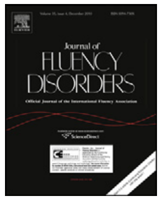
Journal of Fluency Disorders 36 (2011) 349–360

Contents lists available at ScienceDirect

Journal of Fluency Disorders



Speech sequence skill learning in adults who stutter

Kim R. Bauerly[a,*], Luc F. De Nil[a,b,c]

[a] *Department of Speech and Language Pathology, University of Toronto, 160-500 University Ave, Toronto, ON, Canada M5G 1V7*
[b] *Toronto Western Research Institute, University Health Network, Canada*
[c] *Hospital for Sick Children, Canada*

ARTICLE INFO

Article history:
Received 1 December 2010
Received in revised form 31 May 2011
Accepted 31 May 2011
Available online 6 June 2011

Keywords:
Stuttering
Sequence skill learning
Speech task
Consolidation

ABSTRACT

The present study compared the ability of 12 people who stutter (PWS) and 12 people who do not stutter (PNS) to consolidate a novel sequential speech task. Participants practiced 100 repetitions of a single, monosyllabic, nonsense word sequence during an initial practice session and returned 24-h later to perform an additional 50 repetitions. Results showed significantly slower sequence durations in the PWS compared to PNS following extensive practice and consolidation. However, the hypothesis that poor performance gains in PWS compared to PNS during practice would be maintained following a 24-h consolidation period was not supported. Further descriptive analysis revealed large within group differences in PWS which to some extent were attributed to a subgroup of PWS who failed to show any improvements in performance following practice or consolidation. The results and the possible presence of subgroups of PWS are discussed with regard to their limitations in motor learning abilities.

Educational objectives: **:** The reader will be able to (1) explain the difference between practice and learning, (2) define consolidation and explain the importance of measuring performance following a consolidation period, (3) understand past research on PWS' performance during both speech and nonspeech motor tasks, and (4) explain why individual differences in practice effects and learning may have important implications for client variability in treatment outcome.

1. Introduction

Learning of complex motor skills such as speaking may be affected in people who stutter (PWS) (De Nil, 1999b) as evidenced by studies showing that PWS do not benefit to the same extent from practicing speech and nonspeech sequence skill tasks as people who do not stutter (PNS; Ludlow, Siren, & Zikria, 1997; Neilson & Neilson, 1991; Smits-Bandstra, De Nil, & Rochon, 2006; Smits-Bandstra, De Nil, & Saint-Cyr, 2006). Based on recent findings of poor motor practice effects in PWS (Smits-Bandstra, De Nil, & Saint-Cyr, 2006), it has been suggested that these findings may have potential clinical implications regarding the long-term effectiveness of fluency intervention strategies that involve acquiring a novel speech movement pattern such as forming light articulatory contacts or prolonging speech with a high degree of automaticity (Bloodstein & Bernstein-Ratner, 2008). One of the main limitations to stuttering treatment programs in general is the high incidence of relapse, ranging anywhere from 14% to 70% of participants within a year following treatment (Bloodstein & Bernstein-Ratner, 2008). Although there is now some evidence to suggest that a deficiency in motor learning may play a role (Smits-Bandstra,

* Corresponding author. Tel.: +1 416 946 8635; fax: +1 416 978 1596.
E-mail addresses: kimberly.bauerly@gmail.com (K.R. Bauerly), luc.denil@utoronto.ca (L.F. De Nil).

0094-730X/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.jfludis.2011.05.002

De Nil, & Rochon, 2006; Smits-Bandstra, De Nil, & Saint-Cyr, 2006) almost all behavioral studies with people who stutter have measured learning-related changes exclusively during single practice sessions. Little is known whether the observed group differences continue following a period of rest or consolidation. It they do, this could point to a deficit in learning rather than just practice-related effects.

1.1. Sequence skill learning

Motor learning involves the interaction between the pre-existing capacities of an individual and the to-be-learned movement pattern (Kelso, 1995). It refers to the ability to acquire the temporal and spatial characteristics of a movement pattern in order that, with practice, muscle execution becomes increasingly dependent on an internal representation rather than external sensory feedback (Schmidt, 2004). Such motor learning is accompanied by a decrease in sensory and attentional demands (Schmidt & Lee, 2005).

Practice or repetition of a given movement pattern is an essential component of learning. Practice effects are traditionally measured using such variables as accuracy, reaction time and sequence duration. Upon practicing a motor task, an individual's performance is often characterized by shorter response times and sequence durations as well as more accurate responses. Practice effects are thought to represent the momentary changes in performance (Schmidt, 2004) and may be used to predict the relatively permanent consequences of practice (Schmidt & Lee, 2005). Learning, however, cannot be assumed to occur based on practice effects alone as variables in the environment such as fatigue may affect performance during a single practice session. As a result, learning is not directly observable and must be inferred from measured variables such as whether the improvements from practice transfer to a similar but novel task or whether the performance improvement is retained following a period of rest (Magill, 1998).

1.2. The role of consolidation in motor learning

Memory consolidation refers to processes by which a motor memory that is initially encoded into a 'fragile' state (sensitive to interference) is transformed into a more stable state with the passage of time (Fischer, Hallschmid, Elsner, & Born, 2002; Robertson, 2004). Memory consolidation does not stop when practice ends but has been shown to continue across hours, days and weeks following the termination of practice (Fischer et al., 2002; Press, Casement, Pascual-Leone, & Robertson, 2005). For instance, Karni et al. (1995) found that speed and accuracy of a sequential finger tapping task continued to improve after training had ended and that only a small number of repetitions on the following day were required to initiate further gains in performance. Although the time it takes a skill to stabilize is dependent on many factors (e.g. task difficulty and length of practice), several studies using simple, repetitive motor tasks have shown the stabilization of a motor memory following a relatively short 24-h rest period (Walker & Stickgold, 2004; Press et al., 2005).

1.3. Motor practice effects in PWS

Several studies have shown PWS to be slower and less accurate compared to PNS when performing speech-motor tasks. Adams and Hayden (1976) reported that PWS were slower at initiating and terminating phonation when cued by a tone and that this trend continued following practice. Cooper and Allen (1977) found that PWS required more repetitions than control subjects to increase their rate of speech when practicing a repetitive reading task. Similarly, in a study by Ludlow et al. (1997), PWS were slower to learn the correct productions of two, 4-syllable nonsense words and were overall less accurate compared to PNS.

Similar trends in performance have been observed in studies employing nonspeech tasks (Neilson & Neilson, 1991; Smits-Bandstra, De Nil, & Saint-Cyr, 2006; Webster, 1986; Weinstein, Caruso, Severing, & VerHoeve, 1989), suggesting that group differences are not limited to the sensorimotor processes involved in speech production. For instance, Webster (1986) found that PWS were slower and less accurate than control participants when practicing a bimanual finger tapping task. Others have shown that group differences remain when stuttering speakers are given time to practice a motor skill (Neilson & Neilson, 1991; Smits-Bandstra, De Nil, & Saint-Cyr, 2006).

In a series of studies conducted by Smits-Bandstra and her colleagues (2006a, 2006b), PWS's poor practice effects on both a syllable reading and finger tapping task were shown to have an effect on their ability to transition the skill to a more automatic level. Smits-Bandstra, De Nil, and Rochon (2006) found that PWS and PNS performed similarly during the initial sets of practice; however, as practice continued results indicated a trend for slower reaction times and longer sequence durations in the PWS. In addition, the PWS demonstrated poorer transfer and retention abilities. Although suggestive, these results should be taken with caution as the behavioral measures in this study were taken during a single practice session. This may not have provided sufficient time to allow the temporary influences on performance (e.g. fatigue) to dissipate (Schmidt & Lee, 2005), and the results may have reflected practice rather than learning effects.

Dual task paradigms are commonly used in motor learning research in order to measure the level of automaticity achieved following practice (Magill, 1998; Schmidt, 2004). It is assumed that repeated practice leads to a reduction in cognitive demands, leaving attentional resources available for a secondary task. Smits-Bandstra and De Nil (2009) found that the performance of PWS during a single speech and nonspeech task was as slow and inaccurate as the performance of the PNS during a dual task condition. Under such task conditions, the PNS showed a decrease in response time and accuracy rate