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Sensory feedback dependence hypothesis in persons who stutter

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ABSTRACT

The present study investigated the role of sensory feedback (auditory, proprioception, and tactile) at the intra- and inter-gestural levels of speech motor coordination in normal and fast speech rate conditions in two groups: (1) persons who stutter (PWS) and (2) those who do not (PNS). Feedback perturbations were carried out with the use of masking noise (auditory), tendon vibration (proprioception), and nonwords that differed in the amount of required tactile lip contact (/api/ + tactile and /awi/ – tactile). Comparisons were also made between jaw-free and jaw-immobilized (with a bite-block) task conditions. It was hypothesized that if PWS depend more strongly on sensory feedback control during speech production, they would show an increase in variability of movement coordination in the combined presence of fast speech rates and feedback perturbations, in particular, when jaw motions are blocked and adaptations in the other articulators are required to achieve the task goals.

Significant feedback perturbation effects were found for both groups, but the only significant between-group effect was found at fast speech rates in the jaw-free condition, showing that control

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speakers were more perturbed at the intra-gestural level of coordination than PWS when simultaneous (auditory, proprioceptive, and tactile) perturbations were present. The findings do not provide support for either the feedback dependency or the sensory deficit hypotheses described in the literature to explain movement characteristics found in fluent speech production of PWS.

1. Introduction

The "motor skill" view of stuttering (van Lieshout, Hulstijn, & Peters, 2004) posits that persons who stutter (PWS) are at the lower end of a speech-motor skill continuum relative to persons who do not stutter (PNS). According to this view, it is assumed that PNS produce speech like any other well-practiced motor task, weighted towards feedforward control that is highly automatized and based on dynamical principles of motor control (Saltzman & Munhall, 1989; van Lieshout et al., 2004). In contrast, PWS are argued to be less skilled in speech production and are inclined to use a less automated strategy that is more dependent on sensory information for the control of speech movements (Adams, Weismer, & Kent, 1993; van Lieshout, Hulstijn, & Peters, 1996a, 1996b; van Lieshout, Peters, Starkweather, & Hulstijn, 1993). Within this motor skill frame work, PWS are not considered speakers with a sensory deficit as some researchers have suggested (Archibald & De Nil, 1999; Loucks & De Nil, 2006a, 2006b). Rather it is proposed that their speech motor symptoms reflect limitations in efficiency and agility similar to what has been reported for less skilled performances in other types of motor tasks (Broderick & Newell, 1999; De Nil, 1999).

Others have also hypothesized that PWS might show an over-reliance on sensory feedback, but not as a compensatory strategy to prevent stuttering due to limitations in motor skill (Max, Guenther, Gracco, Ghosh, & Wallace, 2004). Rather, these authors claim that this over-reliance on sensory feedback, given the inherent delay between a motor command and its sensory consequences, may actually result in an unstable speech motor system characterized by oscillations and resets, which at a behavioral level is assumed to be reflected in disfluent speech production. It is expected that these instabilities in the speech motor system would increase with increases in speech rate due to the extra demands on temporal processing of sensory information at fast speech rates (Max et al., 2004).

Although over-reliance on sensory feedback has been implicated in stuttering both as a cause and as a compensatory strategy, there is very little information in the stuttering literature on the exact type of sensory information that PWS are assumed to be over-dependent on (whether its auditory, proprioceptive, or tactile[1]), at what level it is being used for motor control, whether its use in PWS differs from that of PNS and so on. This paper is aimed at answering some of these questions.

The role of feedback in speech production is currently a hot topic of research. Broadly stated, auditory and oro-sensory[2] feedback arising from speech related activity is utilized to learn and control speech movements (Guenther, 2006; Postma, 2000; Purcell & Munhall, 2006; Smith, 1992). For example, the importance of auditory information for the control of speech movements has been demonstrated using speech compensation and adaptation paradigms. There are studies that report of bite-block induced vowel distortions and acoustic target variability in hearing impaired (Tye, Zimmermann, & Kelso, 1983) and postlingually deaf cochlear implant users when their implant was temporarily turned off (Lane et al., 2005). Furthermore, studies have also demonstrated the significance of oro-sensory information, independent of auditory information for the control of speech movements. For example, Tremblay, Shiller, and Ostry (2003) used a robotic arm and applied perturbations to the jaw during speech and non-speech tasks that had no auditory consequences (and were undetected by the speakers). After sufficient

[1] The word "tactile" refers to the combined sensations of touch, pressure, and skin stretch that arise from mechanoreceptors in the oral labia during the production of bilabial consonants.

[2] The term "oro-sensory" in this paper will specifically refer to sensations mediated by mechanoreceptors (touch, pressure, and stretch) and proprioceptors (proprioception–sensation of muscle and joint position and movement).