Auditory processing in speech production

The integration of auditory feedback from self generated speech sounds into upcoming motor commands is important for the stability and control of speech production. For example, children with profound hearing impairment experience greater difficulty acquiring and maintaining speech than their normal hearing peers (Campisi, Low, Papsin, Mount, & Harrison, 2006; Kishon-Rabin, Taitelbaum-Swead, Ezrati-Vinacour, & Hildesheimer, 2005; Moeller, Hoover, Putman, Arbataitis, Bohnenkamp, Peterson, Lewis et al., 2007; Moeller, Hoover, Putman, Arbataitis, Bohnenkamp, Peterson, Wood et al., 2007). Also, adults with acquired hearing loss show a gradual degradation of their previously proficient articulatory ability that is partially restored after cochlear implantation (Kishon-Rabin, Taitelbaum, Tobin, & Hildesheimer, 1999). The importance of auditory feedback for speech motor control in normal speakers has been demonstrated via perturbation studies. Various studies have shown the compensatory impact perturbing the volume (Bauer, Mittal, Larson, & Hain, 2006), pitch (Burnett, Senner, & Larson, 1997), phonetic accuracy (Houde & Jordan, 1998) and timing (Jones & Striemer, 2007) of auditory feedback has on the kinematic and acoustic outcomes of speech production in normal speakers. Computational neural network models of speech production have also been used to demonstrate the importance of auditory feedback for articulatory control (Guenther, Husain, Cohen, & Shinn-Cunningham, 1999; Perkell et al., 2000).

Perturbing the timing of auditory feedback in people who are fluent is known to induce a variety of articulation disturbances. Specifically, delayed auditory feedback varied between 200 ms and 400 ms during reading aloud results in a reduced number of correct words, increased total reading time, monosyllabic sound substitutions, omissions, insertions and additions including repetitions(Fairbanks, 1955; Fairbanks & Guttman, 1958; B. S. Lee, 1950; B. S. Lee, 1951; Stuart, Kalinowski, Rastatter, & Lynch, 2002; Yates, 1963). Conversely, delayed auditory feedback has been shown to positively influence speech fluency in people who stutter(Adamczyk, 1959; Kalinowski, Stuart, Sark, & Armson, 1996; Ryan & Van Kirk, 1974; Soderberg, 1968; Stuart, Kalinowski, Armson, Stenstrom, & Jones, 1996; Stuart, Kalinowski, & Rastatter, 1997). The degree of fluency enhancement varies depending on a number of variables (e. g. delay duration, feedback intensity), the context and the individual(Armson, Kiefte, Mason, & DeCroos, 2006; Wingate, 1970). As a result of the variable responses reported in the literature, the clinical effectiveness of altered auditory feedback as a treatment tool remains controversial(Antipova, Purdy, Blakeley, & Williams, 2008; Lincoln, Packman, & Onslow, 2006; O’Donnell, Armson, & Kiefte, 2008; Pollard, Ellis, Finan, & Ramig, 2009; Stuart, Kalinowski, Rastatter, Saltuklaroglu, & Dayalu, 2004; Stuart, Kalinowski, Saltuklaroglu, & Guntupalli, 2006; Wingate, 1970).

The basis for the variable response of adults who stutter to delayed auditory feedback is not known. Various theories have been put forward to describe how delayed auditory feedback induces fluent speech in some individuals who stutter. It has been proposed that delayed auditory feedback results in speech improvement by forcing the person who stutters to assume a new pattern of speech movement(Goldiamond, 1965). The new pattern is claimed to be established and maintained via operant learning principles with the delayed auditory feedback functioning as aversive negative reinforcement. As pointed out byWingate (1970), the conceptualization of this process is unclear and incomplete. However, there is some evidence to support the claim that a new speech pattern is learned(Ryan & Van Kirk, 1974). It has also been proposed that the delayed auditory feedback is corrective in nature thereby improving fluency. However, the contrary that delayed auditory feedback is distorted feedback seems to be obvious(Wingate, 1970). Some authors have posited that the key to delayed auditory feedback's effectiveness is the reduction of meaningful feedback(Wingate, 1970)denying the person who stutters the ability to rely on this potentially inefficient control system. This assertion is somewhat supported by the observation that masking of auditory feedback also induces fluent speech in some individuals who stutter(Sutton & Chase, 1961; Wingate, 1970). Lastly, it has been proposed that delayed auditory feedback is effective because of the tendency of individuals to slow their speech rate, prolong vowel duration and increase vocal intensity and fundamental frequency(Wingate, 1970). However, changes to speech characteristics such as a slower rate cannot be the only reason that delayed auditory feedback is effective, as it has been demonstrated to have similar fluency enhancing effects even at fast rates of speech(Kalinowski et al., 1996; Stuart et al., 2002). The effects of altered auditory feedback on speech fluency in people who stutter demonstrate the importance of auditory processing in the disorder. Advancing our understanding of the role auditory processing plays in the speech production of people who stutter may begin to elucidate the mechanisms behind fluency inducing altered auditory feedback.

1. 5. 2Auditory processing in normal and stuttered speech production:

Behavioural studies of auditory processing in adults and children who stutter have yielded evidence of central auditory processing differences in these populations relative to fluent age-matched peers. Rousey, Goetzinger and Dirks (1959)reported that 20 stuttering children showed below normal performance on sound localization. Lack of sound localization skills may be indicative of temporal lobe disorders(Jerger, Wekers, Sharbrough, & Jerger, 1969). Various studies have employed batteries of audiometric tests to behaviourally evaluate central auditory processing in adults children who stutter. Rousey, Goetzinger and Dirks (1959)reported that 20 stuttering children showed below normal performance on sound localization. Hall and Jerger (1978)reported that adults who stutter performed poorly relative to fluent adults on a subset of such tests. They concluded that the results suggested the presence of a subtle central auditory processing deficit in adults who stutter. Anderson, Hood and Sellers (1988)conducted a similar study and found that adolescents who stuttered performed poorly on only one subtest as compared to a group of age-matched control participants. They similarly concluded that if a deficit exists it is subtle.

Evidence of a subtle central auditory processing deficit has also been demonstrated in children who stutter. For example, children who stutter have been found to have higher thresholds on backward masking tasks than children who do not stutter(Howell, Rosen, Hannigan, & Rustin, 2000). Howell et al. also found a positive correlation between backward masking thresholds and stuttering severity in children who stutter. In a follow-up studyHowell and Williams (2004)investigated children who stutter on a battery of audiometric tests including backward masking tasks. Based on the profile of performance on the audiometric battery of tests, Howell et al. (2004)reached the conclusion that children who stutter had a different developmental pattern of central auditory processing abilities relative to their fluently speaking age-matched peers but they did not specify the nature of that difference.

More recently, central auditory functioning was evaluated behaviourally and with electroencephalography in adults who stutter(Hampton & Weber-Fox, 2008). Behaviourally, adults who stutter performed less accurately and demonstrated longer reaction times in response to the prompt tone in a standard oddball paradigm. However, a small subgroup of adults who stutter was found to be driving the results. The same subgroup of poor performing adults who stutter also demonstrated abnormal evoked auditory waveforms. Hampton and Weber-Fox (2008)concluded that this subgroup demonstrated deficient non-linguistic auditory processing.

Objective tests like AEPs are valid and useful measures to study auditory processing in persons with stuttering as they reflect changes in auditory system as stimuli is processed.