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Investigating speech motor practice and learning in people who stutter

Aravind Kumar Namasivayam[a,*], Pascal van Lieshout[a,b,c,d]

[a] *Oral Dynamics Laboratory, Department of Speech-Language Pathology, University of Toronto, 160-500 University Avenue, Toronto, Ontario, Canada M5G 1V7*

[b] *Toronto Rehabilitation Institute (TRI), Canada*

[c] *Institute for Biomaterials and Biomedical Engineering (IBBME), University of Toronto, Canada*

[d] *Department of Psychology, Human Communications Lab (HCL), University of Toronto, Canada*

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Abstract

In this exploratory study, we investigated whether or not people who stutter (PWS) show motor practice and learning changes similar to those of people who do not stutter (PNS). To this end, five PWS and five PNS repeated a set of non-words at two different rates (normal and fast) across three test sessions (T1, T2 on the same day and T3 on a separate day, at least 1 week apart). The results indicated that PWS and PNS may resemble each other on a number of performance variables (such as movement amplitude and duration), but they differ in terms of practice and learning on variables that relate to movement stability and strength of coordination patterns. These findings are interpreted in support of recent claims about speech motor skill limitations in PWS.

Educational objectives: The reader will be able to: (1) define oral articulatory changes associated with motor practice and learning and their measurement; (2) summarize findings from previous studies examining motor practice and learning in PWS; and (3) discuss hypotheses that could account for the present findings that suggest PWS and PNS differ in their speech motor learning abilities.

Keywords: Stuttering; Motor learning; Motor practice; Speech motor skill; Movement coordination

1. Introduction

In the past decade, various authors have proposed the presence of motor learning/skill limitations in people who stutter (PWS; e.g., Ludlow, Siren, & Zikria, 1997; Smits-Bandstra, De Nil, & Saint-Cyr, 2006; Van Lieshout, Hulstijn, & Peters, 1996a, 1996b, 2004). Primarily, the evidence comes from speech and non-speech motor learning studies. These studies have implied that motor learning and automatization of new speech skills may be limited in PWS and that these limitations may have implications for treatment strategies that focus heavily on learning a new set of speech motor skills (Smits-Bandstra, De Nil, & Rochon, 2006). The results of these specific studies relating to motor learning in PWS and some of their limitations will be reviewed first, followed by a description of the present investigation.

* Corresponding author. Tel.: +1 416 946 8552; fax: +1 416 978 1596.
E-mail address: a.namasivayam@utoronto.ca (A.K. Namasivayam).

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1.1. Motor practice and learning

Typically, practicing a new motor task over repeated trials results in decreases in response latency, shorter execution time (as inferred by increases in speed), higher accuracy and more consistency/lower variability of newly practiced movements (Hamstra-Bletze & Blote, 1990; Meulenbroek & Van Galen, 1988; Moore & Marteniuk, 1986; Salthouse, 1986; West & Sabban, 1982; Zesiger, Mounoud, & Hauert, 1993). The nature of these immediate changes subsequent to practice are typically reflected in so-called performance curves and represent motor practice effects (Schmidt & Wrisberg, 2004). Motor learning on the other hand, is not directly observed but rather inferred by how well these practiced tasks are transferred to other similar types of tasks that were not practiced, and by the extent to which they are retained after a period of rest. Further, motor learning is inferred when these practice-related changes become a relatively permanent feature of the demonstrated behaviors (Schmidt & Wrisberg, 2004).

1.2. Assessment of motor learning

The issue of practice versus learning becomes more complicated in the context of different theoretical views. Traditional motor control models (e.g., the motor schema theory of Schmidt, 2003; Shea & Wulf, 2005) would predict that decreases in movement amplitude (Meulenbroek & Van Galen, 1988; Salthouse, 1986) and variability (Hamstra-Bletze & Blote, 1990; Zesiger et al., 1993) and increases in movement speed (Moore & Marteniuk, 1986; West & Sabban, 1982) would be associated with practice (cf. Schulz, Dingwall, & Ludlow, 1999). However, many of the more traditional kinematic measures show substantial individual variability over time (Alfonso & Van Lieshout, 1997; Van Lieshout et al., 2004). For example, Alfonso and Van Lieshout (1997) found high intra-subject variability in PNS for discrete kinematic parameters and movement sequence patterns (peak velocity timing of upper lip, lower lip and jaw sequence) including some complete pattern reversals across three test sessions 2 weeks apart. These findings suggest that these more traditional discrete spatial and temporal order measurements in speech, including movement amplitude and duration, can be seen as emergent features that do not necessarily reflect organizational principles of the underlying control mechanism (Kelso, 1995; Smith, Johnson, McGillem, & Goffman, 2000; Van Lieshout, 2004). Different approaches have surfaced in recent years to reflect principal mechanisms of motor control. These include linear and non-linear indices of movement pattern stability (e.g., Lucero, Munhall, Gracco, & Ramsay, 1997; Smith, 1997; Wohlert & Smith, 1998), relative phase measures to index the nature and stability of movement coordination (Kelso & Tuller, 1987; Van Lieshout, Hulstijn, Alfonso, & Peters, 1997; Ward, 1997), and cross-spectral coherence, as a measure of the strength of the frequency coupling between articulators (Kay, 1988; Morrison & Newell, 1996; Van Lieshout, 2001, 2004). More details on these measures are provided in Section 2.

One approach to measure individual articulator variability is the spatio-temporal index (STI) which captures movement stability over time (Smith, 1997). The assumption is that an adult speaker's speech is highly practiced and stable. The index is a measure of how well amplitude and time normalized movement trajectories of repeated utterances converge upon a single core template. The lower the STI the lesser the deviation from a single template and vice versa (cf. Smith, 1997; Wohlert & Smith, 1998). Interestingly, the pattern of interest or template could be either defined in linguistic terms in the form of short meaningful phrases (Smith, 1997; Wohlert & Smith, 1998) or in more basic motor terms, in the form of individual movement cycles, in which case it is referred to as cyclic STI (cSTI; Van Lieshout & Moussa, 2000). It is claimed that the cSTI measure is less susceptible to long-term non-linear influences relating to local temporal variations in linguistic structures (cf. Lucero et al., 1997) and more indicative of basic motor control stability (Van Lieshout & Moussa, 2000), and hence could be an appropriate tool to study changes subsequent to motor practice.

cSTI does not address motor coordination between individual articulators during speech production. Motor coordination and learning in speech can be addressed by coordination dynamics theory, which describes lawful relationships for the coupling of limb and speech structures over time (Kelso, 1995). Combining this theory with concepts from the Articulatory Phonology (AP) model, motor coordination can be defined at two distinct levels, namely within (intra) and between (inter) gestures (Browman & Goldstein, 1992; Goldstein, Byrd, & Saltzman, 2006; Saltzman & Byrd, 2000; Saltzman & Munhall, 1989; Van Lieshout, Bose, Square, & Steele, 2007). The nature and variability of coordination (or coupling) both within and between gestures can be assessed using a measure of relative timing that is not confounded with variations in movement duration, called relative phase (for a recent review of this approach and related theories, see Van Lieshout, 2004). Following this combined approach, it can be argued that the phasing (or coupling) between the