Smith, Sadagopan, Walsh, & Weber-Fox, 2010;

* Corresponding author at: SLHS, University of Minnesota, 164 Pillsbury Drive SE, Minneapolis, MN 55455, United States. Tel.: +1 612 626 6001; fax: +1 612 624 7586.
E-mail addresses: sasis001@umn.edu, jsasisekaran@gmail.com (J. Sasisekaran).

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Smits-Bandstra, De Nil, & Saint-Cyr, 2006), although some mixed findings have been reported. The aim of the present study is to investigate skill acquisition abilities in the short-term in adults who stutter (AWS) using nonword repetition, which requires the encoding, assembly, and execution of previously known or unknown speech sound combinations and the constituent motor gestures.

1. Motor skill acquisition: theory

Motor skill acquisition refers to the process by which movements produced alone or in a sequence come to be performed effortlessly through repeated practice and interactions with the environment (Willingham, 1998). Of the different stages involved in skill acquisition, studies in the speech motor literature have focused on *practice* (defined as improvements in performance within a single session) and *retention* (defined as performance of the practiced skill between sessions without any practice in the intervening duration between sessions) in typical and atypical (e.g., stuttering) populations (e.g., Behrman, Cauraugh, & Light, 2000; Namasivayam & Van Lieshout, 2008; Smith et al., 2010; Smits-Bandstra et al., 2006).

A theoretical notion that has received some attention in the motor literature is the *neuromotor noise hypothesis* according to which changes with motor learning are the consequences of reducing variability in neural command signals (Kleim et al., 2002, 2003; Newell, Liu, & Mayer-Kress, 2003). Studies of speech and non-speech motor learning suggest that both children and adults exhibit higher levels of neural noise during the acquisition of new movement sequences, evident as higher movement variability (Green, Moore, & Reilly, 2002; Smith & Zelaznik, 2004; Takahashi et al., 2002; Vangalen, Portier, Smitsengelsman, & Schomaker, 1993; Walsh, Smith, & Weber-Fox, 2006; Yan, Thomas, Stelmach, & Thomas, 2000). With maturation and practice, increasing neuronal synchronization results in reduced neuromotor noise levels, thereby facilitating motor coordination through the formation of optimal movement synergies. Thus, movement coordination is achieved through a neurophysiologically mediated motor learning processs (Harris & Wolpert, 1998; Smith & Zelaznik, 2004).

2. Skill acquisition in AWS

Stuttering has been identified as a form of 'speech clumsiness' with limitations in acquiring speech motor skills (van Lieshout, Hulstijn, & Peters, 2004). Studies in the stuttering literature have reported reduced practice and longer-term learning (e.g., retention) effects in both non-speech and speech tasks (Adams & Hayden, 1976; Cooper & Allen, 1977; Cross & Luper, 1979; Ludlow, Siren, & Zikria, 1997; Namasivayam & Van Lieshout, 2008; Smith et al., 2010; Smits-Bandstra et al., 2006). The focus of this review is on such studies using speech tasks.

van Lieshout, Hulstijn, and Peters (1996) tested 12 AWS and 12 control participants in speech reaction time and word duration in a picture and a word naming task. Target words were 1-, 2-, or 3-syllables in length (word size). They reported that AWS were slower in speech reaction times than controls, but the hypothesized group × word size effect was not found. The authors interpreted this finding to suggest that the AWS and controls do not differ in the assembly of the motor plan during speech production. They also reported that word duration was longer in the AWS group and group differences were larger with increasing word size. For both these findings, the authors also reported delays in relative timing of motor events (e.g., onset of upper lip muscle contraction *vs.* thoracic compression). The findings were interpreted to suggest that AWS may use different motor control strategies to compensate for reduced verbal motor skill in the form of a sensori-motor integration deficit.

Smits-Bandstra et al. (2006) compared nine AWS and nine matched control participants on speed and accuracy in a speech (repeated reading of a 10-syllable nonsense word) and a non-speech (10-item finger tapping) sequence skill learning task. Participants were tested during a practice phase (30 trials), then a transfer phase where two novel sequences were tested.

This was followed by retesting of the original sequence used in practice after a 40-min retention phase. In the finger tapping task, the controls showed practice and retention effects seen as an improvement in finger sequence duration and reaction time while the AWS did not show similar improvements. Group differences with practice were, however, not evident for the speech task either for sequence duration or reaction time. The groups were also comparable in accuracy for both the speech and non-speech tasks. Perhaps, deficits in skill learning may become evident in speech tasks when task complexity is manipulated to reflect a hierarchy of task demands. In this case, the use of a relatively simple nonword sequence (e.g., */ga ba pa ta pa ba ga pa ta ga/*) may not have been sufficient to reveal subtle difficulties in skill acquisition in AWS.

Namasivayam and Van Lieshout (2008) tested practice and longer-term learning (consolidation, retention) effects on the stability of movement kinematics and the strength and stability of inter-gestural coordination patterns of the upper lip–lower lip–jaw synergy in five AWS and five control participants. Participants produced the bisyllabic nonwords /bapi/ and /bipa/ approximately 15 times across three test sessions spanning a week (T1, T2 in a day, T3 a week apart). Comparison of practice effects (T1 *vs.* T2) revealed that the control participants showed higher coherence and descriptively lesser variability in gestural coordination thereby showing larger gains with practice. Comparison of learning (retention) effects (T1 *vs.* T3) revealed that the control group showed higher mean coherence values in T3 compared to T1 while the AWS did not show similar changes.

Bauerly and De Nil (2011) studied practice and retention in 12 AWS and 12 controls. Participants were required to repeat a 11-syllable nonword 100 times (divided into 10 blocks) on Day 1 and 50 times (divided into 5 blocks) on Day 2 session conducted after 24 h. They measured accuracy, response preparation time, and sequence duration on Day 1 as a measure of practice and on Day 2 as a measure of motor learning (retention). Results failed to confirm the hypothesized poor practice and