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PREFACE

This Supplement contains the abstracts of the sixth edition of the International Conference on Speech Motor Control, which will be held in Groningen, The Netherlands, June 8 - 11, **2011**. With this sixth conference a well- established Nijmegen tradition is continued.

Since the first edition in **1985**, the series of international Nijmegen conferences on speech motor control have reflected tremendous progress in this area. The initial focus was on applications in the just expanding field of speech motor control in stuttering. The second conference (**1990**) highlighted the development of more general speech motor control models and the inclusion of higher order psychomotor and psycholinguistic processes, broadening the scope to other motor speech disorders than stuttering. At the third conference (**1996**), more emphasis was put on the emerging field of brain imaging. In addition, development of speech motor control became a prominent topic. At the fourth conference (**2001**), we witnessed the introduction of important theoretical neurophysiological and neurobehavioral concepts, and a strong interest in the 'interface' between higher order cognitive/psycholinguistic processes and speech production. The fifth conference (**2006**) focused on the development of interdisciplinary collaboration in the field of speech motor research on populations with and without speech disorders. Integration was the key-concept: integration of principles and models of perception-action relations; biomechanical and neurobiological aspects of motor control; and the genetics of motor learning (automation) and language disorders.

Thus, in the past five editions, we have witnessed the fundamental insights in speech motor control processes gaining shape, showing a stronger embedding in general aspects of the origin, development and maintenance of cognitive, linguistic and motor processes as well as demonstrating their unique properties as part of the human genetic make-up. In the upcoming conference, we encourage participants to take this evolvement a step further. Special topics of the **2011** conference are:

- Relationship between perception-production processes in speech, including the role of speech motor control in speech perception;
- The Evolution of the Neural Bases of Speech Motor Control;
- New developments in computational models of speech motor control;
- Speech Motor Control and Healthy Aging;
- New applications in speech-technology and rehabilitation of speech-motor functions;
- New developments in genetic research on speech motor functions and disorders.

In addition, special workshops will address apraxia of speech, pediatric speech motor control disorders, and articulography.

Conference organisation

In order to fulfil the main purpose of the conference a relatively large number of keynote speakers have been invited to present tutorials on specific topics. To stimulate a lively interaction, all presentations are plenary. Because of time constraints only a very limited number of submissions could be scheduled as oral presentations. This amounted to less than one third of those submissions that were rated as acceptable for admission. For this

reason thematic poster sessions form a major part of the conference program, offering a large variety of research in speech motor control in normal and deviant speech from all over the world. Many conferences advocate the policy to value oral presentations and posters equally, as do the organisers of this conference. In order to underscore this policy a special prize will be awarded to the most informative and well-designed poster.

The University of Groningen and the organising departments are proud to attract such high-level researchers and clinical workers in the field to travel to Groningen and report on the results of their theoretical and empirical work to this platform of scientific exchange and discussion.

We look forward to a stimulating and productive conference,

Ben Maassen Groningen
Pascal van Lieshout Toronto

May 2011

Program & organising committee

- Ben Maassen, chair (Centre for Language and Cognition Groningen (CLCG), University of Groningen & School of Behavioural and Cognitive Neurosciences (BCN), University Medical Centre Groningen)
- Pascal H.H.M. van Lieshout, co-chair (Oral Dynamics Lab, Department of Speech-Language Pathology, University of Toronto, Canada)
- Hayo Terband (School of Behavioural and Cognitive Neurosciences (BCN), University Medical Centre Groningen)

Venue

The conference will be held in the "Remonstrantse kerk", at short walking distance from the city-centre of Groningen.
Visiting address: Coehoornsingel 14, Groningen.

Secretariat

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Conference website

www.slp-nijmegen.nl/smc2011

ORAL PRESENTATIONS

THE ROLE OF THE SPEECH MOTOR SYSTEM IN SPEECH PERCEPTION

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The motor theory of speech perception was proposed in the 1950s to explain behavioral findings that listeners' phonetic percepts tracked talkers' articulations more closely than the acoustic signals caused by articulation. Among the claims of the motor theory was one that the speech motor system is recruited in phonetic perception to decode coarticulated speech; in the theory, the perceptual system achieves decoding by a process of (perceptual) analysis by (motor) synthesis. The motor theory has been judged highly implausible particularly in respect to that claim and the related one that, in recruiting the motor system in perception, speech perception is "special." Recent research has revealed motor system recruitment in speech perception and some evidence that speech motor system stimulation affects phonetic perception in a phonetically specific way. This supports the motor theory's claim that the motor system has a role in speech perception, but it does not address the particular role proposed by Liberman and his colleagues. I will review the evidence that motor recruitment is quite general not only in varieties of perceiving, but in "higher level" cognitive achievements as well, for example, language and conceptual understanding. Clearly, in respect to motor recruitment, speech perception is not special. I will suggest that understanding the likely roles, if any, for the speech motor system in speech perception requires an embedding that Liberman and colleagues did not anticipate: an embedding of research on speech in the larger context of evidence of pervasive motor system involvement in varieties of cognitive functions.

Additional Readings

D'Ausillo, A., Pulvermueller, F., Saimas, P., Bufalari, I., Beglliomini, C., & Fadiga, L. (2009). The motor somatotopy of speech perception. Current Biology, 19, 381–385.

Galantucci, B., Fowler, C. A., & Turvey, M. T. (2006). The motor theory of speech perception reviewed. Psychonomic Bulletin & Review, 13, 361–377.

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EVOLUTION OF THE NEURAL BASES OF SPEECH MOTOR CONTROL: SOMETHING NEW, SOMETHING OLD, MOSTLY BORROWED

Philip Lieberman
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Charles Darwin in On the origin of species, proposed two evolutionary mechanisms. Natural Selection, the retention of:

...any variation, however slight and from whatever cause proceeding, if it be in any degree profitable...

Darwin also noted the profound changes that occur when an:

"organ might be modified for some other and quite distinct purpose" (1859, p. 61, 190).

Both mechanisms are implicated in the evolution of speech.

Speech involves neural mechanisms and anatomy dating back to Therapsids, mammal-like reptiles who lived 260 million years ago. We retain the middle ear bones found in Therapsids that enhance auditory acuity, and the anterior cingulate cortex (ACC), which regulates phonation and maternal attention in mammals. The middle ear bones found in Therapsid fossils which function as hinges in reptilian mandibles, allow us to infer the presence of the ACC. Human neural circuits linking ACC and basal ganglia control phonation and also direct attention.

The species-specific human tongue allows us to infer the presence of the cortical-to-basal ganglia neural circuits that allow humans to learn and control the internally directed motor acts that yield speech. In the course of evolution, the human tongue descended into the pharynx, carrying the larynx down to a position that increases the risk of choking to death. The selective advantage conferred by the human tongue that overrides choking is enhancing the robustness of speech communication; we are able to produce the quantal vowels [i], [u] and [a].The fossil record shows that the human tongue had evolved between 80,000 and 50,000 years ago. Our tongue would not have evolved unless the human neural circuits for speech were already in place. No evidence exists for a species-specific human direct cortical-brainstem laryngeal circuit that supposedly confers vocal imitation, speech and language.

Circuits linking prefrontal cortex and the basal ganglia play a key role in cognition. They allow humans to learn the myriad details of human culture, including language. Recent genetic studies suggest that the distinction between human and nonhuman behavior involves transcriptional genes, such as FOXP2, ramping up the efficiency of human cortical-basal ganglia circuits by increasing synaptic plasticity and dendrite length in medium spiny neurons.

Additional Readings

Reimers-Kipping, S., Hevers, W., Pääbo, S. and Enard, W. (2011) Humanized Foxp2 specifically affects cortico-basal ganglia circuits. Neuroscience 175: 75–84.

Lieberman, P. and McCarthy R. M. (2007). Tracking the evolution of language and speech. Expedition. 49: 15–20.

AUDITORY-MOTOR LEARNING IN SPEECH PRODUCTION

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Auditory input is essential for early speech development and plays a key role in speech production throughout the life span. This is perhaps most clearly indicated by the impact of hearing impairment on the quality and quantity of early speech output, as well as by the positive influence of auditory-perceptual rehabilitation on the quality of speech production in children and adults. Surprisingly, despite considerable evidence of this association, the precise mechanisms linking auditory input to speech production in children and adults remain poorly understood.

In traditional models, auditory input plays two key roles in speech production: 1) establishing the acoustic correlates of phonemes that serve, in part, as the targets of speech production, and 2) as a source of feedback about a talker's own speech outcomes—information critical to neural processes that improve or maintain the quality of speech output (on-line correction or off-line adaptation). This talk will focus on the second role, and in particular what we have learned from a long history of studying compensatory oral motor adjustments to manipulations of sensory input during speech production. While early manipulations of sensory feedback targeting segmental features of speech were primarily physical in nature (thus affecting orosensory and auditory feedback simultaneously), it has more recently become possible to introduce small, controlled changes to the acoustic-phonetic features of the speech signal in real-time, allowing researchers to directly explore the role of auditory feedback in speech motor control and speech motor learning. The results of these studies, spanning a range of vowels and consonants, have generally confirmed that adult talkers monitor their acoustic output during speech production and, with practice, adjust the planning of oral movements to maintain a degree of accuracy in the speech acoustic signal.

In this talk, I will describe recent work from my own lab and others that addresses two important issues related to this learning process: 1) how auditory-motor adaptation of the kind examined in these laboratory experiments might relate to the sensory-based learning mechanisms that drive speech motor development in children, and 2) the neuroanatomical basis of speech motor adaptation, and what it might reveal about the nature of the information processing that underlies auditory-motor learning in speech production.

CONTROL OF DURATION AND MAGNITUDE IN SPEECH IMITATION

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Previous research has shown that speakers can imitate subphonemic detail in shadowing tasks. Fowler et al. (2003) showed imitation of VOT: a measure of the temporal difference between release of an oral closure and glottal adduction. However, the relative influences of phonological category and phonetic constraints on imitation are not well understood. The current study examines whether imitation extends to control of a single speech gesture. We find that speakers do imitate differences in gestural duration and magnitude, though imitation is stronger for duration than magnitude and can be moderated by intrinsic phonological differences.

Spanish voiced stops are both shorter and less constricted than voiceless stops.

This could be due to constraints on the relation between gestural duration and magnitude, in which case it is not clear whether the phonological target specifies a gestural duration, magnitude, or both. We used an articulatory speech synthesizer (Nam et al., 2004) to create voiced and voiceless intervocalic Spanish bilabial stops (/apa/ and /aba/) with parametric variation in (1) gestural duration (40 to 140 ms) and (2) target constriction degree (0.3 to -1.5 mm). We then used these stimuli in a delayed shadowing task to examine the extent to which speakers control these parameters independently. To prevent anticipation of the response, 50% of stimuli were distractors (/aka/ or /aga/). Speakers were instructed to repeat the nonsense word they heard, and the movements of their lips, jaw, and tongue were recorded with electromagnetic articulometry. Produced duration and constriction degree were both measured from the recorded articulatory kinematics.

We found a significant effect of stimulus duration: both /p/ and /b/ were produced with shorter durations for shorter stimuli, and longer durations for longer stimuli. Produced duration was significantly correlated with time to peak velocity. Constriction degree shows some imitation, though the size of the effect is extremely small. One subject (out of three) showed a significant effect of stimulus voicing for both duration and constriction degree reflecting phonological differences: /p/ was produced with a significantly longer duration and tighter constriction than /b/.

These results indicate that subphonemic intragestural details are imitated and that imitation can be moderated by phonology. Additionally, the inequality of temporal and spatial imitation indicates that the mechanisms of sensorimotor control are (partly) independent. The correlation of duration with time to peak velocity (and that changes in this measure are often found at prosodic boundaries) suggests subjects may be particularly sensitive to prosodic variation in mirroring tasks.

References

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Nam, Goldstein, Saltzman, & Byrd. (2004). TADA: An enhanced, portable task dynamics model in MATLAB. JASA, 115.

TALKERS COMPENSATE FOR SUBPHONEMIC FEEDBACK ALTERATIONS

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The speech motor control system adjusts articulatory plans when there is a discrepancy between observed and expected feedback. Expected auditory feedback has been proposed to come from one of two sources: (1) an internal estimate of the speaker's current articulatory state, as generated by passing the current set of motor commands through an internal model (Bhushan & Shadmehr 1999), or (2) an acoustic region associated with the intended phoneme or syllable accessed from memory. This experiment tested whether vowel expectations are phoneme-specific or state-specific by examining responses to shifts in auditory feedback within a subject's vowel region. A state-based feedback expectation predicts that talkers will detect and compensate for shifts within their vowel regions, while a phoneme-region-based feedback expectation predicts no ability to detect and compensate for such within-region shifts. To understand whether talkers have precise or general expectations for the target vowel's formants, this experiment examines compensation for a small, subcategorical feedback shift.

Seven male speakers of California English produced monosyllabic hVd words while connected to a feedback alteration device–a headset whose microphone was routed through a computer with experiment-specific software and back into the earphones. Participants heard everything they said in real time; the software altered their formant feedback. Previous work shows that hearing 'head' as 'had', with a higher F1 and F2, causes participants to compensate by producing vowels with a lower F1 and F2 (e.g. Purcell & Munhall, 2006).

In this experiment, subjects saw the word 'HEAD' displayed once every two seconds. After an initial set of trials with no formant shift, participants' formants were shifted gradually up to maxima of 30Hz and 90Hz, and held at each maximum shift for 90 trials. Participants were not aware that their feedback was being shifted.

Participants compensated for both shifts in formant feedback. A t-test shows that subjects produced lower formants in the 30Hz shift condition than in the baseline condition, $p < 0.00001$. Subjects compensated for these within-region feedback shifts as well or better than they did for out-of-region feedback shifts, inconsistent with a formant expectation generated from an entire vowel region. We suggest that formant expectations are computed from specific motor commands and a model of the vocal tract rather than computed from whole phonemes or syllables.

Work supported by NSF BCS-0926196 and NIH R01-DC010145.

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ARE SENSORIMOTOR INTERACTIONS CAUSING LATERALIZATION OF SPEECH PRODUCTION?

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Current models of speech processing propose a bilateral ventral stream for speech comprehension with only some advantages for the left temporal lobe, while speech production strongly left-lateralizes a dorsal network (Hickok and Poeppel, 2007). This left-hemisphere preference for speech production could be due to functional specialization of frontal cortex. Alternatively, specialized sensory cortices supply information in a lateralized manner inducing frontal pseudo-lateralization. We recently showed that in anticipation of sensory feedback, sensory cortices are the first brain regions to lateralize during the preparation for overt speech (Kell et al., 2011), providing support for the second explanation. This indicates that sensorimotor interactions could bias speech production towards the left despite bilaterally organized articulatory and speech comprehension systems. Possibly, left auditory cortex provides better information specifically needed for sensorimotor integration than its right homologue. Consequently, in conditions with disturbed sensorimotor integration (e.g. developmental stuttering) left-lateralization of speech production is reduced (Kell et al., 2009).

We performed a 3T fMRI study on 39 healthy right handed participants to test whether the observed lateralization effects during preparation for overt reading were affected by the use of different levels of cognitive baselines. Subjects prepared either to read overtly, covertly, or to observe unutterable pseudowords devoid of vowels or symbol strings, followed by task execution. An additional target detection task assured equal attentional efforts. Independent of the baseline used, lateralization during overt reading always started in auditory and somatosensory cortices, confirming the robustness of our results.

We had the chance to study a patient who recovered from a traumatic lesion of her left superior temporal lobe in adulthood. It took her two years to recover normal speaking after initial global aphasia. In this patient, auditory feedback relies solely on the right hemisphere. To study whether depletion of left auditory feedback changes the structurally intact speech motor network, the patient underwent the same fMRI protocol and functional connectivity analyses were performed. While controls prepared a bilateral articulatory network, motor pre-activation in this patient was right-lateralized, likely because of lack of left auditory feedback. Sensorimotor integration in the right hemisphere was not involving functional connectivity between planum temporale and primary articulatory motor cortex as in controls. Instead, the patient performed sensorimotor integration on a higher hierarchical level between right superior temporal sulcus and premotor cortex. This strongly points to specific properties of left sensorimotor connectivity that are not shared with the right hemisphere as a basis of left-lateralized speech production.

References

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Kell CA, Morillon B, Kouneiher F, Giraud AL (2011) Cerebral Cortex 21(4):932–7.
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FEEDBACK ALTERATIONS ACROSS VOWEL CATEGORY SPACE

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Auditory feedback enables the online control of speech, allowing speakers to monitor speech output and make adjustments to keep their speech on target. This feedback-based control may occur at a relatively low level, without the influence of experience-dependent perceptual categories, or it may occur at a higher level, after phonetic categorization takes place in the cortex. To test the hypothesis that learned phonetic categories influence feedback-based control, we used functional magnetic resonance imaging (fMRI) to measure neural responses to subjects' speech under three conditions: no auditory shift, a shift across a phonetic category boundary, and a shift within a phonetic category. During altered trials, participants' speech was shifted in both the first and second formant frequencies (F1 and F2) before being fed back through headphones, creating a sudden, unexpected mismatch between the vowel target and the perceived realization. The across- and within-category shifts were of the same magnitude for a given subject, allowing the direct comparison of a phoneme change — for example, from the word "bed" to the word "bad" — with a low-level auditory change — for example, from a prototypical example of "bed" to an altered version of the same word.

Subjects compensated for vowel shifts during altered trials, varying the formants they produced in opposition to the imposed shifts. fMRI data for sixteen subjects showed greater cortical activation in bilateral superior temporal gyrus (STg) and bilateral inferior frontal gyrus (IFg) in shifted conditions than in the normal speech condition. Both the cortical activation and the behavioral compensation was greater for shifts that crossed a category boundary than for those that did not, even though these shifts were of the same magnitude. Furthermore, speakers' ability to oppose the shifts was correlated with shift-related activation in bilateral STg and IFg, suggesting that sensitivity to phonetic changes in auditory feedback may drive the corrective response. Additional trial-by-trial analyses suggest that these correlations vary systematically across a speaker's formant space.

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Tourville, J.A., Reilly, K.J., and Guenther, F.H. (2008). Neural mechanisms underlying auditory feedback control of speech. NeuroImage, 39(3), 1429–1443.

SPEECH MOTOR DEVELOPMENT IN CHILDHOOD APRAXIA OF SPEECH: GENERATING TESTABLE HYPOTHESES BY NEUROCOMPUTATIONAL MODELLING

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Introduction

Childhood Apraxia of Speech (CAS) has been associated with a wide variety of diagnostic descriptions and has been shown to involve different symptoms during successive stages of development. The aim of our research program is to trace back the diversity of symptoms of CAS to specific stages of sensori-motor information processing and to identify potential underlying neurological deficits by using computational neural modelling with the DIVA model (Guenther et al., 2006). Our modelling approach comprises 3 steps forming a cycle. First, based on existing approaches and behavioural data, specific hypotheses about the underlying deficits are generated. These hypotheses are then tested in a series of computer simulations, and the resulting speech patterns are compared to the available behavioural data. Finally, the model is used to derive further predictions that can be tested empirically in behavioural experiments and provide possible new directions for clinical intervention.

CAS in DIVA

In psycholinguistic models, the impairment in CAS can be summarized as an inability to transform an abstract phonological code into motor speech commands. In the DIVA model, this corresponds to poor feedforward control. This is substantiated by behavioural data indicating that CAS involves a disordered development of the functional synergies that underlie speech motor coordination (Terband & Maassen, 2010). We will present a brief overview of a series of modelling studies and suggestions for further research, thereby testing the DIVA model as well as the model of underlying deficits in CAS.

Modelling

Behavioural experiments have found a close relation between perceptual acuity and production symptoms in CAS (Groenen et al., 1996). Our modelling studies provide valuable insight in the specific nature of this relation and suggest that the impact poor feedforward control has on the speech production system is largely dependent on the quality of the auditory feedback control subsystem. More specifically, the impairment of the feedforward control subsystem leads to problems at the level of the forward model if the auditory feedback control subsystem is intact, while it leads to problems at the level of the stored motor commands if this subsystem is also impaired. Furthermore, in the DIVA model, the introduction of errors due to poor feedforward control leads to an overreliance on feedback control. Simulations indicate that overreliance on feedback control affects carry-over more than anticipatory coarticulation and that slowing down articulation facilitates the process of acquiring motor commands. These predictions are directly testable in behavioural experiments.

References

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SPEECH PROCESSING DEFICITS IN CHILDHOOD APRAXIA OF SPEECH

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Purpose

Contemporary research questions in pediatric motor speech disorders are generally cast within a four-phase speech processing framework that includes encoding (representing new words), memorial (storage and retrieval of representations), transcoding (planning/programming representations for speech), and execution (speech motor control) processes. A central question in Childhood Apraxia of Speech (CAS) is whether the core phenotype is limited to deficits in transcoding, or whether neurogenetic deficits are also demonstrable in encoding and/or memorial processes (deficits in execution define dysarthria). We report findings from a study that addressed this question using performance and processing data available from the Syllable Repetition Task (Shriberg et al., 2009).

Method

The SRT was administered to four groups: (a) 18 participants ages 5 to 50 years with CAS in neurogenetic contexts (CAS-N), (b) 20 participants ages 5 to 19 years with idiopathic CAS (CAS-I), (c) 20 participants ages 3 to 6 years with moderate to severe Speech Delay (SD) of unknown origin, and (d) 150 participants ages 3 to 18 years with typically developing speech (TS). SRT responses were analyzed using software that provided both performance and processing scores. Z-scores for all variables were derived using the TS database adjusted for differences in speaker age (gender affects have not been reported for the SRT) and measured intelligence. The software provided statistical tests of between-group differences with standardized effect sizes and Fisher-Exact tests of the proportion of affected/unaffected participants in each group. The three speech disordered groups did not differ significantly in severity of speech involvement, as assessed by several competence metrics.

Results

1. SD participants had significantly lower SRT performance and memory processing scores than TS participants. Encoding and transcoding scores for the two groups were not significantly different.
2. Performance and processing scores for the CAS-N and CAS-I groups were not significantly different, allowing scores from both groups to be combined. The combined CAS group had significantly lower scores on SRT performance, encoding, memory, and transcoding than participants in both the TS and SD groups. Notably, the CAS group's significantly lowered encoding and transcoding scores were obtained on SRT items that were least challenging to memorial processes (i.e., two-syllable nonsense words).

Conclusion

Findings are interpreted as support for an explanatory framework for CAS that includes speech processing deficits in auditory-perceptual encoding, memory, and transcoding. This perspective is consistent with neural system gene expression findings for CAS associated with FOXP2 disruptions, the only genetic basis for CAS reported to date.

Reference

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LANGUAGE AND MOTOR INTERACTIONS IN CHILDHOOD APRAXIA OF SPEECH

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Childhood apraxia of speech (CAS) has been described as a disorder of praxis which results in significantly impaired communication skills. Many children with CAS produce unintelligible speech, making verbal communication extremely challenging. It has been hypothesized that speech production difficulties in children with CAS relate to problems with motor processing (Crary, 1984; Grunwell & Yavas, 1988; Nijland et al, 2002; 2003; van der Merwe, 2009; Grigos & Kolenda, 2010) suggesting that speech motor control may be altered in CAS. This investigation compared articulator movement between children with CAS, children with an articulation disorder (SD) and typically developing controls (TD). Forty participants between the ages of 3 and 8 years (10 CAS; 10 SD; 20 TD) were involved in this study. A facial capture system (Vicon, 460) was used to track lip and jaw movement. The target stimuli included words that differed in syllable length, phonotactic complexity and familiarity.

Kinematic analyses included measures of duration, displacement, velocity and variability. A transcription analysis examined consonant (PCC) and vowel (PVC) accuracy, as well as error consistency (PEC). As expected, consonant/vowel errors and error inconsistency were higher in the CAS than the SD and TD groups. Significant differences in PCC/PVC between one, two and three syllable words were only seen in the CAS group ($p < .01$). Preliminary kinematic results are based on jaw movement associated with accurate productions of one, two and three syllable words. Total movement duration was similar between the CAS and SD groups for single syllable words but was significantly longer in the CAS than SD and TD groups for two and three words ($p < .01$). Closing and opening displacement tended to be greater in the CAS than SD and TD groups ($p < .025$). The largest difference between groups was seen in the two and three syllable words. Both opening and closing peak velocities were smallest in the CAS group for one, two and three syllable words ($p < .025$). Jaw STIs for single syllable words were similar between all groups. STIs were significantly higher for the CAS than SD or TD groups in multisyllables ($p < .01$).

These preliminary findings illustrate differences in movement kinematics between children with CAS and those with SD or TD which supports the notion than motor processes differ between these groups. While increases in linguistic complexity influenced articulatory control in all three groups, the most notable impact was seen in the CAS group.

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THE CURRENT STATE OF RESEARCH IN PEDIATRIC MOTOR SPEECH DISORDERS

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Purpose

Systematic reviews are increasingly viewed as the only rational method for summarizing research on given patient groups and identifying research needs, with more traditional narrative reviews rejected for reasons including their failure to weigh stronger evidence more heavily and their potential for bias. In pediatric motor speech disorders (PMSD), the few available systematic reviews report few findings and cite a critical lack of evidence (Morgan & Vogel, 2008; Pennington, Miller, & Robson, 2009). However, because systematic reviews typically include only studies providing the strongest evidence (e.g., RCTs), they cannot shed much light on the actual state of research in an emerging area. The present study will provide a broader descriptive summary of research in PMSD by including all research exceeding the lower but still significant bar posed by publication in a peer-reviewed journal. Thus, this study can realistically appraise the research base from which future efforts must be launched. The study's two specific purpose are to (1) document the relative proportion of research being conducted in PMSD versus other pediatric communication disorders and (2) examine the nature of current research in terms of the research questions being posed and the extent of programatic research being conducted.

Method

Three reviewers identified articles related to pediatric topics in 8 journals: the American Journal of Speech Language Pathology; Clinical Linguistics and Phonetics, Folia Phoniatrica et Logopaedica, Journal of Speech, Language, and Hearing Research; Language, Speech, and Hearing Services in Schools; Seminars in Speech and Language, Developmental Medicine and Child Neurology, and Journal of Medical Speech Pathology. For each article, one reviewer identified its research focus using 8 categories: motor speech disorders, motor speech development, stuttering, language, phonology, cranio-facial/resonance, voice or other. Operational definitions including rules for category assignment were used. Four major databases (Evidence Based Medicine Reviews, PubMed, PsychINFO, and Medline) were then reviewed to identify additional articles for use in describing research themes and programs of research.

Results and Discussion

Of the 695 reviewed articles to date, only 5% focused on issues related to pediatric motor speech disorders, compared to 66% for child language and 16% for phonology. Research questions varied and with a few exceptions lacked programmatic efforts (i.e., multiple, related publications by a researcher or research group). Discussion focuses on establishing specific goals for expanding research in PMSD.

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THE ROLE OF AUDITORY FEEDBACK IN APRAXIA OF SPEECH: EFFECTS OF FEEDBACK MASKING ON VOWEL CONTRAST

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This study was designed to test three hypotheses about the nature of apraxia of speech (AOS), framed in the DIVA model (Guenther et al., 2006). This model combines two control mechanisms: feedback control and feedforward control. The feedback mechanism generates corrective motor commands when the actual speech deviates from the intended speech; the feedforward mechanism generates predictive motor commands based on past experiences with the target. The FF hypothesis states that feedforward control is impaired in AOS, with consequently a greater reliance on feedback control. The FB hypothesis states that feedback control is impaired in AOS (e.g., concurrent feedback is disruptive; Ballard & Robin, 2007). Finally, the SSM hypothesis states AOS reflects damage to the speech sound map that drives both control mechanisms.

These hypotheses were tested in an experiment involving auditory feedback masking. Previous research shows that speakers maintain segmental contrast (suggesting adequate feedforward commands to support speech without auditory feedback) even though contrast is reduced (suggesting on-line use of auditory feedback control) (Perkell et al., 2007). The FF hypothesis predicts a greater reduction of segmental contrast under masking conditions in AOS patients than in control speakers. The FB hypothesis, in contrast, predicts increased segmental contrast with feedback masking. Finally, the SSM hypothesis predicts normal deterioration of segmental contrast.

The experiment involved six vowels in CVC context in a carrier phrase. Participants saw the phrase on a screen and waited for a go-signal to say the phrase. In the masking condition, speech-shaped noise was presented over headphones at 95 dB-SPL (Perkell et al., 2007) during production of the phrase. Phrases were presented in random order within each block, and the 16 blocks alternated between normal and masking blocks. Acoustic measures of vowel spacing were obtained.

To date, six unimpaired speakers and one patient with AOS completed the experiment. Data from one control and the patient reveal that vowel contrast is reduced when self-generated auditory feedback is masked. The magnitude of this effect is similar for both speakers, consistent with the prediction of the SSM hypothesis. Additional data will be available at the conference, and findings will be discussed in relation to the hypotheses above.

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WHY IS [‘JU:DO] EASIER THAN [JU’VE:L]? PERCEPTUAL AND ACOUSTIC ANALYSES OF WORD STRESS IN PATIENTS WITH APRAXIA OF SPEECH

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Background

Several factors are known to influence the error pattern of patients with apraxia of speech (AOS), e.g., syllable structure or word length. However, though rhythm-based treatment methods have proven successful (Wambaugh & Martinez, 2000), the impact of word stress on apraxic speech has been neglected so far. Furthermore, influences of prosodic information at the phonetic encoding stage of speech production remain often unconsidered (e.g. Levelt et al., 1999).

In the present study, we investigated the influence of word stress on error production in German patients with AOS. We compared two-syllabic words with stress on the first syllable (trochaic words) with words stressed on the second syllable (iambic words).

Method

The materials consisted of 64 two-syllabic, low-frequency words with trochaic and iambic stress patterns. Besides words with simple CV and CVC structures (e.g., ‘Puma, engl. *puma* vs. Me’nü, engl. *menu*) we also included words with complex syllables in the stressed word position (e.g., ‘Plastik, engl. *plastic* vs. Kon’takt, engl. *contact*).

Each word was produced twice in a repetition task. The words were analysed for accuracy of production. Errors were classified as segmental (phonetic distortions, phonemic errors) and prosodic (intersyllabic pauses, phoneme lengthening), respectively. Furthermore, we measured acoustic word and syllable durations.

We present the results of 12 patients with AOS, five of them exhibiting pure AOS.

Results

The patients produced significantly more segmental and prosodic errors on iambic than on trochaic words ($p < .001$ for both error types). The complex iambic words turned out to be the most error-prone items (57% segmental errors, 29% prosodic errors), and trochaic words with a simple CV structure proved to be easiest (29% segmental errors, 8% prosodic errors). Acoustic analyses of word and syllable durations are still not completed.

Discussion

The study showed an influence of word stress on the error pattern of patients with AOS. Trochaic words were produced with less segmental and prosodic errors compared to iambic words. It is assumed that the regular metrical pattern in German, the trochaic form, has a facilitating effect on word production abilities in patients with AOS. The results will be discussed against the background of current models of speech motor programming and the hypothesised pathomechanism of AOS. In particular, we will address the issue of interactions between segmental and metrical properties and their impact on apraxic failure.

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ERROR VARIABILITY IN APRAXIA OF SPEECH: THE END OF A DOGMA?

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Background

It has a long tradition to consider error variability a main feature in apraxia of speech (AOS). Perceived errors are typically described to occur inconsistently and to vary in type and location on repeated productions of the same utterance. Although the concept of error variability in AOS seemed to be a hard-and-fast rule, its validness has become questioned in the last years. Opposite to common beliefs, some authors claim a relatively consistent and invariable error pattern in AOS patients (e.g., McNeil et al., 1995). Moreover, this view is now held in the "treatment guidelines for AOS" (Wambaugh et al., 2006), where errors that are "relatively consistent in terms of type and invariable in terms of location" are considered a primary characteristic for diagnosing AOS (p. xvii). Against the background of this controversy and due to its importance as a diagnostic marker, further investigations into the error variability in AOS seem indispensable. For a comprehensive characterisation, investigations should consider (a) perceptual and acoustic data, (b) segmental and suprasegmental properties as well as (c) different speech levels (e.g., words, phonemes) in (d) identical and non-identical contexts.

Methods

Four patients with a relatively pure, mild-to-moderate AOS participated in the study. Four healthy subjects served as controls. The participants repeated eight phrases, ten times each (e.g. "die Gauner"; engl. "the crooks"). In addition, the phrases were presented in a sentence context (e.g. "die Gauner keuchen"; engl. "the crooks wheeze"). Speech materials covered the target consonants /t/, /d/, /k/ and /g/ word-initially, each in different vowel contexts. The two word onsets in the two-syllable words differed by their voicing properties (voiced vs. voiceless). Analyses comprised (a) perceptual error analyses of words and target sounds using narrow phonetic transcription, (b) acoustic measures of segmental (VOT of word onsets, F1/F2 in vowels) and (c) of suprasegmental aspects (word durations).

Preliminary Findings & Discussion

So far, data from three patients are available, one further patient is currently being evaluated. Preliminary results confirm the assumption of error variability in terms of an inconsistent occurrence of errors and a variable pattern of error types and locations. The results of the study will be discussed against the background of the current controversy regarding error variability as a clinical marker for AOS.

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BIOMECHANICAL MODELS OF SPEECH ARTICULATORS TO STUDY SPEECH MOTOR CONTROL

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Visible and audible speech signals are the results of the movements of the vocal tract articulators. These articulators are made either of bones or of soft tissues. Thus, they have complex and variable biomechanical properties. In our research group, we believe that the influence of these biomechanical properties on the spatio-temporal patterning of speech signals is very important and that it has largely contributed to determine the physical characteristics that are relevant for the linguistic oral exchanges between speakers and listeners.

For this reason we have been working in the last 15 years on the development of increasingly complex and realistic biomechanical models of the tongue, the face and the mandible. All kinds of speech movements have been generated with these models controlled on a target-to-target basis. With such a motor control model, the trajectories, the velocity profiles and the actual amplitudes of the simulated movements are not directly specified by the Central Nervous System. They are the consequences of a combination of effects, namely those of the motor commands patterns and their timing, and those of the biomechanical characteristics of the articulators. Various comparisons of the kinematic properties of the simulated movements with those of real articulatory movements recorded from speakers of various languages (French, German, English and Mandarin Chinese) have been carried out. This methodology allowed us evaluating quantitatively the influence of biomechanics on speech movements, and clarifying which speech movement properties seem to require a specific control from the Central Nervous System and which properties could simply emerge from the physical characteristics of the speech production apparatus.

In this talk the methodology used to design our models will be shortly presented. Then, results obtained at different stages of our work, with different models, will be shown, which illustrate how these models can be used to better understand speech motor control. We will consider examples where biomechanics informs us about the trajectory shapes, the relations between velocity and trajectory shape, the relations between motor control accuracy and acoustic variability, and the influence of dynamical properties on the shaping of soft speech articulators.

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INTRINSIC FACTORS OF ARTICULATORY SEQUENCING: ON HOW THE PERIPHERY SHAPES THE TIMING OF CENTRAL INFLUX TO MUSCLES

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Recent models of speech largely focus on the motor-sensory processes involved in producing and learning articulatory-acoustic features. Few models, however, deal with processes involved in the sequencing of articulatory motions. Those that do generally assume that speech gestures follow centrally represented strings of "phonemes". Our presentation aims to show how this dominant assumption misinterprets the role of central processing and overlooks intrinsic factors of articulatory sequencing at the periphery.

A series of findings partly summarized in Boucher (2008) support the view of Abbs (1996) that opening motions of close-open cycles in speech may not imply central influx to articulators. Instead, opening gestures can simply reflect elasticity effects of relaxing tissues. We present a synthesis of observations using electromyography (EMG) of lip and jaw openers and closers. First, we show that close-open cycles in speech may not involve activity for opener muscles. In fact, EMG activity in speech appears at the onset of closing motions and successive EMG bursts for closer and opener muscles may only occur for non-speech motions, such as chewing. On a second point, we present findings confirming Abbs' contention that spring-like properties of relaxing muscles govern opening motions. By Hooke's law, force applied in compressing a spring leads to an opposite elastic force that displaces a mass at a distance and speed that is proportional to system constants. We found that, in producing close-open cycles, force attributes of a closing motion are indeed proportional to the amplitude and velocity of a following opening gesture. Hence, neural influx that occurs at the onset of a close-open cycle specifies the kinematics of opening motions in the absence of neural influx to openers. Finally, the delay that occurs between "consonant"- and "vowel"-related gestures can relate to intrinsic effects of types of muscle fibers. Specifically, whereas numerous consonantal sounds involve fast twitch muscles, all vowel gestures involve slow twitch muscles (Stål et al., 2003 among others). The later can have relaxation times that are five times longer than those of fast twitch fibers. Thus, the delays may not reflect central commands for successive phonemes.

We discuss the implications of the above findings for current speech production models, Frame/Content theory, and research using brain-imaging techniques, where authors often assume centrally represented sequences of phonemes. In our discussion, we refer to a body of work where critics repeatedly point out that concepts of letter-like phonemes link to the tradition of analyzing speech via alphabetic symbols.

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CAN THE LOCATION OF VOCAL TRACT BENDING CONSTRAIN INDIVIDUAL VOWEL ARTICULATION? EVIDENCE FROM BIOMECHANICAL MODELLING

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Although native speakers of a given language share the same phonemic inventory, speakers vary from one to another in their acoustics and articulation. The variability among speakers may be driven by a variety of factors. This paper focuses on anatomical factors, in particular on the position of the bending of the vocal tract relative to its total length. The relative position of vocal tract bending is fundamental for tongue biomechanics, since the soft tongue body has to fit its surrounding vocal tract borders and muscles may not generate forces in exactly the same direction. If the bending position of the vocal tract is relatively anterior (model A), the length of the horizontal dimension (palatal region) is short in comparison to the vertical dimension (pharynx). A more posterior location for vocal tract bending (model B) corresponds to the inverse relationship, if a similar vocal tract length is used in both models. Given these physical relationships we expect greater articulatory variability in the vertical dimension for model A and greater variability in the horizontal dimension for B.

In order to test these hypotheses two bi-dimensional biomechanical models of the vocal tract were built. These models were elaborated first by matching the geometry of an already existing generic biomechanical model at rest to the vocal tract geometry of a speaker producing a schwa. The speaker specific geometry was extracted from MRI data. Then, for model A we lengthened the original contours of the pharynx by 1.5 cm in the vertical direction and we did the same for model B's oral cavity in the horizontal direction. For each model 8000 simulations were run by varying motor commands driving the six major tongue muscles of the model randomly within a reasonable domain of variation. Formants were computed using a speaker specific alpha-beta model transforming the sagittal shape into an area function and an acoustic analog of the vocal tract. Since auditory targets are assumed to be the primary goal of speech production, the vowel targets for /a/, /u/ and /e/ were defined as identical formant ellipses for both models.

Results of our simulations provide evidence that articulatory variability in the horizontal dimension is larger for model B than A, reaching the same acoustic vowel target ellipsis for /e/. For /u/ this effect is similar, but smaller. Furthermore, model A showed more articulatory variability in the vertical dimension than model B for vowel /a/ which is in agreement with the relatively longer pharynx. In our experiment articulatory variability is constrained by the relative position of vocal tract bending. This position can shape the allowed degrees of freedom and constrains speaker specific articulatory precision for a given vowel target.

EFFECTS OF PHRASE-LEVEL PROSODY ON TONGUE-TWISTER ERRORS

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The integration of prosodic and segmental planning during speech production is not well understood. One proposal - the "prosody-first account"- is that information about utterance-level prominence and phrasing is already available at the time segments are associated to frames during phonological encoding (Keating & Shattuck-Hufnagel, 2002). In an alternative proposal - the "segments-first account"- phrase-level prosodic information (e.g. locations of phrase boundaries and pitch accents) is not computed until segments have been associated to frames (Levelt, Roelofs & Meyer, 1999). Segment errors in laboratory tongue-twister experiments are attributed to incorrect segment-to-frame association, therefore if segment errors are sensitive to prosodic structure, this would suggest that prosodic information is available before segment-to-frame association, supporting the prosody-first account.

In Experiment 1, we elicited 20 ABAB-format tongue-twister sentences (e.g. containing words with /d/ and /g/ onsets in alternation in "Dash would just gaze at her, Gab could not doubt") produced 6 times in succession by 16 undergraduate participants. Location of utterance-level prominence across the four tongue twister words was manipulated by varying the elicitation question (e.g. Who would just gaze at her? "**Dash** would just gaze at her, Gab could not doubt"). Prominence condition and position in the tongue twister interacted such that there was a larger difference in error rate for focussed versus de-emphasised words (more errors on de-emphasised words) in medial than initial or final positions in the tongue twister.

Experiment 2 investigated whether the interaction between prominence condition and position in the tongue twister was associated with position in the Intonational phrase or the utterance. Forty ABAB tongue twister word lists (20 high and 20 low neighbourhood density) were produced in sentences with prominence manipulated as in Experiment 1, but as reported speech (with "I said,"at the beginning or end), by 25 participants. There were fewer errors on prominent words, and an interaction between prominence, position in the tongue twister, and neighbourhood density, with most errors to de-emphasised words in phrase-medial positions on low density tongue twisters. Placing tongue twister words at utterance-initial/final versus phrase-initial/final position had no effect, suggesting that the prosodic phrase, rather than the utterance, is the relevant domain for investigations of position in prosodic constituency.

The prominence effects convincingly support the prosody-first account, but further investigations of effects of prosodic phrasing on tongue twister errors are required because position in the prosodic phrase is typically confounded with tongue twister format, such as the ABAB onset alternation used here.

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THE FRAME/CONTENT THEORY: AN EVO-DEVO CONCEPTION OF SPEECH

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Speech errors reveal that the serial organization of speech is controlled by a syllable structure (or 'frame') constraint on the placement of consonants and vowels ('content' elements) whereby these two segmental forms cannot occupy each others' positions in syllable structure. According to the author's frame/content theory of evolution of speech, (MacNeilage, 2008, The Origin of Speech, Oxford UP) the frame constraint in modern speech evolved because the original relatively simple mouth close-open alternation of the basic consonant-vowel (CV) syllable form, (probably exapted from the mandibular oscillation associated with ingestion) involved an alternation of two antagonistic movements-mandibular elevation and depression. Consequently there was never an opportunity in the evolution of speech for control signals related to these two motorically opposite phases to get mixed up with each other-hence the frame constraint.

This talk will primarily explore the possibility that the ontogeny of the frame in babbling, which is composed primarily of rhythmic CV iterations, holds the key to understanding the ultimate causes of the frame constraint on modern speech. It is one of an innumerably large set of innate 'fixed action patterns', (FAP) identified by ethologists, but rarely including babbling, because of anthropocentrism. It shares with the other FAPs an initial independence from specific experience.

Work with Barbara Davis and other colleagues has shown it also shares the characteristic 'stereotypy' and relative 'form constancy' of these other FAPs. A central aspect of these two properties in babbling is rhythmicity, which is a property of many other FAPs. Babbling occurs at a rate of about 3 CVs per second but with a standard deviation of only about 1/40th of a second. This extreme rhythmicity is present from babbling onset, modally at about 8 months, thus showing that it is not the result of a history of practice via trial and error. Rhythmic reduplicative CV stereotypies in 3 different neuropathological populations reveal that this basic cyclical mode remains present throughout the life span, as required for the CV form to exert a frame constraint on speech production.

Another aspect of this stereotypy and form constancy in babbling is 'Frame Dominance' We have shown that babbling results primarily from mandibular oscillation alone with an extremely limited ability to actively adopt new positions in other articulators during the utterance.

A theme of the new biological subdiscipline of Evo-Devo (evolutionary developmental biology) is that 'ontogeny recapitulates phylogeny'. But a more appropriate saw might be 'altering ontogeny formulates new phylogeny' (Quotes from Goodman and Coughlin, PNAS, 2002, p. 4425). Perhaps developmental changes may have led to the fixation of the cyclical syllabic frames of babbling in the human infant ethogram, providing a basis for subsequent development of the content component in both phylogeny and ontogeny.

SPEECH MOTOR CONTROL AND HEALTHY AGING: THE PARTS MAY SHOW WEAR AND TEAR BUT EXPERIENCE MATTERS

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Communication is about exchanging information effectively. Healthy aging may impact on this, not just because it changes the quality of sensory input (hearing, vision) and speech perception, but also due to physiological changes in the speech production mechanisms. In this presentation, I will start with a brief re-view of what I deem the most important changes as known from the current lit-erature (e.g., Chávez, & Ship, 2000) and their potential impact on speech motor control. Following this, I will discuss the sometimes contradictory findings from recent studies in my own lab (e.g., Bennett, van Lieshout, & Steele, 2007) and elsewhere on differences in speech motor control between younger and older speakers. In doing so, I will argue that in many cases the speech production capabilities of aging individuals seem quite well preserved. I will further suggest that similar to what has been shown for speech perception, older speakers may use their communicative experience (including highly practiced oral motor skills) to compensate for potential limitations in their speech production system. The find-ings and implications for speech production in healthy aging will be discussed with respect to possible consequences for those elderly individuals whose sys-tem will be affected by impairments due to illness or incidents. I will also empha-size the need for a line of research that focuses more strongly on the intrinsic re-lationship between speech perception and production in the elderly, as most of this work is currently done with younger subjects (e.g., Perkell et al., 2004) who typically do not suffer from limitations in these systems.

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PHYSIOLOGICAL WINDOWS ONTO LANGUAGE AND MOTOR PROCESSES IN CHILDREN WHO STUTTER

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Introduction, Overview and Aims

The goal of this presentation is to provide a progress report on a subset of data from our ongoing project on the physiological bases of stuttering in young children. Physiological data are being collected from 4 and 5-year-old children who stutter in a longitudinal study to investigate basic motor timing, speech motor control and coordination, neural bases of language processing, and the interaction of linguistic demands and speech motor control. The long-term goal of the project is to determine if physiological measures can be used to predict persistence or recovery from stuttering in young children. The main focus of this presentation will be the kinematic and EMG speech production data collected in sentence production, conversational speech, and in a novel nonword learning paradigm.

Population Characteristics

To date, 72 children who stutter and 47 children who do not stutter are participating in the 5-year longitudinal stuttering project. These participants were recruited at 4–5 years of age.

Speech Production Tasks

These included short sentences, such as "buy Bobby a puppy" and a set of 4 sentences that varied according to their length (short/long) and syntactic complexity (simple/complex). Participants repeated auditory models of each sentence. Sentence order was pseduorandomized. An attempt was made to obtain at least 10 error free and fluent productions of each sentence by each child. Articulatory kinematic data were collected with an Optotrak 3020 camera system (Northern Digital). The LA variability index (Smith & Zelaznik, 2004) was computed for each subject on each sentence.

Coversational Speech

EMG signals were recorded from right and left lower lip muscles during conversational speech in a natural play setting. EMG amplitude and R/L asymmetry indices were calculated. For CWS measures of fluent vs. disfluent EMG amplitude were computed.

Language-Motor Interactions Nonword Learning

We recorded oral speech movements while the children produce nonwords of increasing length and complexity (e.g., "mab", "mabfaishabe"). The lip aperture variability index and nonword duration were analyzed for early and later nonword productions. Thus we can determine if practice effects occur within the short experimental session. CWS, particularly those with concomitant phonological and/or language impairments, show significant deficits in this task.

Conclusions

Preliminary findings from our ongoing investigation indicate that even by age 4–5 years, the neural systems underlying speech, language, and general motor processing are atypical in many children who are stuttering.

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BABBLING AND BANGING: THE RELATION BETWEEN RHYTHMIC MOTOR BEHAVIORS AND SPEECH ONSET

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Background

During the first year of life infants show a variety of rhythmic stereotypies with their arms, legs and torso. These behaviors show developmental regularities. Specifically, an increase in frequency of rhythmic arm movements coincides with the onset of canonical babbling around 6 months of age (Ejiri, 1998). Previous observational studies of stereotypies in infants suggest that a stable pattern of simple rhythmical behaviors provides opportunities for learning more complex motor behaviors. Furthermore, the oral system and arm motor system are believed to be linked oscillatory systems, and mutual entrainment of these systems in infancy is suggested (Iverson & Thelen, 1999). In this view, babbling is considered part of a more widespread motor development in infancy. In the current study we aim to present further evidence for this hypothesis.

Methods

Infants aged 6 months (N = 18) and 8 months (N = 18) received presentations of a female face on a video monitor producing non-speech oral gestures (bilabial smacks and tongue-tip smacks). All 6-month-old infants were pre-canonical babblers. Fifteen 8-month-old infants were canonical babblers. Three infants transitioned into canonical babbling at a second laboratory visit. Six sets of repetitions of three gestures were presented in trials of 50 seconds. Prior to the gesture presentation, infants were familiarized with the model's smiling face and presented with a control trial. Trained coders annotated video recordings of the infants' responses for oral gestures and arm movements. Single oral gestures and single cycle arm movements were distinguished from rhythmic repetitions of movements. The frequency of the infants' motor responses was measured.

Results

Chi-square analysis revealed a significant relation between AGE (6 months, 8 months) and RESPONSE TYPE (oral gestures, arm movements), $\chi 2$ (1, N = 448) = 36.8, $p < .001$. Six-month-old infants showed significantly more repetitions of arm movements (86.4%) than bouts of oral gestures (13.6%), while 8-month-olds showed a similar percentage of both response types (47.5% oral, 52.5% arm movements). Twenty-five percent of the rhythmic arm movements in 8-month-old infants were produced concurrent with oral gestures. The younger infants showed only 4.5% co-occurrence of arm and oral gestures. Interestingly, 6-month-old infants also showed strong sucking or chewing like movements in response to stimulus presentation.

Conclusions

Previous findings are replicated with different elicitation and analysis methods, and extended with detailed observations of oral stereotypies. Together these results support the hypothesis that babbling emerges from simple rhythmic motor patterns already present in the infant and is part of a broader perceptual-motor developmental process.

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MOLECULAR WINDOWS INTO SPEECH AND LANGUAGE DISORDERS

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The majority of children develop proficient speech and language skills with little conscious effort and without the need for formal tuition. However, a significant proportion have unexplained difficulties acquiring fluent spoken language, in absence of any obvious cause. These problems make substantial impacts on education, mental health and social well-being. Family and twin studies indicate that a child's genetic make-up plays a major role, but it appears that many genes must be involved. Innovations in molecular biology have raised the possibility of identifying specific genomic variants that confer susceptibility. In 2001, my colleagues and I discovered an intriguing gene known as *FOXP2*. Children with mutations that disrupt *FOXP2* have problems mastering sequences of co-ordinated mouth movements needed for fluent speech (childhood apraxia of speech or developmental verbal dyspraxia), accompanied by expressive and receptive language impairments affecting spoken and written modalities. Damage to *FOXP2* itself explains only a small percentage of cases of speech problems. Nevertheless, studies of the function of this gene give a novel route for determining the relevant neuronal mechanisms.

The *FOXP2* gene encodes a regulatory protein which acts to switch on and off other genes. It is evolutionarily ancient, present in similar form in diverse vertebrate species, where it helps to regulate development and function of certain circuits in the brain. Analyses of the gene in primates indicate that it underwent accelerated change on the human lineage after splitting from the chimpanzee, suggesting that its role(s) may have been modified in our ancestors. It is emphasised that *FOXP2* should not be viewed as the mythical 'gene for speech', but instead as one piece of a complex puzzle. My talk will describe how *FOXP2* is being used as a unique window into key neurogenetic pathways. To this end, researchers are exploiting a wide range of systems, from brain cells grown in the laboratory, to animal models. For example, state-of-the-art techniques are being employed to identify genes that *FOXP2* regulates in the human brain (its downstream targets). Remarkably, it seems that some of these targets are themselves implicated in common language-related disorders (Vernes et al. 2008). Studies of *FOXP2* in animals and birds suggest that it is important for maintaining plasticity of brain circuits (Groszer et al. 2008). Overall, this body of work may ultimately yield improved diagnosis and treatment of speech- and language-related disorders. It is also shedding the first light on how the human genome helps to build a language-ready brain.

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PERCEPTUAL AND MOTOR CONSTRAINTS ON SPEECH PROSODY IN DYSARTHRIA

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Impaired prosody is a perceptual hallmark of dysarthria, a neuromotor speech disorder resulting in slurred and imprecise speech. Slow rate of speech, reductions in pitch and intensity range, and/or excessive fluctuations in pitch and/or intensity are commonly cited prosodic deficits. Initially these characteristics were construed as artifacts of articulatory imprecision, but there has been renewed interest in both residual control and aberrant manifestations of prosody in dysarthria. Our recent work suggests that speakers with dysarthria (SWD) due to cerebral palsy can mark at least some prosodic contrasts but that they do so using non-standard cue combinations (Patel, 2003, 2004; Patel & Campellone, 2009). These differences in acoustic profiles between SWD and neurologically normal speakers (NN) have largely been attributed to motor limitations rather than perceptual or conceptual underpinnings. However, it is also possible that speakers with congenital impairments have atypical knowledge of grammatical prosody (phrasing and accent) given their persistent, life-long motor deficits, and that these altered prosodic categories contribute to differences in production prosody. This hypothesis is in line with contemporary computational models of speech production that highlight the importance of auditory feedback in speech motor learning and control (Guenther, 1995; Saltzman & Munhall, 1989) and recent findings demonstrating that experience producing speech can alter speech perception (Houde, 2009; Ito, Tiede, & Ostry, 2009; Nasir & Ostry, 2009). This talk will present data from acoustic, perceptual and perturbation studies on children and adults with and without dysarthria to begin to understand the complex and multifaceted nature of prosodic control. Novel methodologies to assess prosodic categories and production abilities will be discussed.

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EFFECTS OF SPEECH TASK ON MOTOR SPEECH PERFORMANCE IN BASAL GANGLIA DYSFUNCTION: REVIEW AND UPDATE

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Dysarthria arising from motor speech disorders was previously believed to be uniform across speech modalities. Recently, evidence from studies of other motor gestures in basal ganglia dysfunction, such as Parkinson's disease (PD), suggests that initiation and execution of movements are influenced by task conditions contingent on the presence or absence of external models. For example, stepping and arm movements in persons with PD are performed more successfully with an external model (lines on floor, lights for arm movement) (Burleigh, et al.,1997; Schenk et al., 2003). Little attention on analogous task differences has been accorded motor speech (Kent & Kent, 2000).

This paper reviews studies of conversational as contrasted with repeated speech, targeting measures of prosody, voice, intelligibility, and fluency. First, a subject with basal ganglia stroke was found to be dysprosodic in conversation but able to produce normal affective-prosodic contrasts in repetition, as determined by acoustic measures and listeners' ratings (Van Lancker et al., 2006). Further, significantly higher intelligibility scores for repeated compared to conversational utterances were observed in two cases of severe dysarthria, supported by acoustic and clinical data (Canter & Van Lancker, 1985; Kempler & Van Lancker, 2002). In group studies, acoustic measures from 7 PD subjects with deep brain stimulation (DBS) revealed significantly improved voice quality in repetition and DBS ON than in matched spontaneous utterances, while dysfluencies increased in conversation (Sidtis et al., 2010). More recently, listeners' accuracies comparing matched spontaneous and repeated utterances from 13 PD subjects yielded significantly higher intelligibility for repeated exemplars (Sidtis et al., submitted). Finally, a PD subject with severe acquired neurogenic stuttering produced nine times as many dysfluencies in the conversational as in the matched repetition task, with a corresponding (viable) words-per-minute counts: conversation = 100.8 and repetition = 201.0 (Sidtis et al., in prep.). These studies indicate that basal ganglia disease interferes more with spontaneous than repeated speech and support the proposal that the availability of an external model influences articulatory and phonatory parameters during motor speech production.

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DEVELOPMENT OF A BRAIN-MACHINE INTERFACE FOR SPEECH RESTORATION

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This study describes the development of a brain-computer interface involving electrodes implanted in a speech-related area of the motor cortex of a human volunteer suffering from locked-in syndrome, characterized by near-complete paralysis with spared cognition. Neural signals detected from the electrode were used to drive a formant synthesizer in real time. A neural decoding system translated signals corresponding to the intention to produce a sound into parameters for controlling a speech synthesizer that provided the volunteer with immediate (within 50 ms of neural firing) auditory feedback of the decoded sound. In keeping with the DIVA model of speech production, which posits the use of an auditory planning frame in premotor and motor cortex, the decoded parameters correspond to the first two formant frequencies (F1 and F2) of the intended utterance. Offline measurements of neural signals during attempted vowel production verified the DIVA model prediction of significant formant frequency information in the premotor/motor cortex. In the real-time feedback sessions, a training session was first run in which the volunteer attempted to produce sequences of vowels in sync with an audio stimulus. A neural decoder was then trained to map neural signals collected during these attempted productions to the formant frequencies of the intended utterance. After training, the decoder's output was sent to a formant synthesizer to provide real-time audio feedback during attempts to produce vowel sounds. On the first day with real-time feedback, significant improvement in performance (44% decrease in endpoint formant error; $p < 0.005$) was measured from the first five attempts to produce each of three vowels (all failures) to the last five attempts for each vowel. Further improvement was found on subsequent days, with the participant reaching 90% correct productions on a 3-vowel task by the end of the last session. These results support the feasibility of brain-computer interfaces that can provide natural speech output for paralyzed individuals.

DEVELOPMENT OF AN MEG COMPATIBLE SYSTEM FOR THE MEASUREMENT OF SPEECH KINEMATICS: THE MASK PROJECT

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Magnetoencephalography (MEG) recordings can provide detailed information regarding patterns of brain activity that accompany hand and limb movements (Cheyne, 2008). However, there are relatively few MEG studies of overt speech or orofacial motor control, in part, due to the lack of methods for measuring real-time orofacial kinematics in the MEG environment, which cannot tolerate electromagnetic artifacts from commercial motion detection systems. However, modern MEG systems can continuously monitor head position using the MEG detectors to track small coils that emit weak high-frequency magnetic signals that are removed from the MEG data by low-pass filtering prior to analysis [Wilson, 2004]. Similar coil tracking systems are used to obtain non-line-of-sight kinematic data during speech or oromotor movements (Steele & Lieshout, 2004). We present here a novel MEG-compatible coil tracking system designed to monitor brain activity in parallel to ongoing orofacial and speech movements. This new technology, dubbed MASK (Magneto-articulography for the Assessment of Speech Kinematics), can be integrated into existing MEG recording measurement systems in order to acquire orofacial kinematic data simultaneously with neuromagnetic brain activity with millisecond precision and millimeter spatial resolution. The MASK system employs similar principles used in MEG head tracking systems to track the independent motion of up to 12 lightweight coils placed on the head and articulators, using customized electronics and post-processing software that extracts the coil locations over time, and merges this information off-line with the MEG data, providing continuous motion signals perfectly time-locked with the MEG data. Our initial results confirmed the ability to track small coils at movement rates up to 50 cm/s with less than 1 mm error in relative coil position. We will show preliminary data demonstrating the ability to measure the 3-dimensional motion of lips, jaw and tongue and their related brain signals. These new measures provide a novel approach to the study of neural activity accompanying speech production and other oromotor functions in relation to the dynamics of individual movements and their coordination patterns. This technology will also provide an innovative tool for clinical diagnostics for individuals with speech, swallowing and other oromotor disorders and the ability to monitor neural changes resulting from therapeutic (e.g., stuttering therapy) and other clinical interventions (e.g., facial surgery).

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PERIORAL BIOMECHANICS, KINEMATICS, AND ELECTROPHYSIOLOGY IN PARKINSON'S DISEASE

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Hypokinetic dysarthria is characterized by excessive rigidity of agonist and antagonist muscle groups, resulting in a decreased rate and range of movement of the articulator structures (Yunusova, Weismer, Westbury, & Lindstrom, 2008). Despite the fact that more than 80% of PD patients exhibit hypokinetic dysarthria, the effects of orofacial rigidity (stiffness) and coordination of articulators are not well understood. This investigation quantitatively characterized the perioral biomechanics, labial kinematics, and associated electromyography (EMG) patterns in individuals with Parkinson's disease (PD) as a function of anti-PD medication state. Passive perioral stiffness, a clinical correlate of rigidity, was sampled using a perioral-referenced device (OroSTIFF, Chu, et al., 2010) in 10 individuals with mild idiopathic PD and 10 age/sex-matched control elderly. Perioral stiffness, derived as a quotient from resultant force (ΔF) and interangle span (ΔX), was modeled with a multilevel regression technique. Labial movement amplitudes and velocities were evaluated using a 4-dimensional computerized motion capture system during speech production at 2Hz, 3.5Hz, and 5Hz. Associated perioral EMG patterns were sampled to examine the characteristics of perioral muscles and compensatory muscular activation patterns during repetitive syllable productions.

Multilevel regression modeling showed greater perioral stiffness in PD participants, confirming the clinical correlate of rigidity in these patients. As speech rate increased, PD speakers down-scaled movement amplitude and velocity compared to the control participants, reflecting a compensatory mechanism to maintain target speech rates. A significant correlation was found between perioral stiffness and the range of labial movement, indicating these two symptoms may result in part from a common neural substrate. EMG from orbicularis oris inferior (OOIm) and depressor labii inferioris (DLIm) muscles revealed a limited range of muscle activation level in PD speakers, reflecting the underlying changes in motor unit firing behavior due to basal ganglia dysfunction.

The results of this investigation provided a quantitative description of the perioral stiffness, labial kinematics, and EMG patterns in PD speakers. These findings indicate that perioral stiffness may provide clinicians a quantitative biomechanical correlate to medication response, movement aberrations, and EMG compensatory patterns in PD. The utilization of these objective assessments will be helpful in diagnosing, assessing, and monitoring the progression of PD to examine the efficacy of pharmacological, neurosurgical, and behavioral interventions (Sepehri, et al., 2008).

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LEFT DORSAL PREMOTOR CORTEX IS ESSENTIAL FOR SPEECH PRODUCTION: EVIDENCE FROM A VIRTUAL LESION STUDY

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Even though left dorsal premotor cortex (LPMd) has been shown to be active during normal speech production by several functional studies (Price, 2010), not much is known about the nature of this region's involvement in speech output. Therefore, we investigated the exact role LPMd may play in speech production by virtual lesion studies using transcranial magnetic stimulation (TMS). We hypothesized that LPMd, being a pre-motor area, may send feedforward motor programs to the primary motor cortex. Disruption of this area by virtual lesioning would then result in incorrect readout of motor programs and cause a speech deficit akin to apraxia of speech (AOS).

Nine healthy right-handed participants whose primary language was English were enrolled (6 males, mean age 26.8 ± 5.5). LPMd in each participant was identified by blood oxygen level dependent functional magnetic resonance imaging (BOLD-fMRI) during overt speech. Varying intensities of 4 Hz TMS were applied to LPMd using image guided robotically delivered TMS (irTMS) (Lancaster et al., 2004) (Cadwell figure 8 coil). Audio and video were recorded while participants read standard passages during the conditions of TMS, sham TMS, and no stimulation. Perceptual ratings of speech were performed by a speech pathologist blinded to these conditions. Ratings on the quality of intelligibility, articulatory precision, prosody, and vocal quality were performed using a direct magnitude estimation procedure (Weismer & Laures 2002). Intra-judge reliability was confirmed by repeating 25% of the samples in the analysis.

The average location of LPMd where TMS was delivered was at –49, –9, 46 (Talairach coordinates). Perceptual analysis of intelligibility, articulatory precision, and prosody during TMS were found to be significantly decreased compared to no stimulation condition ($p < 0.007$). Vocal quality was not significantly different among the 3 conditions. Across all perceptual ratings of speech, there was a correlation ($r = 0.9$) between speech quality and intensity of TMS with greater intensity of TMS causing greater impairment (lower ratings).

These findings corroborate our hypothesis that transient TMS-induced dysfunction of LPMd results in impaired speech production, consistent with AOS. The decreased intelligibility and articulatory precision observed during the TMS-induced speech disruption indicate impaired access to motor programs. These data provide evidence that LPMd is an important region for speech production that is involved in articulatory plan generation. Investigating for potential lesions in LPMd in patients with AOS can provide further evidence to our preliminary findings.

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EVALUATION OF THEORIES ABOUT STUTTERING

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Two facts about stuttering are that recovery can occur in childhood and that stuttering is ameliorated when auditory feedback of the voiced is altered (AAF). Few theories address both observations but an exception is EXPLAN. According to EXPLAN stuttering arises when speech is produced too rapidly to deal with extracts where language is complex. Speakers can avoid problems on these extracts by pausing or repeating prior words (stalling) that slows motor rate. If speech is not stalled, linguistic breakdown occurs and the complex language forms are produced with part-word repetitions, prolongations and word breaks (advancings).

EXPLAN accounts for high rates of recovery in childhood by proposing that stallings are prevalent at this age and this prevents advancings. Conversely, at teenage when advancings predominate, chance of recovery is unlikely. According to this view, whole-word repetition, WWR (a way of stalling) has a different role to advancing disfluencies. Evidence that supports the different roles of stalling and advancing are reviewed. Lu's recent work on establishing connectivity patterns that has offered support for the CNS architecture involved in stalling and advancing is reviewed. New scanning work that supports the claim that motor centres are involved in stallings and that language centres are involved in advancings is presented.

EXPLAN includes a proposal about why AAF improves the speech control of people who stutter: AAF (and other events that occur concurrent with articulation) slows speech rate and this reduces the chance of stalling and advancing disfluencies. Speech feedback does not need to be analyzed so information can be obtained about how to correct any articulatory errors that may have arisen in spontaneous speech. Past evidence for this view is given. A recent study that showed that performance under DAF correlates with motor, but not linguistic performance that supports this view is presented.

Whilst auditory feedback does not appear to be necessary for ongoing control of speech, there is some evidence that speakers compensate when changes are made to auditory feedback over longer terms. This suggests linguistic or articulatory information can be extracted from the feedback and used to modify the stored motor program for future productions (motor learning). This is a feature of the feedforward control system in the DIVA model. However, recent work by Shiller and colleagues suggests that the process involved in motor learning is different from a classic feedback process. In particular, a feedback process requires a stable perceptual referent to guide production whereas Shiller et al. showed that when production and perception were biased by presenting sounds for categorization with unequal frequencies, perception and production readjusted. Some recent work using Shiller et al.'s paradigm with a novel speech contrast are reported.

SPEECH-MOTOR SKILLS AND SENSORY-MOTOR PROCESSES IN PERSONS WHO STUTTER

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Recent studies suggest that the origin, maintenance and/or exacerbation of stuttering may result from limitations in the speech motor control system to prepare and perform complex motor actions in the presence of cognitive, linguistic, emotional, and speech motor demands. The crucial link between these factors and the speech motor system in people who stutter (PWS) can be found in the speech motor skills (SMS) approach, which views speech production as a motor skill like any other fine-motor skill that humans possess (e.g. writing) with individual skill levels distributed along a continuum. Within this view, PWS are not assumed to have a "disordered" speech motor system, but instead are thought to be located more toward the low end of the speech motor skill continuum (Van Lieshout, Hulstijn, & Peters, 2004). We describe a series of studies carried out to directly test the basic premises of the SMS. If PWS are at the lower end of a motor skill continuum, then one should be able to find differences between PWS and people who do not stutter (PNS) in tasks that impact on such motor skills. Persons with limited motor skills are typically found to show less benefits from practice, reduced functional adaptability to changing task demands, and a greater dependency on compensatory strategies (including the use of sensory information to control and stabilize movements) compared to persons with better motor skills. The results of these studies indicate: (a) PNS improve their motor performance with practice to a greater extent and also retain improvements from practice for a longer time than PWS (b) PWS may have a less efficient, less flexible and less adaptable speech motor system as evidenced by their responses to oral-articulatory bite-block perturbations (c) based on responses of PWS to multi-modal sensory distortions there is no indication that PWS have significant oro-sensory deficits. Instead there is an indication that PWS may selectively use sensory feedback as a compensatory strategy to stabilize their less efficient speech motor control system especially as task demands increase. In sum, these results support the position that PWS may be located more toward the less-skilled (weak) end of a presumed normal speech motor skill continuum (Van Lieshout et al., 2004).

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DIFFERENTIATING BETWEEN AFFERENT AND EFFERENT DEFICITS IN THE SENSORIMOTOR MECHANISMS UNDERLYING STUTTERING

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Theoretical and empirical work suggests that individuals who stutter show deficiencies in sensorimotor learning and control for both speech and nonspeech movements. Here, our aim was to dissociate the afferent component of the orofacial system from the related efferent component in order to examine whether kinesthetic integrity itself is compromised in stuttering individuals (as suggested by De Nil & Abbs 1991; Loucks & De Nil 2006) or, alternatively, whether group differences are observed only when tasks require the generation of motor commands.

We investigated 11 stuttering and 11 nonstuttering adults' kinesthetic sensitivity and accuracy for passive jaw movements as well as their minimal displacement and spatial accuracy for active jaw movements. The experiment involved four tasks with a common experimental set-up. A robotic device, coupled to the jaw by means of a rotary connector and individually-fitted dental appliances, implements passive movements of the jaw in two tasks and records the kinematics of active jaw movements in two other tasks. In the passive jaw movement tasks, subjects manually operate a joystick to provide information about the perceived movements.

In Task I (active, minimal movement threshold), subjects actively made the smallest possible jaw movements. In Task II (passive, kinesthetic detection threshold), the robot moved the jaw passively and subjects indicated whether or not they felt the displacement. In Task III (active, normal range of motion accuracy), the robot first moved the jaw to a position within the range of motion for speech, subjects were asked to memorize that position, the robot moved the jaw back to baseline, and then subjects actively returned to the memorized position. In Task IV (passive, normal range of motion accuracy) the robot moved the jaw to a position within the range of motion for speech, and subjects moved the joystick to indicate the perceived jaw position.

Results indicate that the stuttering group differed from the nonstuttering group only when active movement generation was involved and not in the sensation of passive movements. Within the context of a theoretical framework of stuttering (Max 2004), we discuss the potential role in stuttered dysfluencies of sensorimotor integration (using current and future state estimation in planning/correcting movements) and motor command generation (inverse kinematics/dynamics by means of internal models).

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CENTRAL INTEGRATION OF DUAL SOMATOSENSORY INPUT TO THE OROFACIAL REPRESENTATION IN PERSON WHO STUTTER

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Introduction

Persistent developmental stuttering is a speech fluency disorder affecting 1% of the adult population, predominantly males. The etiology is unclear with likely contributions from intrinsic factors pertaining to brain anatomy and neurophysiology (Buchel & Sommer, 2004). To further clarify part of the intrinsic factors we investigated whether stuttering shows neurophysiological alterations typically observed in focal dystonias. We adapted a method from Tinazzi et al. (2000) who observed abnormal central integration of dual somatosensory input in patients with dystonia ("sensory overflow").

Material and Methods

31 participants were recruited, 16 persons who stutter (mean age 28.73, SD 11.61, 3 females) and 15 age matched persons who do not stutter (mean age 30.2, SD 7.62, 4 females). All participants were otherwise healthy. Somatosensory evoked potentials were induced by stimulating separately or simultaneously the face at the corner of the mouth and the tongue. The left and the right side were studied separately. The SEPs were recorded conventionally and bilaterally at C5' and C6'. Latencies (N13, P19 and N27) and peak-to-peak amplitudes (N13-P19 and P19-N27) were measured off-line. Ratios for either amplitude were calculated by dividing the amplitudes induced by simultaneous stimulation by the sum of the amplitudes recorded after separate stimulation. Repeated-measures ANOVA with 'group' as between-subjects-factor and 'side of stimulation', 'hemisphere', and 'type of stimulation' was used for preliminary analysis.

Results

In both groups, amplitudes were smallest with face only stimulation and slightly increased by simultaneous facial and tongue stimulation (effect of type of stimulation, $F(2, 58) = 12{,}18$, $p < 0.0001$). The amplitude ratios did not show an effect of group, indicating that excessive sensory overflow does not play a major role in persistent developmental stuttering. Unexpectedly, the SEP latencies were shorter in the patient group than in the control group (effect of group, $F(1, 29) = 5.04$, $p = 0.033$); particularly after tongue stimulation and after simultaneous tongue and face stimulation (interaction of type of stimulation by group, $F(2, 58) = 4.1$, $p = 0.022$).

Discussion

As already suggested by recent data on intracortical motor cortex excitability, the clinical analogy between focal dystonia and persistent stuttering is not supported on a neurophysiological level. Rather, the data provide evidence of shorter latencies of somatosensory evoked potentials, pointing to conduction abnormalities in afferent sensory fibers predominately from the tongue area in individuals with persistent developmental stuttering.

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IMPAIRMENT OF THE BASAL GANGLIA THALAMO-CORTICAL LOOP MAY LEAD TO DYSFLUENCIES: SIMULATING NEURAL IMPAIRMENTS TO SYLLABLE-LEVEL COMMAND GENERATION IN STUTTERING

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Recent findings of neural abnormalities in the brains of persons who stutter provide the best evidence for a neurological basis of stuttering. We hypothesize that some or all of these neural abnormalities lead to an impairment in the ability of persons who stutter to read out motor commands for well-learned syllables (feedforward commands). This impairment may lead to different types of dysfluency: sound/syllable repetition, prolongation or block.

We propose that the integrity of the basal ganglia (BG) - thalamus - left ventral premotor cortex (vPMC) loop is essential for proper readout of feedforward commands. Neural abnormalities may disturb this circuit in at least two hypothesized ways: 1) due to white-matter impairment in the corticostriatal projections carrying corollary discharge of motor commands, and 2) due to increased dopamine binding in the striatum leading to a ceiling effect, i.e., multiple thalamic neuron populations have maximum activation. In both hypotheses, dysfluencies result from delayed activation of the vPMC neuron population responsible for reading out the feedforward commands for the next syllable.

Most past hypotheses concerning BG dysfunction in stuttering cannot be tested using imaging data because they cannot predict whether particular brain regions would be over- or under-activated during stuttering. The BG's internal circuits are very complex, including many inhibitory connections, and as a result the relationship between metabolism and signaling is unclear, making it difficult to predict neural activations. We overcome this problem by testing our hypotheses with an extended version of the GODIVA model (Bohland, Bullock & Guenther, Neurosci, 2010). As a neurobiologically specified model, it is able to predict the blood-oxygenation-level-dependent (BOLD) response of the brain during simulated speech tasks (cf. Guenther, Ghosh & Tourville, Brain Lang, 2006).

Simulations of the GODIVA model demonstrated that both white-matter impairment and increased dopamine binding can account for key aspects of stuttering. Furthermore, the neural activations predicted by the simulations agree with most published results: hyper-activation in the putamen and thalamus, and deactivation in GPi and vPMC. The simulations also account for the alleviation of stuttering with D2 antagonists. In both hypotheses, the D2 antagonists strengthen the indirect pathway of the BG by preventing dopamine from exerting its inhibitory effect on the putamen D2 neurons. The strengthening of the indirect pathway counteracts over-excitation of the direct pathway of the BG (in the increased dopamine binding hypothesis), and compensates for the impaired inputs to the striatum (in the white-matter impairment hypothesis). Simulations of future variants of the model could clarify how other drugs, such as the partial D2 agonist aripiprazole, affect the frequency of stuttering.

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BRAIN LESION-SYMPTOM MAPPING IN PATIENTS WITH STROKE-INDUCED NEUROGENIC STUTTERING

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Introduction

Neurogenic stuttering is an acquired speech disorder characterized by the occurrence of stuttering-like dysfluencies following neurological disease. In published case studies, neurogenic stuttering following stroke has been associated with lesions in a wide variety of brain regions including subcortical regions such as thalamus, brainstem, basal ganglia and cerebellum, as well as cortical regions including temporal and parietal lobe, supplementary motor area, and frontal cortex in both hemispheres (De Nil, Rochon & Jokel, 2009). In this study voxel-Based Bayesian Lesion-Symptom Mapping (vBLSM) (Chen & Herskovits, 2010) was used to identify lesion-symptom correlates in a group of stroke patients with neurogenic stuttering.

Methods

Twenty stroke patients diagnosed with neurogenic stuttering and 17 stroke patients without stuttering participated in the study. Lesion maps and behavioral data were analyzed using vBLSM. This analysis technique allows researchers to calculate the probability that the lesion proportion in a given voxel differentiates between patients with and without neurogenic stuttering. For the purposes of the present study, the lesion proportion differences threshold was set at >0 and the probability threshold for inclusion of the identified voxels was set at >.95.

Results and Discussion

Comparative analysis of the lesions of the patients with neurogenic stuttering and controls revealed that 9 left-hemispheric areas were more frequently lesioned in patients with neurogenic stuttering. These areas could be localized to both grey and white matter and most of them are commonly included in neural models of speech production. These findings are consistent with the presence of a cortical-subcortical network associated with fluent speech production and they indicate that stroke-induced lesions anywhere in this network may result in neurogenic stuttering. Interestingly, many of the brain regions observed to differentiate between stroke patients with neurogenic stuttering and controls are part of the cortico-basal ganglia-cortical loop which has been implicated in developmental stuttering as well.

Conclusion

Consistent with the view that speech production emerges following an intricate interaction between both cortical and subcortical areas and their white matter connections, we suggest that a dysfunction in the neural network responsible for speech production might result in a disordered integration of neural functions necessary for fluent speech and thus in the onset of stuttering-like dysfluencies following stroke. The imaging data obtained in this prospective study of stroke patients provide a basis for the development of specific hypotheses regarding the role of brain processes in the onset of neurogenic stuttering. In addition, these findings may contribute to the development of neural processing models of normal speech production and developmental stuttering.

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INTERGESTURAL MOTOR CORTEX EXCITABILITY IN PERSISTENT DEVELOPMENTAL STUTTERING

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Persistent developmental stuttering (PDS) is a speech fluency disorder that affects 1% of the adult population, predominantly males. Its etiology is unclear and likely multifactoral, with contributions from intrinsic factors pertaining to brain anatomy and neurophysiology, particularly abnormal right-hemispheric lateralization of blood flow in motor and premotor areas (Fox et al., 1996). Clinically, a major feature of stuttering is the paroxysmal inability to pass on from ongoing to the subsequent articulatory configuration, resulting in repetitions. This pattern is reminiscent of the start hesitation in advanced Parkinson's disease (Alm, 2004). To clarify the neurophysiological basis of this intergestural transition, we investigated changes in motor cortex excitability between articulatory gestures.

We studied 27 native speakers of German, 13 individuals with PDS (mean age 33.9 years, SD 11.85; four females) and14 age- and sex-matched fluent speakers (mean age 31.24 years, SD 8.71, four females). To test the modulation of motor cortex excitability in the intergestural phase of speaking, participants were asked to read isolated verbs aloud in a delayed reading paradigm. All verbs started with the prepositional prefix "auf" followed by a verb stem (controlled for frequency, phonetic complexity, amount of letters, amount of phonemes, amount of syllables and word accent; e.g. "aufbleiben" [to stay awake]). Subjects were asked to pronounce the prefix ("auf") and to prolong the "fff" until a visual cue indicated to pass on. Excitability of the primary motor cortex of the tongue was assessed with transcranial magnetic stimulation interspersed in this verbal non-choice reaction time task.

Both hemispheres were stimulated in separate sessions in a balanced order, with 70 trials for either hemisphere. Bilateral electromyography was recorded from a mouthpiece placed on the upper top of the tongue. Acoustics were recorded simultaneously. Off-line, we determined the motor evoked potential amplitudes and normalized these amplitudes to the individual baseline tongue motor evoked potential (i.e. during pronouncing, "auffff"). To determine the time course of excitability modulation we extracted the acoustic latencies relative to the individual voice onset of the target items.

Fluent-speaking control subjects showed an increase of motor evoked potential amplitudes before voice onset of the target gesture after stimulation of the left motor cortex, and to a much lesser extent after stimulation of the right motor cortex. By contrast, stuttering adults lacked any premovement facilitation in the left motor cortex, but showed a marked premovement facilitation in the right motor cortex.

These results clearly indicate a dysfunctional left motor cortex modulation in the intergestural phase in adults who stutter, and an excessive and possibly compensatory involvement of the right motor cortex.

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POSTER SESSION I

DORSAL PATHWAY TRANSFORMS PERCEPTION TO ACTION, NOT SENSATION TO MOTOR

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Introduction

Current thinking proposes a dual-stream model for speech processing: A left-lateralized dorsal stream that maps perceived speech signals to frontal lobe articulatory networks and a bilaterally organized ventral stream that is supposed to subserve speech recognition (Hickok and Poeppel, 2007). Because lateralization of overt reading starts in sensory cortices and is not seen in the dorsal stream (Kell et al., 2011), the proposed model is challenged. We set out to disentangle the role of the ventral and the dorsal streams during speech perception and production and their lateralization during task preparation and execution.

Methods

We performed an fMRI experiment on 39 healthy right-handed participants and on a patient who recovered from a traumatic left posterior superior temporal lesion in adulthood. Our cue-target paradigm involved three different conditions contrasted against a visual control condition (observing symbols): reading sentences overtly (speech production) or covertly (speech comprehension), or observing consonants that had a sentence-like structure (prelexical speech processing). An auditory cue informed subjects about the upcoming task and implicitly informed about the expected stimulus type while prediction of specific stimulus (linguistic) content was impossible. Subjects were trained for cognitive association of a specific cue with a specific stimulus type and task. The variable instruction delay (2–4s) allowed for a dissociation of task preparation from execution. Data were analyzed in SPM8. Results were family wise error corrected for multiple comparisons at $p < 0.05$.

Results and Discussion

Covert reading targets the bilateral ventral and left dorsal stream both during preparation and execution. Due to the perceptive nature of the task, we propose that these two classical streams originating in posterior temporal lobe are primarily involved when perceived speech is transformed in motor routines. Lateralization of the entire dorsal pathway would be a consequence of specialization of its input region. This is supported by the lack of left premotor/prefrontal involvement during covert reading if posterior input is impossible due to a lesion. In this patient, speech comprehension of written language involves a left occipitotemporal route linking visual word form area to Broca's area (Hickok et al., 2011).

During preparation for overt reading, lateralization is only seen in sensory cortices while the rest of the anterior frontotemporal network is pre-activated bilaterally. Subsequent sensorimotor integration may bias the speech production system to the left.

Lateralization of the dorsal pathway may thus point to transformation of perceived speech into production routines in the framework of state feedback control (Hickok et al., 2011). If speech is internally generated, a lack of dorsal stream involvement can be envisaged.

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CORTICAL RESPONSES TO SPEAKING AND LISTENING WITH PITCH-ALTERED FEEDBACK

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The role of sensory feedback in speech is complex and remains poorly understood. Experimental manipulation of auditory feedback during speaking offers a unique window to understand the neural substrates of speech motor control. Functional neuroimaging allows for study of the neural correlates of speech production and the effects of speech production on auditory perception. Evoked activity studies have shown speech causes "speaking induced suppression" (SIS) in auditory cortex and other areas of the superior temporal plane (Houde et al, 2002; Ventura et al, 2009). In this study we explored the dynamics of speech production and auditory perception during single vowel utterances using magnetoencephalography (MEG). Data was collected using a 275-channel biomagnetometer (VSM MedTech, Coquitlam, Canada) and analyzed in the time-frequency domain using the NUTMEG software package. Subjects produced single vowel utterances and heard their voice through headphones in randomly interleaved trials of either unaltered or pitch-shifted voice. The pitch shifts were of either one hundred or three hundred cent magnitude. In a separate run, subjects passively listened to the recording of their unaltered and pitch-shifted voice. During speech and speech preparation oscillatory power in the beta range (12–30 Hz) decreased and oscillatory power in the high gamma range (65–115Hz) increased over sensorimotor cortex, representing motor preparation and execution. In both the speaking and listening conditions, voice onset caused event related desynchronization (ERD) in the beta range in auditory areas (superior temporal gyrus). However, the ERD was greater in the listening condition than the speaking condition in posterior superior temporal gyrus (STG). This difference in activity demonstrates speaking induced suppression in the beta band. In the high gamma band (65–115Hz) the response to auditory onset of voxels centered around STG/Brodmann area 22 modulates significantly with alteration level during speaking. These results suggest that neural activity in auditory cortex is modulated with expectation of auditory signal. The results of this study also highlight the importance of analyzing the neural data in distinct frequency bands. This work was funded by NSF BCS-0926196, NIH R01-DC010145 and Predoctoral Fellowship from Bay Area Consortium for Affective Science.

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DO PHONOLOGICAL NEIGHBOURHOOD DENSITY AND PHONOTACTIC PROBABILITY INFLUENCE AUDITORY WORD RECOGNITION IN HEALTHY AND IMPAIRED SPEAKERS

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Introduction

This study investigated whether phonotactic probability (PROB) and phonological neighbourhood density (ND) influence auditory word recognition in healthy and impaired speakers. Previous studies have been hampered by the confoundedness of these two predictors. We chose a cross language paradigm to address this issue. Uniquely, English and German share a large number of phonetically similar or identical real words (e.g. leader-Lieder). These words have the same language-independent features (e.g. number of syllables) but differ in language-specific factors (e.g. PROB, ND, frequency). Comparing the performance of English and German speakers on such quasi-homophones enables examination of language independent and language specific variables as predictors of performance of auditory word recognition.

Methods and Results

Sixteen healthy English, 16 healthy German and four English speakers with aphasia and speech output problems completed an auditory lexical decision task employing one- (N = 63) and two-syllable (N = 62) real (N = 125) and non-words (N = 125) ranging in syllable complexity. Response accuracy and reaction time were measured. Real words were (near) homophones across German and English; non-words were plausible in both languages.

Regarding reaction time, ND had an inhibitory effect for healthy speakers, i.e. higher ND was associated with slower reaction times. PROB showed a facilitatory effect (faster reaction times) for the healthy English speakers only. No ND/PROB effect was seen for healthy speakers' response accuracy. For 1-syllable items no ND/PROB effect was noted. However, ND had an inhibitory and PROB a facilitatory effect considering 2-syllable real and non-words. PROB showed a facilitatory effect on reaction time for 2-syllable items.

Neither ND nor PROB demonstrated an independent significant effect on impaired speakers' reaction times or response accuracy.

Discussion

Only language-specific variables appeared to influence auditory word recognition in the healthy and impaired speakers.The inhibitory effect of ND found in the literature (e.g. Luce & Pisoni, 1998) was replicated here for the reaction time data. Accounting for the facilitatory PROB effect is less straightforward. Other studies suggest PROB effects are seen once lexical competition is removed. However, theoretical models claim that both activation and competition between phonologically similar words are the hallmark of lexical decision employed in this study (e.g. Luce et al., 2000). Finding the facilitatory PROB effect only when considering 2-syllable items might be explained by the level of competition between phonologically similar words. This however cannot explain why the ND effect was also only shown when considering 2-syllable items.

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BOLD RESPONSES TO PITCH-SHIFTED VOICE FEEDBACK

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Introduction

Recent studies have demonstrated that voice fundamental frequency (F0) control relies in part on auditory feedback. Perturbations in voice pitch feedback result in compensatory changes in voice F0 (Burnett et al., 1998). The latency of these responses (100–150 ms) suggests that the neural mechanisms responsible for these responses occur within 50 to 100 ms. The present study was done in order to define brain regions where part of the processing of these responses may occur.

Methods and Results

3T fMRI data were collected on 8 healthy volunteers using a sparse sampling technique triggered by each vocalization. Each trial began with visual and auditory cues. During vocalization, subjects sustained an "ah" vowel for 5 seconds while listening to their own voice. During vocalization the pitch of the voice was shifted upward or downward (±100 cents, 200 ms duration). Trials were also conducted where no shift was applied and during baseline trials (rest). One functional volume taking 4 seconds was acquired per trial 5.25 seconds after stimulus onset. Image analysis was performed using SPM8 software. While substraction analysis (shift vs. no shift) was used initially, we are currently analyzing data with multivariate correlations of the degree of response to shifts in each subject.

A comparison of the BOLD response for shift vs. no shift demonstrated bilateral activation in the primary auditory cortex, superior temporal gyrus (STG) (BA 41/42), insula, inferior frontal gyrus and cerebellum. Two individual clusters of activation, one being more anterior and one more posterior, were identified within the STG during pitch-shifted feedback.

Discussion

Voice F0 responses to pitch-shifted auditory feedback involve several processes including, identification of self-vocalization, perception of vocal pitch, detecting differences between the desired F0 and pitch feedback, and activating various muscles. All these processes take place within approximately 50 ms without conscious awareness. Results of the present study suggest these processes occur within the premotor cortex, inferior frontal gyrus, STG, insula, cerebellum and motor cortex. While many of the locations found are similar to other studies, there were also differences (Zarate and Zatorre, 2008, Tourville, 2008) that may reflect the specific tasks used which include involuntary (this study) versus longer range voluntary adjustments in voice F0 control mechanisms.

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AUDITORY AND SOMATOSENSORY ADAPTATION IN ADULTS WITH COCHLEAR IMPLANTS

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The interactions between sensory feedback and feedforward speech commands have direct implications for adults with cochlear implants who have experienced long-term auditory deprivation (Lane, et al., 2007). In this study, somatosensory and auditory feedback were manipulated in adults with normal hearing (NH) and adults with a cochlear implant (CI) to test the role of sensory feedback manipulations on fricative production (/s, ʃ/). The auditory manipulations in normal speakers involved either delayed auditory feedback or pink masking noise. In CI speakers, audition was manipulated by turning the CI ON and OFF. For both groups, the somatosensory perturbation was a modified electroplatography (EPG) palate in which the alveolar portion was substantially built up, which was contrasted with an EPG palate that followed the individual's actual palatal contour. We predicted CI speakers would take longer to adapt to the sensory perturbations as evidenced by reduced /s- ʃ/ in terms of acoustics and tongue-palate contact. Anatomically accurate EPG palates and perturbed EPG palates will be constructed for six right-handed, normal hearing (NH) speakers of American English and six right handed CI speakers of American English. To date, we have completed testing with 2 NH speakers and 1CI speaker. The experimental Sequence was (1) Baseline (2) Perturbed palate + Perturbed Hearing (3) Perturbed palate + Normal Hearing 4) Normal palate + Perturbed Hearing (5) Normal palate + Normal Hearing. We identified /s/and /ʃ/ productions in the acoustic record first followed by a 'center of gravity' (COG) measure that indicated the degree of anterior vs. posterior tongue contact. Multi-taper estimation was used to generate spectra of the fricatives. We have completed testing with 2 NH speakers and 1 CI speaker (Testing of 2 additional NH speakers and 2 CI speakers will occur between February-March, 2011). The combined effect of the somatosensory and auditory perturbation on the syllable /asa/ in NH speakers was unexpected. In the first two trials of the perturbation condition (Perturbed palate + Perturbed Hearing), the EPG and acoustic records indicate that speakers did not form a channel for /s/ and instead produced a distorted stop type production. In Trial 3, the speakers were able to form a channel to produce a somewhat distorted /s/. Perceptually, this pattern was repeated in the single CI speaker. Ongoing analyses are looking at the /s/-/ʃ/ contrast in trials where a channel for a fricative was achieved. The current results suggest that combined sensory perturbations can alter typical productions that must be corrected in subsequent productions.

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USING SINE-WAVE SPEECH TO EXAMINE THE PERCEPTION-ACTION LINK IN SPEECH

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Humans are able to recognize their own actions even when perceived from unfamiliar angles or from impoverished stimuli. This has been shown for a variety of tasks in both the visual and auditory domain, lending support to theories of perception which assume a common representational currency between perception and action. There is a continuing debate as to whether a common coding of perception and action can be shown to exist in speech, as proposed among others by Direct Realism and Motor Theory (Fowler et al., 2003). Here we investigate the nature of the perceptuo-motor link in speech using sine-wave speech (SWS). SWS lacks voice-related speaker characteristics while preserving formant dynamics. Previous work has shown significant effects of speaker familiarity in SWS recognition, providing evidence for the characteristic production dynamics of a speaker being preserved in SWS (Remez et al., 1997). We therefore used SWS to investigate whether speakers employ self-knowledge of their own production dynamics in speech perception. We recorded 28 speakers on a set of 100 sentences. Several weeks later, the same speakers participated in a perception experiment in which they listened to time-normalized sine-wave replicas of their own and others' recordings. Half of the participants were required to identify their own speech in a simple yes-no task. Results showed that these participants were on average not able to reliably identify their own speech. The other participants performed a sentence-recognition task in which they wrote down the SWS sentences they heard. During the first 50% of trials of the experiment speakers showed a 5% higher recognition score for 'self'- than for 'other'-produced sentences, even though this difference did not reach significance. Due to a learning effect over the course of the experiment, for the second 50% of trials, participants performed equally on 'self' and 'other' trials. The results provide some support for speakers using knowledge of their own production dynamics in speech perception and are as such consistent with models that assume a common coding for perception and action (Hommel et al., 2001). However, they also show that perceiving one's own SWS speech differs to such an extent from our usual auditory self-experience that direct self-recognition does not occur.

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SPEECH MOTOR DEFICITS IN HEREDITARY CEREBELLAR DEGENERATION

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Objective
To specify the profile of ataxic dysarthria and its severity in patients with different variants of a hereditary neurodegenerative ataxia, i.e. Friedreich's ataxia (FA) and two spinocerebellar ataxias (SCA3, SCA6), and to relate the speech data to various clinical features.

Background
The common core symptom of FA and SCA is the presence of ataxia. From a neurological and clinical perspective, FA and the various subtypes of SCA are, however, quite heterogeneous constellations (Schöls, Bauer, Schmidt, Schulte & Riess, 2004). Nearly all patients develop "ataxic dysarthria" but there is a lack of studies comparing the motor speech characteristics of these patient groups and it is not clear if / to what degree clinical features are related to variables of speech motor control (Ackermann, Mathiak & Riecker, 2007).

Methods
37 patients (18 FA, 10 SCA3, 9 SCA6) and 10 healthy control speakers participated in this study. Neurological diagnoses were based on molecular-genetic analyses. Ataxia was rated using the "Scale for the Assessment and Rating of Ataxia" (SARA). Speech assessment included a) intelligibility rating, b) various speech production tasks (guided interview, sentence repetition, text reading, and picture description), and c) "para-speech" tasks (oral diadochokinesis (DDK) and sustained vowel productions (SVP)). The obtained data were analyzed by means of acoustic measurements and perceptual evaluation.

Results
There was a strong correlation between the SARA score and the severity of dysarthria. Regression analysis disclosed the speech parameters 'voice regularity' and 'speech rate' as significant predictors of the severity of ataxia (SARA). The patient groups showed, in general, no significant differences in dysarthria profiles. Nevertheless, some interesting trends emerged: For example, the SCA3 group decelerated speech rate to a lesser degree than FA / SCA6 patients and the SCA6 group showed less pronounced voice irregularities, but more frequent respiratory problems than the other two groups. Furthermore, a discrepancy between speech tasks and DDK / SVP performance could be observed.

Conclusions
Clinical ataxia scores are correlated with the severity of dysarthria. The variables 'voice regularity' and 'speech rate' are predictors of the severity of ataxia. If severity of impairment is accounted for, motor speech deficits across the considered etiologies show a quite homogeneos profile. The validity of the widely used DDK and SVP tasks must be considered with caution as they are less valid and can be misleading.

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ASSESSING DYSARTHRIA USING VARIABILITY MEASURES FROM AUDIO RECORDINGS

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Classification and characterization of motor speech disorders (MSDs) is important from the viewpoint of diagnosis and treatment. Clinical diagnosis is primarily based on auditory-perceptual characteristics of perceived speech abnormalities, but is subject to unreliable clinical judgement and quantification, and difficult to relate to the underlying pathophysiology. In this study we investigate whether it is possible to diagnose dysarthria based on measures of speech variability by using Functional Data Analysis (FDA) (Ramsay et al., 1996). A reliable quantification of variability in speech can potentially reveal underlying motor control problems, enable early detection of sub-clinical speech abnormalities, and provide sensitive and quantifiable outcome measures that aid treatment strategies. FDA has been shown to be successful in investigating variability of kinematic movements obtained by lip displacement tracking, but may also be applied to other dimensions of speech, including amplitude envelopes and pitch and formant tracks. Anderson et al. (2008) used FDA to calculate spatial and temporal variability of amplitude envelopes of sentence repetitions produced by patients with hypokinetic and ataxic dysarthria and demonstrated that variability characteristics were influenced by dysarthria type.

In the current study, we aim to extend these findings by employing a wider range of speaking conditions and speech variables, and including a standardized acoustic clinical assessment of dysarthria. Participant groups included five patients with mild to moderate hypokinetic dysarthria due to Parkinson's disease; five patients with mild to severe ataxic dysarthria due to various underlying neuropathologies, and ten control participants without a speech disorder. The phrase "Tony knew you were lying in bed" was repeated around twenty times during six speaking conditions: at habitual, slow and fast speech rate, and at habitual rate with increased sentence length with and without increased syntactic complexity, and whilst performing a simultaneous drawing task. The amplitude envelope, fundamental frequency, first and second formant tracks were extracted, filtered and normalized. The tracks were then non-linearly stretched using FDA, allowing a separate calculation of spatial and temporal variability. For the acoustic speech assessment, a series of diadochokinetic tasks, a vowel prolongation task and a reading task were employed. Rate, regularity and accuracy of syllable repetitions, maximum phonation time and pitch and intensity ranges were measured to evaluate motor control performance and speed, flexibility and regularity of articulatory movements. The measures of speech variability were compared across speaker groups, and correlated to the results of the acoustic speech assessment.

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PRINCIPLES OF MOTOR LEARNING IN STUTTERING TREATMENTS

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Evidence that developmental stuttering is an impairment of the speech-motor system is given credence by neural studies and computational modelling (e.g. Civier, Tasko & Guenther, 2010). It is well known that relapse following stuttering treatment is problematic with short-term gains following treatment not being sustained in the longer term (Cream, O'Brian, Onslow, Packman & Menzies, 2009). Strategic application of principles of motor learning (PML) to treating speech motor disorders may offer more sustainable, long-term speech-motor change for people who stutter (Maas et al., 2008).

Thus, seven stuttering treatments that met inclusion criteria of (1) being manualized and (2) having at least one published, peer-reviewed study were examined to determine the presence of Principles of Motor Learning as described by Maas et al., 2008. Selected stuttering treatments were examined against a checklist which detailed all elements of PML in both prepractice and practice conditions detailed by Maas et al., 2008.

Overall, no one treatment used all preferred elements of PML and none of the treatments clearly differentiated a prepractice phase from a practice phase in the treatment. Overridingly, treatments used blocked and mass practice schedules as well as feedback based on knowledge of performance as opposed to knowledge of results. These factors may contribute to poor retention and transfer of learning, key elements in averting relapse following treatment.

The implications of these findings and directions for future research are discussed.

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SPEECH AND PAUSE CHARACTERISTICS IN ADULTS WITH MULTIPLE SCLEROSIS: COMPARISON OF SPEAKERS WITH HIGH AND LOW NEUROPSYCHOLOGICAL TEST PERFORMANCE

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Introduction

Contemporary models of motor control suggest that speech motor behavior should be viewed as a "cognitive-motor accomplishment," such that motor acts are influenced by cognitive ability (Kent, 2004). Research from the limb motor literature suggesting that faster motor performance is associated with better cognitive performance for both normal controls and individuals with Multiple Sclerosis (MS) supports this idea (Benedict et al, in press).

Despite the fact that dysarthria and cognitive impairment have a high rate of occurrence in individuals with MS and dysarthria management must take place within the broader cognitive framework of the disease, research investigating both motor speech abilities and cognition in MS is mostly limited to survey studies (Yorkston et al., 2003).

Therefore, the purpose of this study was to investigate how neuropsychological impairment in MS impacts speech production tasks with varying cognitive-linguistic demands.

Methods

Speakers

Eighteen speakers participated, including 12 speakers with MS and six age and sex-matched healthy controls. Participants were selected from a larger database on the basis of standard clinical neuropsychological tests of information processing speed and executive functioning. Six speakers with MS comprised a high-performing group and six speakers with MS comprised a low-performing group. All speaker groups demonstrated equivalent overall speech severity, as indicated by average sentence intelligibility scores of at least 95%.

Procedures

Speakers read the Grandfather Passage and produced a Narrative while being audio-recorded. A variety of acoustic measures were obtained, including speech rate, articulation rate, pause duration, pause frequency, grammatical correctness of pauses, and pause type (filled/silent).

Results and Discussion

At the time of submission, acoustic analyses for 100% of the Grandfather passages and 90% of Narratives are complete. Data reduction and analyses are in progress.

It is hypothesized that all speaker groups will demonstrate certain differences in speech and pause characteristics for the Grandfather Passage and Narrative tasks owing to increased cognitive-linguistic demands associated with the latter task. It is further hypothesized that these differences will be greater for the low-performing MS group as compared to other groups. If cognitive function is shown to influence speech measures, then broad clinical implications exist for testing and treatment in populations with a high incidence of dysarthria and cognitive impairment, as reported for MS.

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THE EFFICACY OF PROMPT FOR CHILDREN WITH APRAXIA OF SPEECH

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PROMPT (Prompts for Restructuring Oral Muscular Phonetic Targets) is a widely-used treatment approach for children with speech sound disorders. PROMPT's unique diagnostic and therapy protocol, which includes dynamic tactile information to support, shape and organize movements of the oral articulators, seeks to improve the quality and intelligibility of sounds, syllables, words, and connected speech. Little research has examined PROMPT for children with childhood apraxia of speech (CAS). In this study we treated four children with CAS (3.6–4.8) to determine the effectiveness of PROMPT approach and its use of tactile information. Following ASHA guidelines, participating children had normal sensory, cognitive, social and receptive language skills; articulation below –1.5SD; and performance on VMPAC sequencing below the 5th percentile. All children were highly inconsistent on repeated productions.

All children received 8 weeks, 2x/week of treatment including at least 4 weeks of full PROMPT treatment (FP); two children received 4 weeks first of all PROMPT components except tactile information (WT=without tactile). This enabled a comparison of the specific impact of the tactile cues. We asked:

– Does FP produce greater gains than WT in the first 4 weeks on articulation and consistency measures (DEAP, treated+untreated probes), and on quality and sequencing of speech movements (TOCS, VMPAC, treated+untreated probes)?
– Do additional gains occur in these measures when all children are receiving FP?
– How well do the effects of treatment generalize to untrained words (TOCS, untreated probes)?

Preliminary Findings Include the Following

1. On the VMPAC, all children improved significantly on nonspeech and speech sequencing, focal-oromotor, and connected speech and language scores.
2. On the TOCS+, intelligibility increased significantly from pretest through followup on word and phrase production.
3. On the Vineland, pretest-followup gains were significant and strongest in the Socialization domain.
4. All children showed improvement on production of treated words. The TOCS+ gain demonstrates generalization. For the one child whose untreated probes have been scored, significant changes were observed in untreated words reflecting the targeted aspects of speech. The remaining probe data will be presented in the poster.
5. Improvement was generally stronger in the first 4 weeks than the second phase, but all children continued to improve through follow-up. The largest changes in the second phase occurred for the child who changed from WT to FP.

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ARTICULATORY STRATEGIES IN THE OBSTRUENT PRODUCTION IN MANDARIN ESOPHAGEAL SPEECH

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Esophageal speech is a commonly adopted alaryngeal speech after total laryngectomy. A main concern after the operation is how to improve the intelligibility of esophageal speech (Hillman et al., 1998; Tikofsky, 1965). Using the pharyngoesophageal (PE) segment as the neoglottis, esophageal speech has a significantly different voice quality from normal laryngeal speech. Previous studies have examined various aspects of esophageal speech, such as aerodynamics (Motta et al., 2001; Snidecor & Isshiki, 1965), acoustics including fundamental frequency (F0), intensity, voice quality, and resonance frequencies (Bellandese et al., 2001; Liu et al., 2005; Liu & Ng, 2009; Robbins et al., 1984; Snidecor & Curry, 1959), and the perception (Doyle et al., 1988; Fukter & Hyman, 1975; Liu et al., 2006; Ng et al., 2001). It has been found that esophageal speech is typically characterized by a perceptually hoarse voice quality, and significantly reduced airflow volume, fundamental frequency (F0), intensity, and speech rate. However, previous studies mainly focused on the acoustic and perceptual aspects of esophageal speech and few has been done on the articulation of esophageal speech. This study examined the temporary coordination between the sub- and supra-systems of speech organs and the lingopalatal articulation in the obstruent production in Mandarin Chinese. It is assumed that since the use of the PE neoglottis dramatically changes both the phonatory setting and speech airstream mechanisms, speech motor system has to be reprogrammed during the articulation of esophageal speech.

On the basis of a comparison between 4 esophageal speakers and 4 normal laryngeal speakers, this study investigated the voice onset time (VOT) characteristics of plosive and affricate consonants in Mandarin esophageal speech and explored the linguopalatal articulation by using the electropalatography in the production of Mandarin plosive, affricate and fricative consonants. Results show that esophageal speakers distinguish the unaspirated vs. aspirated plosives and africates in a similar way as laryngeal speakers do. However, the aspirated plosives and affricates have a shorter VOT whereas the unaspirated plosives and affricates have a longer VOT in esophageal speech than in laryngeal speech. As for the linguopalatal articulation, esophageal speech, in general, exhibits a significantly more extensive linguopalatal contact than normal speech does. Results suggest that articulatory strategies have been adjusted in esophageal speech to facilitate the linguopalatal articulation by using a narrower air way for compensating for the limited air volume. Also, the sub-to-supra-laryngeal coordination is reprogrammed due to the significantly different vibratory behavior of the PE segment vis-à-vis vocal folds.

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ASSESSING THE UNDERLYING NATURE OF INTONATION DISTURBANCE IN FOREIGN ACCENT SYNDROME

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Foreign accent syndrome (FAS) is a motor speech disorder that is perceptually defined by the presence of a foreign accent in speech, whereby segmental as well as suprasegmental changes, i.e. rhythm and intonation, have been associated with the perceived foreign accent in speech. This study systematically investigated the intonation patterns in FAS using the established autosegmental-metrical theory of intonational analysis. The main objective of this investigation was to determine possible intonation changes in FAS, to identify their potential underlying nature and through this offer further insights into the principles of intonation realisation in this speech disorder.

To achieve this goal, the speech of four individuals with FAS was compared to the performances of four healthy gender-, age- and dialect-matched control speakers using a variety of scripted and unscripted text styles. The data were annotated using the IViE transcription system (e.g. Grabe, Post & Nolan, 2001) and analysed phonologically and phonetically in relation to the four dimensions of intonation posited by Ladd (1996), i.e. the inventory, distribution, implementation as well as functional use of intonational elements, i.e. pitch accents and boundary tones. In addition, screening tests were administered to gauge the involvement of phonation and respiration issues associated with dysarthria and to screen for signs of apraxia of speech.

The analysis of the speech corpus revealed a retained inventory of intonational elements in FAS combined with changes in the distribution, implementation and functional use of these elements. The findings further suggest that none of the observed intonational changes in FAS directly reflected an underlying intonation deficit, but represented a combination of primary and secondary manifestations of physiological limitations affecting speech support systems as well as compensatory tactics to cope with the restrictions. Consequently, these findings provide new insights into the intonational system in speakers with FAS and highlight the potential involvement of dysarthric features in the manifestation of intonation deficits in FAS.

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INTERACTION OF LANGUAGE AND MOTOR PROCESSES IN THE SPEECH MOTOR PERFORMANCE OF CHILDREN WHO STUTTER

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Background

Multifactorial models of speech production posit that language and motor processes interact to affect speech motor control. Consistent with these models, increases in utterance length and/or syntactic complexity result in increased articulatory movement variability during the fluent speech of adults who stutter (Kleinow & Smith, 2000) and adults and children who do not stutter (Kleinow & Smith, 2006).

Purpose

This study examined the effects of increased sentence length and syntactic complexity on the speech motor performance of children who stutter (CWS) compared to children with typical development (CTD). It was hypothesized that increased linguistic demands would affect the performance of both groups, but that the effects would be greater in CWS.

Method

A total of 102 children (63 CWS, 39 CTD) from 48–83 months of age participated. Participants repeated sentence stimuli following auditory models. Sentence length (short vs. long) varied by syllable number. Syntactic complexity (simple vs. complex) varied by the absence/presence of a relative clause. Kinematic data are reported for a subset of children (16 CWS, 16 matched CTD) with age-appropriate language and articulation skills who had adequate data for all sentence conditions. The lip aperture variability index (LAVAR), which reflects the degree of variability in upper lip, lower lip, and jaw coordination to control oral opening over repeated productions of an utterance, was computed for each sentence condition for each participant. Movement duration was also measured.

Results

Sentence length significantly affected the articulatory coordination of both groups, with long sentences associated with increased lip aperture variability. However, CWS showed a different pattern of response to sentence complexity. For simple sentences, the LAVAR of CWS was significantly higher than that of CTD. For complex sentences, both groups had high levels of variability. There were significant effects of length and complexity, but not of group, on movement duration. Finally, it is notable that the percent of participants (out of 102) with adequate data for each sentence condition decreased as length and complexity increased. This decrement was greater for CWS than CTD.

Conclusions

The speech motor systems of both CWS and CTD are affected by sentence length and syntactic complexity; however, CWS are more vulnerable to increased linguistic demands. This study provides the first direct evidence that speech motor processes in CWS near the onset of stuttering are affected by sentence length and syntactic complexity. Results are consistent with the multifactorial, dynamic model of stuttering.

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USING REST INTERVENTION FOR PAEDIATRIC CEREBELLAR ATAXIA

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Ataxic dysarthria is a motor speech disorder with a key feature of equal and excess stress (Duffy, 2005). Currently there are no published treatments for prosodic impairment in Ataxic Dysarthria in children. Rapid Syllable Transition Treatment (ReST) (Ballard, Robin, McCabe & McDonald, 2010) was developed for children with Childhood Apraxia of Speech to address both lexical stress and articulation impairment. The ReST intervention uses three syllable CVCVCV strings as nonword, orthographically-biased stimuli which can be read or imitated. ReST has a pre-practice and a practice phase developed in accordance to the Principles of Motor Learning (Maas et al, 2008). Multiple single case studies have demonstrated promising gains and a randomised control trial is underway with this population. We hypothesised the ReST treatment would improve lexical stress in an 8 year old with severe ataxia.

The participant had a surgical resection of a posterior fossa astrocytoma at 18 months causing severe ataxic dysarthria which was characterised by equal and excess stress, vowel distortions, inconsistent hypernasality, decreased rate and difficulty varying pitch and volume. She has received prior treatment at a children's hospital.

Prior to this treatment block, the participant's speech, receptive and expressive language, reading, phonological memory, rapid naming and phonological awareness were assessed as within the normal range.

The ReST treatment was provided twice a week for 6 weeks at The University of Sydney, Australia. Daily home practice was also completed on non-treatment days. Probes of treated nonwords, untreated nonwords, control nonwords and 2 and 3 syllable real words were conducted: three times prior to treatment, twice during treatment and three times post treatment. Perceptual and acoustic measures (pairwise variability index) were analysed to determine treatment effects. Treatment fidelity averaged 97%. Transcription inter-rater reliability averaged 85.6% and intra-rater reliability averaged 87.3.

Results indicated a promising treatment effect. For treated nonwords, percentage accuracy at baseline averaged 5% and post-treatment averaged 70%. She gradually increased her accuracy over the 12 sessions and maintained these gains at 2 weeks post. The pairwise variability index results also demonstrated gains in lexical stress. For treated strong-weak nonwords, there was an moderate effect size using cohen's d (–0.727). For treated weak-strong nonwords, a large effect size was demonstrated (1.59). Control words showed no effect.

Related 3 syllable real words also demonstrated change from an average of 39% at baseline to 80% following treatment. The participant's results on the Polysyllable Test (Gozzard, Baker & McCabe, 2004) also demonstrated gains in percent phonemes correct and stress matches. Data on 2 months post will also be provided.

The implications of these findings and directions for future research are discussed. Further research into ReST as a treatment for ataxic dysarthria is warranted.

SIMULATING THE NEURAL CORRELATES OF STUTTERING

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Introduction

Neural activation associated with dysfluent speech in developmental stutterering is characterized by hyperactivity of right hemisphere motor and premotor cortex, combined with overall reduced left-hemisphere perisylvian activation, particularly in auditory cortex. However, two challenges exist for neuroimaging studies of stuttering, namely (1) the elicitation of naturally stuttered versus fluent speech and (2) the separation of activation associated with abnormal motor execution from activation that reflects the cognitive substrates of stuttering (see De Nil et al. 2008). We made use of a speaker's insight into his own stuttering behavior, to create a list of single-word trials on which he is likely to stutter, versus a matched list of 'fluent' words. In addition, a speech pathologist was trained to imitate the articulatory and facial motor pattern associated with this speaker's stuttering. Both performed an fMRI experiment of single word reading, with the same lexical items.

Methods

A sparse scanning design was used, with a fixed SOA of 10 seconds. Participants read aloud words presented on a screen, with a control condition showing a nonsense letter string, not requiring a response. One brain volume was acquired 3 seconds after each word presentation, for a total of 48 trials per condition. The dysfluent speaker's (DS) recorded responses were analyzed for whether his stuttering pattern matched the anticipated pattern. For the fluent speaker (FS), word trials were color coded to achieve complete matching between his output and the real stutters of DS. Data were analyzed separately, using one-way ANOVAs by trial with condition as a three-level factor.

Results & Discussion

Both DS and FS show bilateral temporal and auditory cortex activation in fluent as well as dysfluent speech. In contrast to De Nil et al.'s (2008) group results, we do find differences between dysfluent and fluent speech in FS, which are overall very similar to those observed in DS. However, for the contrast of dysfluent speech versus the control condition, DS does show a greater right-hemisphere activation bias than FS, visible in motor cortex, supramarginal gyrus and anterior middle temporal gyrus. In addition, DS shows bilateral prefrontal activation that is not observed in FS' simulated stuttering. These results suggest that some of the classically reported neural activation patterns associated with stuttering are driven more by nonspecific motor patterns than by the cognitive substrates underlying stuttering. Nevertheless, the generally observed right-hemisphere lateralization in speakers who stutter appears to reflect a true characteristic neural correlate of developmental stuttering.

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TONGUE-JAW COORDINATION IN SPASTIC DYSARTHRIA

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Dysarthria is a motor speech disorder resulting from neurological injury that is characterized by poor speech articulation. The primary deviant speech patterns involve imprecise consonants, distorted vowels, hypernasality, and excessive or monotonic vowel intonation (Darley et al., 1975). Bartle et al. (2005) reported that the temporal and spatial coordination between tongue and jaw was disturbed with large variability across speakers in the speech of individuals with dysarthria due to traumatic brain injury (TBI). In this study, we examined the spatio-temporal coordination between tongue and jaw kinematics along with relevant muscle activity in dysarthria associated with spastic cerebral palsy (CP), focusing during alveolar consonant release.

Electromagnetic articulography (EMA, AG500 system) was used to track the tongue and jaw movements of three speakers with CP and three control speakers. Surface electromyography (EMG) was used simultaneously with EMA to capture submental muscle activity during consonant release.

Both kinematic and EMG results indicate disturbances of tongue function in CP speakers related to reduced tongue tip velocity and inappropriate timing of tongue-jaw muscle activation. An opposite pattern was found for the jaw in that movements were more rapid in CP speakers. Timing relations between tongue tip and jaw kinematics appeared to be less affected than movement velocity.

Reduced mobility of tongue could prevent CP speakers from achieving an articulatory target. Increased jaw movement amplitude and velocity could be a compensatory strategy to accommodate the disturbance in tongue function. On the other hand, the aberrant jaw may reflect kinematic patterns of an immature oromotor system in which lingual movement control is insufficiently differentiated. As the jaw's neuroanatomic infrastructure develops earlier than those supporting lip and tongue, the jaw could act as a primary articulator in early infancy development of speech. The speakers with CP may not be able to develop more mature oromotor control patterns due to disturbed lingual function. This possibility is further suggested by the EMG findings that CP speakers consistently recruit submental muscle activity during consonant release while control speakers recruit more modest submental activity during this gesture. Examining the tongue-jaw coordination in CP-related spastic dysarthria provides important information on deviancies in the underlying speech physiology related to CP. This study raises important questions about the role of jaw motion in contributing to the characteristics of dysarthric speech.

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FORMANT TRANSITIONS IN ATAXIC SPEECH: EFFECTS OF WORD LENGTH, SPEECH RATE AND SEVERITY OF DYSARTHRIA COMPARED TO CONTROL SPEAKERS

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Speech timing is closely related to intelligibility and articulatory precision in individuals with dysarthria (Tjaden, 2007). In theoretical and clinical work it would be useful to be able to measure F2 slope independent of an individual's general rate of speech, i.e. apply a measure that separates movement speed and number of units per second. The present project uses formant pattern rate of change as a way of indirectly estimating articulatory movement, using a method for numerically specifying the shape and speech of formant trajectories.

A previous study (Hartelius et al., 2010) evaluated the method analyzing formant transitions of 10 speakers with ataxic dysarthria due to multiple sclerosis (MS) and 10 control speakers, pronouncing the syllables /da:/, /do:/, and /du:/ in a carrier phrase. The formant transitions were traced from spectrograms and subsequently fitted with damped exponentials, determining their time constants. Comparisons between the two groups showed that the time constants were significantly different in the two groups. Speakers with MS were slower, and given that this measure in independent of speaking rate, we can conclude that the actual articulatory movements were slower.

In many languages embedding stressed syllables such as syllables /da:/, /do:/, and /du:/ in polysyllabic words gives rise to the so-called word length effect. To give a few examples, in an English the [i] vowel of speed, speedy, speedily gets progressively shorter as more and more syllables follow the stressed syllable. In normal speech the word length effect provides a principled way of controlling the speaking rate experimentally. The shortening implies that the segments observed are spoken faster. Defined in terms number of units per second the speaking rate thus increases.

The question arises whether articulatory rate co-varies in such cases. Since the stressed vowel shortens in polysyllables, one might suppose that articulatory rate might be compensatorily be sped up to ensure a sufficiently accurate approximation of the intended articulatory and acoustic goal. On the other hand, the duration-dependence of formant undershoot points in the other direction suggesting that, with stress kept the same, articulatory rates tend to stay more or less constant and independent of the number of entities produced per unit time.

The present project addresses these issues by comparing acoustic data from 14 speakers with MS and 10 control speakers with respect to the two measures of speaking tempo mentioned above: articulatory rate as measured by the time constants of formant transitions and phoneme rate as reflected by the number of segments per unit time. The questions we ask are: Do the two measures co-vary? What are the differences between the two groups of subjects? What are the implications of answers to those questions for phonetic theory and clinical work?

KINEMATIC CHANGES IN JAW AND LIP CONTROL OF CHILDREN WITH CEREBRAL PALSY FOLLOWING PARTICIPATION IN A MOTOR-SPEECH (PROMPT) INTERVENTION

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This study evaluates kinematic movements of the jaw and lips in six children (3-to-11 years) with moderate-to-severe speech impairment associated with cerebral palsy before, during and after participation in a motor-speech (PROMPT) intervention program. A single subject multiple-baseline-across-participants research design, with four phases: Baseline (A), two intervention phases (B and C) and maintenance (D), was implemented. Phase B targeted each participant's first priority of the PROMPT motor speech hierarchy, Phase C one level higher. These data form part of a larger study that also examined changes in speech intelligibility, percentage phonemes correct and perceptual performance on weekly speech probes.

Kinematic data were collected at the end of each study phase (four time points) using 3D motion analysis (Vicon Motus 9.1). Thirteen typically-developing age-and gender-matched peers were recruited to compare the trend of changes in jaw and lip movements to those of the children with cerebral palsy. Jaw and lip measurements of distance, duration and velocity, during the production of 11 untrained stimulus words, were obtained. The words contained vowels that spanned the articulatory space and represented motor-speech movement patterns at the level of mandibular and labial-facial control, as classified according to the PROMPT motor speech hierarchy.

All participants showed significant changes in specific movement characteristics of the jaw and lips. Phases B and D were characterized by positive changes towards the movement characteristics of the age-matched peers. Phase C showed evidence of regression in some measures, for some participants. Kinematic changes were associated with significant positive changes to speech intelligibility, in five of six participants.

The results indicate all participants benefited from participating in the PROMPT intervention approach. This study therefore makes a contribution to providing evidence that supports the use of a hierarchical subsystems approach to improve the motor-speech movement patterns and speech intelligibility in children with cerebral palsy. The trend towards a decrease in performance on some measures in phase C, suggests the need for further research to evaluate therapy dosage. This would enable clinicians to structure intervention programs that would maximize the stages of consolidation and adaptation following establishment of new motor-speech behaviours.

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POSTER SESSION II

INTRINSIC AND EXTRINSIC PROSODY CONTROL IN NORMAL SPEAKERS

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While there is agreement that prosodic cues organize spoken language, the manner and scope over which they do so has been the subject of debate (Carmichael, 2003). Pierrehumbert's (1980) account focused on intonation while Morton, Tatham and Lewis (1999) considered stress on syllables so as to assign lexical stress and to formalize "focus", potentially a paralinguistic (pragmatic) effect. Interestingly, duration/timing has only recently come within the purview of linguistic modeling of prosody. Byrd and Saltzman (2003), in this regard, have demonstrated slowing/acceleration of spatio-temporal indexes of articulation at the edge of prosodic gestures. They claim that timing of the latter is conditioned by linguistic categories. Since then, several studies have shown that linguistic category (content vs. function; prosodic prominence in linguistic stress) and lexical knowledge affect speech motor control as indexed by spatio-temporal stability in speech (Goffman et al., 2006, 2007 and Heisler et al., 2009).

In line with Lindblom (1990), Boutsen (2008) has argued that aside from intrinsic prosody which has been addressed in the aforementioned studies, extrinsic prosody is an important vector in speech planning. Unlike intrinsic prosody, the latter vector is informed by expressive intent and/or the needs of the listener. Thus far, constraints imposed by extrinsic prosody have not been investigated in studies of speech motor control. This void led to the present study. Its purpose was to investigate intrinsic and extrinsic prosody while employing an acoustic-temporal rather than a spatio-temporal measure of variability.

Towards this goal 16 adult participants (8 males and 8 females) were asked to repeat sequences of "pink, black, blue" 10 times in each of 7 conditions where these morphemes serve as words devoid of linguistic function in 2 non-phrasal conditions ("pink black band blue"; "pink black and blue"), and as adjectives, objects and proper names in 3 phrasal conditions. In addition to these intrinsic prosody conditions, 2 conditions required expression of contrast in the verbal response. As for stimulus presentation (E-prime), it was either graphemic requiring participants to read the words or pictorial requiring a non-graphemic formulation mode.

Acoustic temporal indexes were computed using MATLAB. Statistical analysis (condition (7) by gender (2) by presentation format (2) three-way ANOVA) revealed no main effect for presentation format or for gender on this measure. Condition and condition by gender were significant, however ($F = 5.45$; $p < 0.0001$; $F = 3.48$, $p = 0.0041$). Conditions that involved very simple variations of linguistic function were no different from baseline motor speech (non-phrasal) conditions where linguistic load was minimal. On the other hand, the acoustic temporal indexes were elevated in the linguistic expressive conditions. Overall, this study indicates that the acoustic temporal index is useful to document control over acoustic output.

THE PARAMETER REMAPPING EFFECT IN CHINESE AND ENGLISH

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Few studies have investigated 'parameter remapping' (Rosenbaum et al., 1986) as a mechanism for speech motor-programming. Performance tends to be better when repeated sequences have fixed parameter mappings and suffer when they are varied. It is still unclear what parameter mappings are relevant to speech motor-program production, and whether varying some has a greater effect on performance than others (Rogers & Storkel, 1998). Rosenbaum et al. (1986) found that participants produced more errors when repeating lists of letters, if the mapping of stress to letters changed each repetition. In this study we extended these findings using tongue-twisters in English and Chinese, hypothesising that error rates would be higher on tongue-twisters requiring segment-to-tone (Chinese) or segment-to-prominence (English) remapping than tongue-twisters without remapping. We also aimed to compare remapping for motor-programs across sequences of words, with remapping across sequences of word pairs.

In Experiment 1, 52 native Mandarin Chinese speakers read aloud 40 tongue-twisters, repeated 6 times consecutively. Half the tongue-twisters alternated initial segment in ABAB format and tone in ABBA format (ABABsABBAt, e.g. tu1ku3tu3ku1). The other half alternated initial segment in ABBA format and tone in ABAB format (ABABtABBAs, e.g. tu1ku3ku1tu3). Tongue-twisters were elicited in four prominence conditions varying the location of prominent words. The experiment yielded 2,155 segment errors (4.3%), with more errors at positions 1 and 3 in the ABABtABBAs condition, and positions 3 and 4 in the ABABsABBAt condition. There were 825 tone errors (1.7%) with more errors at positions 3 and 4 in both conditions. There was no effect of prominence.

Experiment 2 used tongue-twisters that matched the segmental content of the Chinese materials while still being English lexical items. They alternated initial segments in ABAB or ABBA format. The same prominence conditions were used as the previous experiment. 25 native English speakers uttered 1,787 segment errors (2.7%). There was a 3-way interaction between format, position and prominence.

Results suggest the main determiner of errors was the number of parameters being remapped. The most error prone tongue-twisters involved remaps across word pair sequences and two segment remaps across words (segment-to-tone in Chinese, segment-to-prominence in English). Given that we found similar segment error patterns in both languages, there appears to be similar mechanisms for segment-to-tone mapping in Chinese and segment-to-prominence mapping in English, but phrase-level prominence did not contribute significantly to parameter remapping in Chinese.

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QUANTIFYING FEEDFORWARD VERSUS FEEDBACK CONTROL THROUGH KINEMATIC ANALYSES OF UNPERTURBED SPEECH MOVEMENTS

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Introduction

Approaches to examine feedforward versus feedback control of unperturbed movements have been used in studies of limb motor control. For speech production, the extent to which movements are preplanned versus adjusted online is not well understood, and there are no quantitative methods to determine the weighting of feedforward versus feedback strategies in normal subjects, across different speaker groups, or at different stages of development. This study examined the feasibility of applying to the study of speech motor control a set of analysis procedures previously used in the context of limb movements. We used electromagnetic articulography to transduce speech articulatory movements, and we measured kinematic landmarks (peak acceleration, peak velocity, movement endpoint) and the two-dimensional spatial coordinates at the time of those landmarks. If movement endpoints are highly predictable from the early kinematic landmarks and their spatial coordinates at the time of those landmarks, movements must have been largely preplanned. If, on the other hand, movement endpoints cannot be reliably predicted from early kinematic characteristics, it is likely that substantial online adjustments occurred as the movements were unfolding.

Methods

Each subject produced 10 to 15 trials of 36 different combinations of utterances with embedded CV or VC target syllables. Target syllables were constructed by combining three voiceless consonants (t, s, k) with three different vowel positions (high, mid, low) to obtain three distinct movement distances similar to the aforementioned limb movement paradigms. EMA sensors were attached to the tongue (three sensors), jaw, and lips with reference sensors on the nose and upper gums. All kinematic data were low-pass filtered, corrected for head movement, and re-expressed relative to an anatomically-defined coordinate system. We measured three kinematic variables (peak tangential acceleration, peak tangential velocity, movement distance) and the spatial coordinates (x,y) at the time the articulator reached peak tangential acceleration, peak tangential velocity, and movement endpoint. Correlation coefficients were calculated among the three kinematic variables and among the x,y coordinates at the corresponding time points. Moreover, a statistical model was used to quantify the contributions of feedforward versus feedback control, including the compensatory influence of movement duration.

Results and Conclusions

Results show that it is possible to apply the paradigm and analyses to speech articulatory movements, and specific findings from each analysis procedure will be presented at the meeting. A number of challenges that are uniquely associated with the analysis of orofacial movements as opposed to limb movements will also be discussed, and possibilities for comparing neural control strategies across different speaker groups (e.g., individuals with speech motor disorders) will be presented.

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ON THE INTERACTION OF PHRASAL LENGTH AND WORKING MEMORY ON THE SIZE OF THE SPEECH PLANNING UNIT

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A controversial issue in psycholinguistic research is how far ahead speakers plan the upcoming sentence. In particular, it has been hypothesized that the size of the planning unit is flexible, depending on both cognitive and linguistic constraints. For instance, Swets et al. (2007) suggested that the attachment of syntactically ambiguous constituents might depend on working memory (WM) capacities: in their study, readers with low WM spans tended to break up the sentences into smaller prosodic chunks because of their limited working memory, thus attaching high (i.e. to the first chunk) the syntactically ambiguous constituent.

A common measure of planning processes is pause duration, with longer pauses indicating more planning time. Moreover, phonetic studies suggested that fundamental frequency (f0) is another indicator of planning (Prieto et al. 2006). The available evidence on f0 planning provides, however, an inconsistent picture. For instance, some speakers appear to start with higher f0 when producing longer utterance, while others do not show any effect of utterance length on f0 values.

In this work, we examine the influence of phrasal length on pause duration and on the f0 value of the utterance-initial pitch accents. Moreover, we test that speech planning depends on individual differences in WM capacities. It is predicted that the scope of planning is narrower in speakers with lower WM span than in speakers with higher WM span. As a consequence, speakers with higher WM span will start higher when producing longer utterances, since they are able to plan larger prosodic constituents.

A corpus read by 24 German speakers has been collected. The corpus consisted of Subject-Verb-Object sentences in which the Subject and the Object were modified only in length. The target sentence was preceded by a context sentence ending with a colon to induce the speakers to produce a pause between the two sentences. Prior to the acoustic experiment, speakers performed a WM reading span task.

Preliminary results for f0 show that this parameter mirrors length effects of the first prosodic phrase only and it is therefore a more "local" parameter of planning. This effect appears to be positively correlated with individual working memory capacities. This would be one way to reconcile the contradictory results reported in the literature, since the presence vs. absence of f0 rising would depend on speaker-specific differences in the size of the planning unit.

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THE INFLUENCE OF ARTICULATORY CONSTRAINTS ON PATTERNS OF SPEECH ERRORS

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Introduction

To better understand mechanisms that trigger speech errors, this study addresses how articulatory constraints affect patterns of gesture-based speech errors. This relationship was indicated in a recent study (Goldstein et al., 2007), which showed more gestural intrusion errors on onset consonants in the proximity of the vowel /I/ than /A/. The authors suggested that this asymmetry could have been caused by the tongue position associated with these vowels. To further explore these findings this study investigates how a broader range of vowels and consonants affect patterns of intrusion errors.

Design

The stimulus material consisted of C1VC3#C2VC3 word pairs, which contained all combinations of the consonants /p/, /t/, and /k/ and the vowels /A/, /{/, /U/ and /I/ (e.g., kop top). The consonants could occur in both initial and final word position. Within a word pair the two onset consonants differed, but the following vowel and coda consonant were kept constant. Fifteen monolingual Canadian-English speaking participants were instructed to repeat C1VC3#C2VC3 word pairs as often as possible on a single breath at a normal speech rate. Movement data from individual articulators were recorded with the 3D electromagnetic Articulograph (Van Lieshout, 2007). Position maxima for the target tongue tip (TT), tongue dorsum (TD) and lower lip (LL) during the onset consonants /t/, /k/ and /p/ respectively, were extracted, and the amplitude values of the simultaneous non-target articulator positions were determined. Medians and median absolute deviations (MAD) for the non-targets were then calculated over all repetitions in one trial. Two MAD's above the median of the non-target value was taken as a threshold to mark an intrusion. An ANOVA was performed with non-target articulator and type of vowel as independent variables. Differences within these factors were compared using a post-hoc Tukey-Kramer test.

Results

The results showed that the non-target TD was intruding significantly more during target TT and LL activations than the non-target TT and LL. Moreover, a trend was observed showing that the TD intruded more frequently in the context of /{/ and /I/ compared to /A/ and /U/. This trend became significant after collapsing the vowels into front and back categories. Although context affected the patterns of errors in a different way as predicted by the Goldstein et al study (2007), these results indicate that coarticulatory properties can facilitate non-target articulators to be activated erroneously.

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SPEECH TIMING PHENOMENA: THE OUTCOME OF A MOTOR CONTROL CHALLENGE, NOT JUST A TASK FOR MOTOR CONTROL

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In seeking to understand speech timing phenomena, researchers in the past put forward explanations that invoked embodiment, aerodynamics, effort and other factors that might lead to timing changes. These proposals largely failed, and major timing phenomena - 'rhythm', contextual vowel length effects, VOT, and so on - are almost always now investigated on the basis that time is, indeed, the variable that the speaker is seeking to control directly, attempting to meet some combination of 'rule-based' temporal targets.

However, this conceptual approach to speech timing phenomena faces two basic problems: (1) it is producing a situation that grows ever more complex and intractable as each new study reveals further detail that putative 'rules' must specify, and (2) the developmental data contradicts it at various points.

Non-clinical speech research has largely ignored speech breathing. This is understandable, since the work that was done by experimental phoneticians found no significant differences in speech breathing across speakers of different languages,. Some researchers (e.g. Ohala 1991) failed even to discover a relationship between respiratory system activity and routine sentence stress in English, where one certainly might have been expected.

But speech researchers have been largely unaware that the mechanics of ventilation in children is completely different from that in the adult model. Working from first principles with this and our understanding of other speech production mechanisms in a child, presses the conclusion that there are differences in speech breathing between adults and children and, for example, between young speakers of English and French (Messum 2007). Unfortunately, the limited sensitivity of instruments that can be used with young child subjects means that the latter is hard or impossible to demonstrate.

The most plausible model of speech breathing in a child speaking a West Germanic language like English, German or Dutch, has it being pulsatile both before and during the period when the characteristics of stress-accent are developed. Speech timing phenomena develop over the same period. I will describe mechanisms by which pre-fortis clipping (the vowel length effect), 'stress-timed' rhythm, and tense and lax vowel classes may develop in these learners.

Thus the apparent complexity of speech timing may be the result of simple, non-temporal mechanisms, the results of which would be completely consistent with the current developmental data. These mechanisms explain timing phenomena as the outcomes of challenges to the motor control system - to reconcile various linguistic demands with the potential and constraints of a child-sized and still developing speech production system - rather than as computed tasks which require faithful motor execution.

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INDIVIDUAL VARIABILITY IN SPEAKING RATE AMONG TYPICALLY DEVELOPING 5-, 6-, AND 7-YEAR-OLD CHILDREN

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The current study investigated whether variability in typically developing children's speaking rates signals differences in articulatory competence. Adults achieve faster speaking rates by disproportionately compressing vowels relative to consonants. Some studies of adult speech have shown a relationship between vowel compression and vowel reduction, but other studies indicate that reduction is not a necessary feature of faster speech and that speech intelligibility and/or clarity is uncorrelated with speaking rate. These latter findings suggest that mature speakers can attain segmental targets even at fast speaking rates and that listeners can easily recover these targets. The goal of this study was to determine if fast-speaking children are similarly capable or if there is a trade-off between rate and intelligibility/clarity in children's speech.

Forty-nine typically developing children, 62 to 93 months in age, participated in the study. Children spontaneously narrated a wordless picture book while being audio recorded. Three fluent, pause-delimited, grammatical utterances were then identified in each narrative and selected for further measurement. The resulting 147 utterances were 2.35 seconds (SD = .47) and 8.61 syllables (SD = 2.37) long on average. Vowel and nonvowel segments were labeled for each utterance and their durations extracted. Utterances were then amplitude normalized and presented twice in random order to naïve adult listeners (N = 3) who first transcribed all the utterances and then judged their clarity on a 7-point Likert scale. Transciptions will provide a measure of speech intelligibilty, but remain to be coded. The ratings provided a measure of speech clarity.

Speaking rate varied substantially by speaker from a slow tempo of 1.97 syll/sec to a fast tempo of 5.40 syll/sec. As in other studies of speaking rate in children, a child's age had no effect on their speaking rate; variability was the norm across ages. Like age, the variable 'speaker' did not affect speaking rate. Instead, average vowel duration, percent vowel duration in the utterance, and number of syllables per utterance accounted for the variance (R-squared = .826). Average vowel duration decreased with increased speaking rates. Percent vowel duration in a phrase increased with speaking rate as did the number of syllables. There was no relationship between speaking rate and speech clarity, but–as in adult studies–boys were perceived to speak less clearly than girls.

Overall, the preliminary findings suggest that children, like adults, compress vowels at faster speaking rates. The findings also suggest that they are as competent as adults at achieving segmental targets even at fast articulation rates. If maintaining articulatory precision at speed signals high articulatory competency, then fast-speaking children may indeed be especially competent speakers.

Background

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AGE-RELATED DIFFERENCES IN REPETITION VARIABILITY: ANALYSIS OF LIP MOVEMENTS USING FUNCTIONAL DATA ANALYSIS

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This study examined repetition variability of lip movements as a function of age in Swedish speakers. A number of studies, using acoustic analysis and movement recordings, have shown that variability decreases with age until adolescence. The purpose of the present study was to apply functional data analysis (FDA, e.g., Ramsay et al. 1998) to lip movements. Our aim was to extend earlier findings of decreasing variability with age to see if both amplitude and phase change together, or only one of them. Previous studies have used the Spatiotemporal Index (STI, Smith et al. 1995), which only provides a single metric of variability (cf., Lucero et al. 1995), incorporating both amplitude and phase. Our long-term objective is to examine if children with atypical language development differ from typically developing children in terms of articulatory variability.

Movements were recorded of the upper and lower lips along with a microphone signal using the Carstens Articulograph AG500. To obtain as large lip movements as possible, the Swedish phrase "Mamma pappa barn"(Mummy, daddy, children) was used. 15–20 repetitions from 31 typically developed children and adults (age 5–44 years) were recorded. Euclidean distances between upper and lower lip movements in three dimensions were used as input to the FDA. This is a technique for time-warping and aligning a set of signals to examine differences between them. The following steps are involved: (1) temporal normalisation of the signals from a number of repetitions, (2) calculation of the mean signal, (3) alignment of individual signals to the mean signal using nonlinear time-warping, and (4) computation of one index of amplitude variability and one of temporal variability (phase).

To analyse the relationship between age and the FDA indices, we fitted simple linear regressions models to the data. The correlation coefficients (amplitude: –0.41, phase: 0.19) indicate weak relationships. The lines of best fit show that an age increase of 10 years lowers the expected amplitude variability by 7.5 and raises the expected phase variability by 0.04. For amplitude variability, the effect is rather noticeable and statistically significant ($p = 0.0231$). For phase variability, the effect is smaller and not statistically significant.

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EFFECTS OF AGE ON REACTION TIME AND BRAIN ACTIVATION DURING SPEECH PRODUCTION

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Pseudoword repetition is a task that has been used to study speech production in normal speakers and individuals with speech disorders. By systematically manipulating different characteristics of the pseudowords and observing the effects of the manipulations on repetition behavior, we can gain insight into the cognitive and motor processes underlying speech production. A common manipulation is to alter the frequency of occurrence of the initial syllable of the pseudowords. It has been shown that when initial syllables are more frequently occurring, this speeds production of pseudowords. In addition, increases in phonotactic probability, or the frequency with which phonological segments and sequences of segments occur in words in a given language, also facilitate production of pseudowords. However, it is unclear how manipulating these variables might affect the production of *real* words as compared to pseudowords. One might predict that there would be little difference between the time to repeat real words and the time to repeat pseudowords, if: a) real and pseudowords are matched for initial syllable frequency and phonotactic probability; and b) the unit of speech production is the syllable and both types of words have to be assembled on a syllable-by-syllable basis (as suggested by some models of speech production). In fact, production of pseudowords might be faster than production of real words, since they would not require lexical access. In a recent fMRI study, Shuster (*Brain and Language*, 2009) found that repetition of pseudowords was slower and activated larger regions of the brain than repetition of real words matched for initial syllable frequency and phonotactic probability. In that study, the pseudowords were constructed by starting with Turkish words and then Anglicizing them. However, despite the Anglicization, the pseudowords might have been dissimilar enough to English words to outweigh the positive effects of phonotactic probability and initial syllable frequency. Here we present behavioral and fMRI data from 11 young healthy adults and 10 middle-aged healthy adults. To increase the similarity of the pseudowords to real English words, we rearranged the syllables of English words. They were matched with the real words for initial syllable frequency and phonotactic probability. We measured subjects' reaction times (RTs) to repeat the words. For the younger subjects, there was no difference between RTs to repeat real words and RTs to repeat pseudowords. The middle-aged subjects were significantly slower to repeat pseudo as compared to real words, but there was no difference between the two age groups for RT to repeat real words. Although RTs were similar for both groups for real words, the fMRI patterns of activation were different in the two groups for repetition of both real and pseudowords. These findings will be discussed relative to models of speech production and aging.

RHYTHM EFFECT, MOTOR CONTROL AND TIMING IN FLUENT AND STUTTERING CHILDREN

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The purpose of this study was to investigate the central motor speech control in stuttering and fluent children through tasks of diadochokinesis (DDK).

The Research Group (RG) consisted of 19 children (mean age 6y;11m) diagnosed with stuttering, based on the following criteria:

a. fluency profile score outside reference values for age and gender;
b. 11 points or more on the Stuttering Severity Instrument - 3.

The Control Group (CG) consisted of 31 children (mean age 7y;5m) with no complaints of stuttering and without any communicative deficits based on the following inclusion criteria:

a. fluency profile score within reference values for age and gender;
b. 10 points or less on SSI-3;
c. no family history for recovered or persistent stuttering.

The repetition rate of articulatory segments was analyzed through tasks involving the ability to alternate (AMR - alternating motion rates) and sequence (SMR - sequential motion rates) movements.

For the AMR, participants were asked to repeat the sequence 'pa-pa-pa' as fast as possible and without losing articulatory precision. Three sequences of fifteen seconds were collected.

For the SMR, participants were asked to repeat the sequence 'pa-ta-ka' as fast as possible and without losing articulatory precision. Three sequences of fifteen seconds were collected.

Electromyographic data were recorded through a pair of electrodes set 2 mm below and at the middle portion of the lower lip. Amplitude data of muscle activation were analyzed.

The obtained results indicated a high standard deviation for both groups. ANOVA revealed a statistically significant difference between groups for SMR ($F(1,48) = 4.628$, $p = 0{,}037$). No significance was observed for AMR ($F(1,48) = 1.1014$, $p = .299$).

No within group statistically significant difference was observed for any of the groups on the comparison between AMS and SMR (RG: $F(1,36) = 1.8603$, $p = .181$; CG: $F(1,60) = .48318$, $p = .489$).

Although, high levels of standard deviations were found for both groups, a statistically significant between groups difference was observed for SMR, suggesting that fluent children presented a better ability to quickly change the position of articulators. This probably occurred because the SMR task demands an increased motor resource. This result is similar to those found in cases of apraxia of speech involving the left hemisphere.

In our study, the measure of DDK was made from the motion speed of a single structure. Although it is logical and almost inevitable that the increase in motor events per time unit indicate the performance of the motor task, we must highlight the possibility of we have simply captured the variability in the movement amplitude and not the change of speed.

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THE EFFECT OF THALAMIC DEEP BRAIN STIMULATION ON ORAL AND PHONATORY SUBSYSTEMS IN ESSENTIAL TREMOR PATIENTS

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Introduction

In this study we investigate the effect of chronic deep brain stimulation (DBS) of the nucleus ventralis intermedius (VIM) on the production of speech in patients with essential tremor (ET). VIM-DBS is an effective treatment for medication resistant essential tremor. However, stimulation induced dysarthria occurs postoperatively in up to 25% of the implanted patients (Benabid 1996). Although Kronenbuerger et al. (2009) found no discernable effects of VIM-DBS on syllable durations in ET patients, Pützer et al. (2007) found that stimulation leads to glottal hyperfunction and reduced precision of oral articulation in multiple sclerosis patients. In the present study we investigate acoustic parameters related both to duration, and to precision of glottal and oral gestures and their coordination.

Methods and Results

Fifteen native speaking German ET patients were implanted with a DBS system in the VIM at least three months before the recordings. They performed an oral diadochokinesis task involving alternation of voicing in CV syllables with three places of articulation (POA): labial /papapa/, alveolar /tatata/ and velar /kakaka/. Each patient was recorded with DBS on and off (defined as one hour after deactivation). Analysis of 900 target syllables (15speakers x 3POA x 10repetitions x 2DBS-states) showed no effect of syllable duration across the two conditions. However, for all three POA, the ratio voiced:voiceless was significantly greater with DBS-on. Further, there was increased friction during the intended closure for /k/.

Discussion

The increase in voicing ratio is mainly due to voicing during closure. Unlike Pützer et al., we interpret this as a problem in the coordination of the oral closure and glottal spreading gestures, rather than glottal hyperfunction. It is the spreading of the glottis for the plosive which has to be actively realized, rather than the vocal fold setting for voicing (usually assumed to be default in speech mode). Incomplete closure results from articulatory imprecision.

Our findings for the VIM-DBS in ET patients are in line with those of MS patients treated in the same anatomical target although our interpretations differ in terms of gestural coordination in the speech motor system.

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SPEECH SOUND DISORDERS ASSOCIATED WITH APHASIA

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Speech sound disorders associated with aphasia have been attributed to disintegration of both phonologic and motoric processes in different subtypes of aphasia (Pierce, 2001). In Broca's aphasia (BA), which often co-occurs with apraxia of speech, motor programming and motor planning difficulties are often the proposed error generating mechanism. In contrast, phonemic paraphasia observed in conduction aphasia (CA) is typically thought to be related to inability to retrieve and maintain sequences of phonemes for production. Distortion errors, often indicative of motor programming deficiency, predominate in AOS; but also have occurred to a lesser extent in CA (Odell, McNeil, Rosenbek & Hunter 1991), whereas undistorted phonemic level errors also have been reported in both CA and BA subtypes (Pierce, 2001). This study examines the occurrence of phonetic distortion, phonemic errors, and acoustic measures of word duration in speech produced by individuals diagnosed with BA with AOS versus CA with phonemic paraphasia, in comparison with the speech of non-aphasic controls.

Participants were ten adult male speakers with aphasia (5 with BA; 5 with CA), ranging in age between 40 to 67 years. Five non-aphasic adults with similar age range served as control speakers. Stimuli consisted of five polysyllabic words (e.g., "administration") which each participant repeated five times in response to a model provided by the examiner, yielding a total of 125 word productions. Phonemic transcriptions of each word were obtained using consensus methods, supplemented by descriptive spectrography. Perceptual scaling judgments of phonetic distortion were obtained for each word production. Acoustic measurements of word duration were obtained, as well as coefficients of variation, across the five repetitions of each word. Data were analyzed using 2-way ANOVAs with repeated measures for each dependent variable.

Results indicated that both CA and BA groups produced significantly more phonemic errors than the control speakers, but they did not differ from each other. Both groups produced significantly more consonant than vowel errors. Distortion ratings were greatest in the BA group, which differed significantly from controls. Distortion was elevated in the CA group relative to controls; however, the CA group did not differ significantly from the other groups. Word durations were significantly greater for both groups with aphasia in comparison with controls; however, CA speakers exhibited significantly greater variability than BA or control groups. Implications of these findings will be discussed relative to a greater understanding of AOS.

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DIFFERENCES IN SPEECH-MOTOR STABILITY BETWEEN NORMALLY FLUENT PEOPLE AND PEOPLE WHO STUTTER UNDER DELAYED AUDITORY FEEDBACK

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Delayed auditory feedback (DAF) is known to have a fluency inducing effect in people who stutter (PWS), but depending on the delay length, disfluencies can be elicited in people who do not stutter (PWNS). The mechanism underlying this dissociation is unclear. Increased dependency on auditory feedback in PWS, however, could allow for more stable speech production processes under altered feedback, while the same alteration is perturbing to PWNS. The purpose of this study was to identify whether the dissociation is present at the level of speech articulation. DAF was applied during sentence production to test whether speech motor stability, as measured by the Spatio-temporal Index (STI) of lower lip (Smith et al., 2000), is differentially affected in PWNS compared to PWS. We hypothesized PWNS would show decreased lip-motor stability (higher STI) under DAF conditions than under natural auditory feedback (NAF) conditions. In contrast, speech production would become more stable in PWS (lower STI) under DAF compared to NAF.

Participants were 22 monolingual native English speakers (11 PWS and 11 PWNS) who were naïve to DAF. Reflective markers on the lower-lip and upper-lip were tracked by four motion sensitive cameras. The stimuli included one non-word task and four different sentences that varied in length and syntactic complexity in four feedback conditions: NAF, amplified NAF (aNAF), 25ms-DAF, and 50ms-DAF conditions. Following Smith et al. (2000), the STI of the lower-lip was measured for each stimulus in each feedback condition.

The results revealed PWS exhibited higher STI than PWNS across the auditory feedback conditions for the four sentence stimuli. PWS, however, showed decreasing STI under aNAF and 25ms-DAF for the longer stimuli compared to NAF and 50ms-DAF. PWNS showed variable patterns under altered feedback but in general, their STI was higher under 50ms-DAF than NAF and aNAF.

This study has demonstrated that DAF has different influences on speech movement variability in PWS compared to PWNS. In PWNS, higher speech motor stability under DAF may indicate less dependency on auditory feedback for ongoing speech production and also intact ability to adapt to a perturbation.

If PWS are more dependent on auditory feedback for speech production, then auditory-to-motor integration under aNAF and a short delay (25ms-DAF) may have been facilitative leading to higher speech motor stability. Also, the speech-motor control of PWS was less influenced by altered feedback in short phrases than longer phrases. This may indicate an interaction between linguistic complexity and speech motor demands at least for the PWS. The group differences suggest divergent auditory-to-motor processing for speech production in typically fluent and stuttering speakers.

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DEEP BRAIN STIMULATION OF THE CAUDAL ZONA INSERTA IN PARKINSON'S DISEASE: EFFECTS ON JAW MOVEMENT IN SPEECH

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An increasing number of patients with advanced Parkinson's disease (PD) are now treated using electrical neurostimulation of deep brain structures, via surgically implanted electrodes. The subthalamic nucleus (STN) is today the most common stimulation target but recent surgical trials have indicated that caudal zona inserta (cZi) may be a better target to alleviate motor symptoms in PD (Plaha et al 2006). The effects of STN stimulation on speech motor function have been found to be generally small and variable. Additionally, worsening of speech (dysarthria and dysphonia) can occur as an occasional side effect. The effects of cZi stimulation on speech are virtually unreported at this stage.

This study reports the effects of cZi stimulation on jaw movement during a connected speech task for four PD patients (3 males, 1 female, aged between 54 and 73 yrs) from an ongoing study of PD patients who have received bilateral electrode implants for bilateral stimulation of cZi. Jaw movement during repetition of six short sentences was recorded for six different experimental conditions: before surgery (with and without medication) and 6 and 12 months after surgery (with stimulation off and on). In this study only the post surgical conditions were investigated. The movement was monitored using a 3D passive marker video system (ProReflex) with 120Hz frame rate, synchronized with the corresponding audio speech recording via an external trigger. Three dimensional coordinates of the jaw and head-neck movements were computed using recordings from two cameras that tracked the movements of four light weight spherical 5mm reflective markers: three attached to a spectacles frame (head-neck) and one to the chin (jaw). This marker arrangement allowed computation of vertical movement of the jaw in relation to the head. For each of the six sentences one landmark jaw manoeuvre associated with a consonant-vowel sequence was identified. The amplitude and duration of the vertical jaw excursion were measured for these six landmark manoeuvres in each of the four post surgical experimental conditions.

No patient showed larger amplitudes of vertical jaw movement at the landmarks in the stimulation ON compared with stimulation OFF condition for either the 6 month or 12 month post surgical measurement. Two patients showed no change between the two conditions for both post surgical occasions of measurement, while the remaining two had small reductions in amplitude in the ON state. There seemed to be no systematic changes in the corresponding duration of the jaw manoeuvres. Interestingly the two patients who showed reduced amplitude of jaw excursion ON stimulation also had been rated with lower clarity of speech articulation in a previous perceptual study (Doorn et al, 2010).

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AUDITORY FEEDBACK MASKING IN APHASIA: NEURAL CORRELATES OF INCREASED SPEECH FLUENCY

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Auditory feedback masking (AFM) is known to temporarily reduce disfluencies in persons who stutter. A handful of studies have investigated the effects of AFM in aphasia as well, though with mixed results. While initial studies reported temporary speech "improvement" in 75% of participants with aphasia (Birch & Lee, 1955), others did not find the same results (Wertz & Porch, 1970). The purpose of this study was to identify aphasic participants with a positive speech response to auditory masking and provide a preliminary analysis of lesion site correlates.

Method

Seven adults with aphasia participated in the study (3 females), including four with anomic aphasia, two with Broca's, and one with conduction aphasia, based on Western Aphasia Battery administration. Presence and severity of apraxia of speech was determined on the basis of a computerized motor speech exam.

AFM was tested using an ABA paradigm, with speech-shaped noise delivered via foam-tipped earphones at 85 dB during the "B" phases. Speech tasks included production of multisyllabic words, sentences, and a story recall procedure.

Digital images of previously brain scans (T1, T2, and FLAIR) were obtained, deskulled, and registered to MNI space. Initial lesion tracings were made by the first author (AJ) and confirmed by the third author (HR).

Results

Four participants responded positively to AFM, with increased speech rate (syllables/second) and decreased ratings of disfluency. Six of the seven participants' brain scans have been analyzed to determine potential lesion correlates with the AFM response, including 4 responders and 2 non-responders. Preliminary results show common lesion areas for all responders in a large area in left inferior posterior frontal cortex, including a large portion of anterior insula and extending to Brodmann's area 44, spanning inferior pre- and post-central gyri. The two non-responders had smaller lesions not affecting these areas.

Discussion

Preliminary results suggest a common area of brain lesion affecting individuals with a positive speech response to AFM, primarily including left posterior inferior frontal cortex, including the anterior insula. Results will be discussed in the context of the DIVA model of speech processing (Tourville & Guenther, 2010), including potential maladaptive activity in the auditory feedback system for speech in aphasic individuals with frontal lesions. Alternative accounts for the masking response will be considered, including effects of aphasia severity and lesion size.

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SOURCES OF MISSING DATA IN VOT MEASUREMENTS OF PATIENTS WITH PARKINSON'S DISEASE UNDER DEEP BRAIN STIMULATION IN SUBTHALAMIC NUCLEUS AND CAUDAL ZONA INCERTA

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The motor actions of the tongue, glottal folds and respiratory muscles must be carefully coordinated during the production of voiceless plosives. The acoustic measure of Voice Onset Time (VOT) is an established acoustic correlate of the voiced/voiceless distinction for healthy speakers. Due to the measure's dependence both on the achievement of complete closure (and the subsequent oral release) and the achievement of a sufficient control of the vocal folds and of the respiratory system to produce voicing, VOT has been used as an indirect tool to quantify production quality in patient groups (e.g. Auzou, Õzsancak, Morris, Jan, Eustache & Hannequin (2000)). In these studies, the number of productions achieving sufficient coordination between the laryngeal and supralaryngeal movements has been evaluated through the relative success rate in finding a measurable VOT in the plosive. For dysarthric patients, Õzsancak, Auzou, Jan, & Hannequin (2001) evaluated motor proficiency of patients with Parkinson's disease by categorizing failures to measure VOT by their influencing factors into four main categories of acoustic factors preventing VOT measurements. By categorizing VOT measurement failures in this way, Õzsancak et al. (2001) were able to provide data affording deeper insight into the reasons behind the perceived articulatory difficulties in the patient group.

The present study aimed at investigating the effect of Deep Brain Stimulation of the Subthalamic Nucleus (STN) and the Caudal Zona Inserta (cZi) on motor control and coordination using an extended version of Õzsancak et al's classification scheme. Voiceless plosives produced by 7 patients treated with DBS-STN and 7 patients treated with DBS-cZi were investigated in terms their fulfilment of VOT criteria during diadochokinetic speech tasks. The 2520 plosive productions were classified as measurable or not measurable, as well as having a presence of multiple releases, continuous voicing, turbulence noise and combinations of these factors demanded by the recorded speech material. The results showed a complex interaction of effects of DBS treatment in general, but no significant differences between treated localizations. Contrary to the results provided by Õzsancak, et al. (2001), however, the productions did fail to meet even a liberal VOT measuring criteria du to turbulence noise in the plosive. Details of the observed production's acoustic properties are presented, and the implications in terms of effect of DBS treatment localization discussed.

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THE SAME DYSARTHRIA IN DIFFERENT LANGUAGES: ACOUSTIC CHARACTERISTICS OF KOREAN SPEAKERS WITH PARKINSON DISEASE

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Since the seminal studies of DAB (1969a, b), where the dysarthrias were classified based on neuroanatomic and neurophysiologic considerations, efforts have been made to describe and identify speech characteristics (acoustic, perceptual or physiologic features) of each type of dysarthria, and these characteristics have been interpreted in the frame of neuroanatomy and neurophysiology. However, our current knowledge on dysarthria, a group of "speech"disorders, is somewhat limited partly because of the fact that previous studies have been mostly conducted on individuals with dysarthria whose native language is American English. The scarcity of data on speech characteristics of dysarthria in non-English speakers provides not only practical limitations in applying the knowledge to non-American English speakers with dysarthria, but also theoretical limitations in understanding dysarthria itself, such as the relationship between underlying pathophysiology and speech output.

In recognition of this issue, this presentation aims to provide preliminary data on acoustic characteristics of Korean speakers with hypokinetic dysarthria, secondary to Parkinson disease. Korean was chosen because it is different from American English in several interesting aspects, including its relatively simple vowel system, complex stop consonants, and monotonous prosody. First, Korean has a smaller number of monophthongs than English, and from this point, it is hypothesized that vowel errors will not predict reduced/enhanced speech intelligibility as much as in American English. Instead, consonants are expected to be more vulnerable to the disorder compared to vowels, because of its 3 cognates for one place of articulation (lax, tense, aspirated), unlike the two cognates in American English (voiced vs voiceless). Second, Korean is a syllable-timed language where each successive vowel has relatively equivalent duration, unlike American English which is a stress-timed language and characterized by near-isochrony in the time intervals between stressed syllables. In addition, f0 and intensity contours are expected to vary to a lesser degree compared to American English, partly because Korean does not have lexical stress.

As a preliminary step, in this presentation, acoustic data from 5 Korean male speakers with Parkinson disease will be reported in comparison to 5 age-matched healthy Korean speakers. Participants were asked to read a passage at comfortable loudness and speaking rate. Acoustic measures included acoustic vowel space, VOT of stops, speech rate, and f0 and intensity variation.

In the meeting, the results will be discussed with respect to 1) Korean-unique characteristics of speakers with Parkinson's disease, and 2) common acoustic characteristics of Parkinson's disease between Korean and American English by referring to previous literature on American-English speakers with Parkinson's disease.

ULTRASOUND FEEDBACK FOR TREATMENT OF LATERAL /S/ IN AN ADULT

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Lateralised production of /s/ and /z/ is notoriously difficult to remediate. While this may be a minor speech error, adults with lateralised /s/ report stigma, anxiety and other social consequences. Instrumental feedback in treatment for speech production has included electropalatography (EPG) and electromagnetic articulography (EMA) to aid correct tongue positioning, and spectrographic display. While EPG and EMA have been successful, few clinicians have access to either system, the methods are expensive and intrusive, and some people do not tolerate the artificial palate in EPG. Spectrographic feedback provide direct information about tongue positioning and may be difficult for some patients to interpret.

Here, we test use of ultrasound to provide a dynamic visual display of the tongue during speech production and directly guide reshaping of tongue positioning. Ultrasound displays the tongue surface in sagittal or transverse sections in real time. Ultrasound feedback has been used effectively to improve speech production in diverse populations including people with hearing impairment or Down Syndrome. To our knowledge use of ultrasound with lateralised alveolar fricatives has not been reported to date.

Purpose

This study uses a within-subject design with multiple-baselines-across-behaviors within a principles of motor learning framework: ultrasound feedback was provided during pre-practice of /s/ production but not during practice trials or daily home practice. The participant was an otherwise healthy 19yo monolingual Australian English speaking male. Treatment was provided twice weekly for 4 weeks with daily documented home practice. Production of treated and untreated stimuli was tested pre-treatment (x3), weekly during treatment (x4), and post-treatment (x3).

It was hypothesised that using ultrasound feedback in pre-practice only would result in:

(a) improved production of /s/ in connected speech
(b) unchanged production of untreated /R/ (Australian rhotic)
(c) generalisation of treatment effects to production of /z/ in connected speech
(d) retention of treatment effects 4 weeks post-treatment.

Data were analysed by an independent examiner blinded to study design and hypotheses. Preliminary data from the three baselines and first three treatment probes suggest hypotheses are supported. Full results and clinical and research implications will be presented.

Additional readings

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INTELLIGIBILITY AND PERCEIVED SEVERITY IN MULTIPLE SCLEROSIS AND PARKINSON'S DISEASE: A COMPARISON OF HABITUAL, CLEAR, LOUD, AND SLOW SPEECH

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Introduction

Rate reduction, increased vocal intensity and clear speech are all used in the treatment of dysarthria. Tjaden, Lam and Wilding (2010) recently reported that speech acoustics in dysarthria can be altered even after a single exposure to each of these techniques , and that the magnitude of the acoustic adjustments varies across techniques. Relevant perceptual studies are lacking, however. Thus, the primary purpose of the current study was to compare judgments of intelligibility and perceived severity for sentences produced in Habitual, Loud, Slow, and Clear conditions by speakers with Multiple Sclerosis (MS) and Parkinson's disease (PD). Healthy speakers were included for comparison.

Method

Speakers and Speech Task: 78 speakers participated including 16 speakers with PD, 30 speakers with MS and 32 age- and sex-matched Controls. Speakers read 15 sentences in their typical voices (Habitual) as well as in Clear, Loud, and Slow conditions. A magnitude production paradigm was used to elicit variations in clarity, intensity, and rate.

Listeners and Perceptual Task

Eighty adult listeners participated. 40 listeners judged intelligibility and 40 listeners judged speech severity. Listeners who judged intelligibility were instructed to focus on how well sentences could be understood. Listeners who judged speech severity were instructed to focus on voice, resonance, articulatory precision, and speech rhythm, without regard for intelligibility. We previously reported that listeners can separately judge intelligibility and overall speech severity for Habitual speech produced by individuals with PD or MS (Sussman et al., 2009). It therefore was of interest to investigate whether Clear, Loud, and Slow speaking conditions would differentially affect intelligibility and perceived severity.

To prevent ceiling effects, sentences were mixed with multitalker babble to yield a SNR of –3 dB. Stimuli were presented at 75 dB SPL via headphones. Listeners judged intelligibility and speech severity using a computerized, 150 mm Visual Analog Scale. 10 listeners were assigned to judge all sentences in a given speaking condition. Sentences were pooled across speakers and randomized, such that a given listener judged sentences produced by all 78 speakers without knowledge of speaker identity.

Results and Discussion

Data collection is complete and analyses are underway. It is predicted that listeners will judge Clear, Slow, and Loud sentences to be more Intelligible and Less Severely impaired than Habitual productions. In addition, results will show which dysarthria therapy techniques produce the greatest perceptual changes compared to Habitual or typical speech.

Recommended Readings

Smiljanić, R., & Bradlow, A. R. (2009). Speaking and hearing clearly: Talker and listener factors in speaking style changes. Language and Linguistics Compass, 3(1), 236–264.
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HOW DO ADAPTIVE ALTERED AUDITORY FEEDBACK PROCEDURES AFFECT THE SPEECH OF ADULTS WHO STUTTER?

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The effects of Altered Auditory Feedback (AAF) on the fluency of people who stutter were discovered decades ago, however the underlying mechanisms have not yet been identified.

Numerous studies have investigated both delayed auditory feedback (DAF) and frequency altered feedback (FAF), with convergent evidence that these conditions generally reduce overt stuttering by 50–80% in some people who stutter.

An obvious weakness of AAF procedures is that they provide no signal at phrase onsets, a problem known as 'cold starts'. Another limitation is that the feedback function is static, so that speakers hear themselves continuously, which might not be optimal both in terms of potential fluency carry-over effects and everyday usability.

One way to address these limitations is to design adaptive rather than continuous feedback functions, with the idea of selectively targeting those regions of speech which are at higher risk of being dysfluent (Howell, 2004). The adaptive feedback procedure we explore in this study deals with 'cold starts' by providing an audio signal only in the silent intervals between phrases. That way, the audio signal targets only to prime the onsets of phrases.

Methods and Results

An experiment has been conducted with 8 adults who stutter. Each participant produced spontaneous speech under 4 auditory feedback conditions assigned in random order. The conditions included: (a) no auditory feedback, (b) a 'classic' DAF with 100 ms delay, (c) an adaptive feedback condition, where DAF with 1500 ms delay is given only during silent intervals, (d) a combination of conditions a + b. Participants also rated their relative comfortability with the different audio signals. Speech samples we examined for overt dysfluencies, in terms of percentage of discontinuous speech time (PDST), and for speech rate. Group results show that the adaptive feedback condition (c) leads to enhanced fluency of speech in relation to control condition (a), however not significantly. Conditions (b) & (d) do lead to significant fluency improvement. There was no effect of condition on speech rate. There was no clear indication for preference between conditions in terms of comfortability. Individual data reveals high variability in participant's responses to different feedback conditions. This, as well as participant's own impressions, suggest that different AAF procedures may have differential affects on various types of dysfluent speech.

Although the adaptive feedback procedure used in this study did not yield better results than a 'classic' DAF, it may be worthwhile to explore alternative designs, and devise methods for AAF procedures to be 'tailored' to individual's speakers needs.

Reference

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POSTER SESSION III

COMPENSATORY ARTICULATORY STRATEGIES IN SPEECH WITH DENTURES

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Purpose

The goal of the present study was to compare effectiveness of implant-retained vs. conventional dentures in terms of accuracy of speech production.

Temporary to permanent changes in articulation have been shown to occur both with conventional and implant dentures: previous studies, based on acoustic, logopaedic or perceptual analyses of speech with dentures, found distortions in labial, labiodental, dental and alveolar fricative or stop consonants, in different languages (Rodrigues et al., 2010).

Contrasting evidence seems to support either superiority of implant, or conventional dentures, or to report no difference in terms of speech errors.

The present study provides a novel articulographic investigation of movements of tongue blade for production of English /s/, /t/ /n/ consonants and of lips for production of /p//f/ by speakers with and without dentures.

The goal was to describe compensatory articulatory strategies emerging during adaptation to the denture (3–4 weeks to 6 months after application), to verify whether similar adjustments to the new dentition were adopted by different patients, and whether some new articulatory patterns were more effective than others in restoring speech functions.

Methods

5 patients with implant dentures, 5 with conventional dentures, and 5 age-matched controls with normal dentition, were selected.

Sentences containing mono- and multisyllabic words with dental and labial consonants in onset and coda in different phonetic environments, were repeated by the participants.

Articulographic recordings were obtained by a Carstens AG200 EMA, and tracked movements of tongue (T1, T2, T3, T4), upper lip, lower lip and mandible.

Analyses of kinematic parameters relative to specific movements and to their coupling, will be performed according to the procedures of the ESMA protocol (Van Lieshout and Moussa, 2000).

Results

Preliminary data from one patient with implant denture and two controls, showed emergence of a compensatory strategy in anterior and posterior blade (T1 and T2) movements, in productions with denture.

Restructuring of anterior blade movements unfolded progressively during repetitions: at first, movements of anterior and posterior blade overlapped. During next repetitions, the patient gradually retroflected the tip of the tongue, first for production of alveolar consonants in coda, then for all alveolars.

Conclusions

Preliminary results suggest presence of a dysfunctional compensatory strategy for the anterior blade movement in production of alveolar consonants with implant dentures.

The gradual emergence of the new movement pattern through repetitions, seems compatible with a Coordination Dynamics view of organization of synergistic movements as a dynamic system, tending to equilibrium states (Kelso, 1995): data might indicate that, from a preferred state perturbed by the denture, a new preferred state (retroflection) is developed, which, however, is dysfunctional and produces an incorrect speech outcome (retroflex /s/, /t/ and /n/).

References

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THE ACCURACY OF PREDICTING LINGUAL MOVEMENTS FROM FORMANTS

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Tongue height and advancement are known to be associated with the first and second formants (F1, F2). These acoustic measures have been used to characterize the degree of impairment in dysarthria and also to document treatment-related changes. The purpose of the present study was to compare kinematic measures of lingual movement during diphthongs with time-aligned formant transitions in order to quantify the extent to which these acoustic measures accurately predicted the movements of the tongue.

Twenty-two speakers repeated 5 times a sentence containing diphthongs, "the boy gave a shout at the sight of the cake." Movements of the tongue were measured with a single fixed magnet attached to the tongue surface at midline, 1 cm posterior to the tip. The magnet's position was measured in three dimensions with a modified jaw tracking system (Dromey et al., 2006). The signals from the tracking system were digitized along with the audio signal.

Vertical and anteroposterior tongue movements were measured in Matlab. Praat software was used to extract F1 and F2 histories which were correlated with the kinematic records for the tongue movements during the diphthongs. A 50 sample window was moved along the recording of the diphthong and a continuous correlation function (Tingley and Dromey, 2000) was used to track the association between the formant frequency and tongue position during the diphthong.

The data from many of the diphthong tokens followed the predicted patterns, in that F1 correlated well with vertical tongue movements and F2 with anteroposterior movements. However, there were numerous exceptions to this pattern. In some cases the lingual movements tracked by the magnet were smooth and predictable, while the acoustic data were far more variable. However, there were also cases where the predicted formant transitions co-occurred with unexpectedly curved kinematic traces. Some of the patterns observed in the current dataset can be attributed to coarticulation. Others suggest that the tongue may not have been the main determinant of the formant histories where the kinematic and acoustic measures were poorly correlated.

The sometimes nonlinear linkage between speech movements and the resultant acoustic signal has been addressed by Stevens (Stevens, 1989). This quantal relationship appears to be implicated in some of the patterns observed in the data. Motor equivalence may also be a contributing factor. A degree of caution appears appropriate when drawing inferences about lingual movements from formant transitions.

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FREQUENCY OSCILLATION IN PHYSIOLOGIC JAW TREMOR: A QUANTITATIVE APPROACH

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Movement physiology of the jaw muscles, including stability in force control, is an important aspect of speech motor control in normal subjects and those with neurodegenerative motor impairments such as Parkinson's disease (PD). Physiologic jaw tremor of PD patients has previously been investigated through isometric jaw-force-control tasks and found to contain component frequencies in the 4–6 Hz range (Boutsen *et al.* 2008).

Jaw-tremor frequency analysis in the 2008 study involved converting a sampled (f_s = 1000 Hz) pressure-transducer signal (Barlow 1983) from the time domain to the frequency domain through a discrete-time Fast Fourier Transform. Specifically, a custom-written GUI was developed in MATLAB allowing epoch selection and control over smoothing as well as amplitude-threshold parameters when performing frequency analysis. While this method was shown to be useful in detecting and quantifying high-frequency components, it is not without limitations (Boutsen *et al*. 2008). This is because jaw oscillations are quasi-periodic and may exhibit changes in component frequencies over time. The single-spectrum FFT conflates such changing components into single scalar values, yielding component-frequency values that may not actually be present in the signal.

The analysis method in this study addresses this problem by extending the technique of the short-time FFT spectrogram, traditionally used for auditory speech signals, to the domain of jaw movement and tremor analysis. The approach was tested on a sample (n = 5) derived from Boutsen *et al.* (2008). So as to maximally target frequencies of interest (i.e. the higher components) and to improve SNR of the resulting spectra, data were preprocessed using a 10th-order Butterworth band-pass filter from 3–12 Hz. The Goertzel algorithm (Goertzel 1958) was then used to restrict the spectrogram to the 3–12 Hz region and to increase frequency resolution for this region (approximately 57 points/Hz). This band of frequencies was selected since it spans those observed in Parkinsonian tremor.

Visual inspection of the short-time FFT spectrogram revealed variation in the primary tremor frequency. This variation was transformed into a frequency-domain functional-form by applying a motor-speech analogue of formant detection, allowing visual inspection and further quantification. In this manner quasi-periodic frequency oscillations were detected and quantified, providing an initial data set for evaluating change in jaw-tremor frequencies. Overall, it was shown that the tremor rate itself is not constant, but in fact evolves in a quasi-periodic manner at 1–2Hz within a ±1.25Hz range.

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STANDARDIZATION OF A COMPUTER ARTICULATION INSTRUMENT (CAI)

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Background

To diagnose and classify different speech production disorders in childhood, an up to date speech production test is needed. In the Netherlands there is a lack of a norm-referenced standardized speech production test for children. A standardized test is especially needed for the indication for special education for children with speech and language disorders.

Besides the need for a standardized test, there is a need for an instrument which can differentiate between the different speech production disorders in childhood. Therefore, it is important that a test comprise measures of the degree of involvement of subtypes of underlying speech deficits, particularly phonological disorder and childhood apraxia of speech.

To meet the above requirements, a speech production test was developed based on a series of studies in children with developmental and acquired speech sound disorders (Thoonen, 1998; Nijland, 2003). Applying a naming task, word and nonword repetition and diadochokinetic tasks, yielded measures which allow for differential diagnosis of phonological disorder, dysarthria, and childhood apraxia of speech.

Methods & Results

The Computer Articulation Instrument (CAI) for children of 2 to 7 years of age contains 4 subtests. Analyses are based on phonetic transcription and are fully automated.

The construction phase of the CAI is completed. In total 1120 typically developing children will be tested, representative for region and urbanization in the Netherlands. At the conference, results of the norm data of 75% of the ultimate sample will be presented and discussed. Furthermore, data were compared with different groups of children with speech-language difficulties.

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EFFECTS OF GLOSSOPHARYNGEAL BREATHING ON LUNG FUNCTION, VOICE, SPEECH AND COMMUNICATION IN ADVANCED MULTIPLE SCLEROSIS: A CASE STUDY

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About 50% of patients with multiple sclerosis (MS) suffer from impaired respiration (Gosselink, Kovacs & Decramer, 1999) and dysarthria (Hartelius & Svensson, 1994). Respiratory dysfunction leads to insufficient alveolar ventilation and cough, reduced voice loudness and short breath phrases. When inspiratory musculature is weak, vital capacity can be increased by using glossopharyngeal breathing (GB). In GB, the patient inspires to total lung volume and then, with movements of the glossopharyngeal musculature, pistons additional air into the airways. This way the rib cage is stretched, resulting in an increased passive expiratory pressure, which can be used to improve voice loudness and mobilize pulmonary secretions (Nygren-Bonnier et al, 2009).

In this single subject study we present the short and long term effects of a 7-week intervention, during which the participant learned to use and practised the GB-technique. The participant, a 47 year-old male with MS and tetraplegia, had limited respiratory function which restricted his voice function. Lung function was measured using spirometry, and voice and speech were analyzed with perceptual and acoustic methodology before, during and after the intervention and at follow ups after 6 and 12 months. Self rating of speech was carried out before and after intervention. Questions on social validity were answered.

Post intervention the subject's respiration, voice and speech were further impaired, likely due to a viral chest infection during the intervention period. However, when the subject used GB, there was a 100% increase in forced vital capacity and peak cough flow. The length of breath phrases and maximum duration of a sustained vowel ("a") were more than doubled. Mean voice intensity increased with 6 dB when counting numbers. Functions remained stable at 12 months post intervention. The effects on the subject's voice were dramatic: he was again able to make himself heard on the telephone and experienced that GB intervention had positive effects on his life situation. Cough was found to be more efficient with the help of GB than with a coughing machine.

Given the fact that respiratory impairment is central in advanced MS and that the speech problems in MS are partly related to respiratory dysfunction, GB may be an important intervention for MS patients. Thus, further studies evaluating the effects of GB on respiration, cough and speech in a group of MS patients are needed.

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INTELLIGIBILITY OF CLEAR SPEECH: EFFECT OF INSTRUCTION

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Introduction

The perceptual benefits of clear speech are suggested by research reporting greater intelligibility for clear versus conversational speech (Smiljanić & Bradlow, 2009). However, "clear speech" has been elicited using a variety of instructions or paradigms such as 'hyperarticulate', 'speak clearly', or 'speak to someone with a hearing impairment speaker'. We recently reported that different instructions for eliciting clear speech were associated with differences in both spectral and temporal acoustic measures (Lam, Tjaden, & Sussman, 2010). The current study sought to investigate whether different instructions for eliciting clear speech, as reported in Lam et al. (2010), were associated with differences in intelligibility.

Methods

Speakers and Listeners

12 healthy speakers produced sentences selected from the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1984). Each speaker was audio-recorded reading a unique set of 18 sentences in four conditions, including Habitual, Clear ('speak clearly'), Overenunciate ('overenunciate each word') and Hearing Impaired ('speak to someone who has a hearing impairment'). 40 normal hearing participants served as listeners.

Procedures

To prevent ceiling effects, sentences were mixed with 12-talker babble at a signal to noise ratio (SNR) of –5 dB. Listeners heard stimuli via headphones at 70 dB and typed their responses into a computer program. All listeners orthographically transcribed sentences produced in one condition for each of the 12 speakers. Groupings of speakers and listeners were carefully controlled so that all listeners transcribed sentences produced in a variety of conditions.

Results and Discussion

At the time of submission, stimuli preparation is completed and data collection is in progress. Data analyses will focus on comparing percent correct intelligibility scores for Habitual, Clear, Overenunciate, and Hearing Impaired conditions. Interspeaker differences in intelligibility will also be examined. Finally, the relationship between acoustic measures reported in Lam et al. (2010) and judgments of intelligibility will be explored.

A finding that intelligibility for Clear, Hearing Impaired and Overenunciate conditions differs would suggest that clear speech instruction has perceptual consequences. In contrast, a finding of no difference in intelligibility among these conditions would suggest that different instructions for eliciting clear speech are equally effective - at least as far as global judgments of intelligibility are concerned. Results are of importance as they address the validity of directly comparing findings from studies employing different 'clear speech' instructions. Results also have clinical implications in so far as clear speech is used as a treatment strategy for dysarthria.

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APPLYING CROSS RECURRENCE ANALYSIS TO THE LABIAL CORONAL EFFECT

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There is a lack of methods for the analysis of non-stationary continuous time series in speech research. Hence, most studies focus on measures of single data points or intervals. A growing body of studies uses Functional Data Analysis, a method that allows to separate temporal variability from amplitude variability by aligning the signals. However, it is not always reasonable to separate temporal and amplitude variability, especially when dealing with multidimensional signals.

We introduce a new method borrowed from physics called cross recurrence analysis to speech production (Marwan et al., 2007) which can be used to measure the similarity between time series without the need to align them. Furthermore, our implementation of the cross recurrence analysis reduces statistical problems that are caused by the inter-dependence of successive samples.

An ideal application of the cross recurrence analysis is the study of the Labial Coronal effect as triggered by speeded repetition paradigm. This effect relates to the preference of CVCV sequences to have a labial consonant before a coronal consonant (La-Co order) rather than the other way round (Co-La order).

This effect has been elicited in an articulatory and acoustic study by Rochet-Capellan and Schwartz (2007), and it has been replicated for German by Fuchs et al. (2009).

In the current study, acoustic data from these two experiments are analyzed for 5 speakers of French and 5 speakers of German who produced the sequences /tapa/, /pata/, /tafa/, /fata/, /pasa/, /sapa/. The speech rate was varied by asking the speakers to articulate in pace with a visual metronome.

To assess the relative order between successive consonants, we measured their relative temporal cohesion through an index of the relative timing between each consecutive pair of acoustic consonant releases (henceforth ΔC index). When ΔC is positive, a labial consonant is more overlapped with the following coronal consonant and an underlying La-Co order is inferred. Results show that as speech rates increase, speakers spontaneously switch to the La-Co order. By means of cross recurrence analysis we compared the acoustic signals of consecutive utterances. At fast speech rate, successive La-Co utterances are more similar than successive Co-La utterances. Hence, we conclude that the labial-coronal utterances are more stable.

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A COMPARISON OF METHODS FOR DECOUPLING TONGUES AND LIPS FROM JAW MOVEMENTS IN 3D ARTICULOGRAPHY

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Purpose

One of the most established methods used to study the motion of oral cavity structures in speech is the 3D Electro-Magnetic Articulograph (EMA). For many purposes, it is important to use algorithms to decouple the motion of the tongue and the lower lip from the motion of the mandible (Vatikiotis-Bateson & Ostry, 1995). In this paper, a new method called JOANA (Jaw Oral Dynamics Analysis) for correcting jaw motion in 3D tongue and lower lip data is proposed, which only requires one sensor coil attached to the lower jaw. JOANA is implemented in a Matlab-based EMA processing software developed at the Oral Dynamics Lab (Department of Speech Language Pathology, University of Toronto), called EGUANA (EMA GUI analysis).

Material and Methods

For the evaluation of the new method, we acquired motion data from tongue blade, tongue dorsum, tongue body, lower lip, three reference coils on the head and three on the jaw (incisors and molars). The jaw reference coils were used to estimate residual errors for jaw correction using a similar procedure suggested for dynamic head correction [Kroos, 2009]. These data provide benchmark information to be used for evaluating different jaw correction methods. Next to the JOANA method, we assessed the effectiveness of two other single coil methods (i.e., simple subtraction and an adapted version of the method proposed by Westbury et al. (2002)).

Results

In comparison with other methods that also use information from a single reference coil, the proposed method shows smaller residual errors and is comparable to methods that use information of more than one sensor coil attached to the jaw.

Conclusion

The proposed method is an efficient method to decouple tongue and lower lip motion from jaw motion, since it is able to perform a correction with a reduced error and without requiring more than one mandibular coil.

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SPONTANEOUSLY OCCURRING SPEECH ERRORS IN THE BAS CORPORA

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Speech errors data have long been used to gain insights into otherwise opaque mental planning processes and to develop models of speech planning and execution (Goldrick, 2006). Thereby errors have mostly been evaluated based on auditory transcription. The most frequent error pattern identified has been a categorical phonological substitution of an intended segment by an unintended, intruding segment. However, acoustic and articulatory studies of errors have shown that in many cases the phonetic properties of errors substantially deviate from those identified by auditory evaluation, suggesting that errors do not arise from a discrete phonological substitution process (Pouplier & Goldstein, 2010). In the light of these conflicting results, the methodology of error collection has become a pressing issue. Articulatory and acoustic studies of errors use highly artificial error elicitation methods, which raises the question of whether errors triggered in the laboratory are comparable at all to naturally occurring errors. Transcription records, on the other hand, may be severely tainted by perceptual biases.

Large speech corpora offer an up to now largely unexplored resource for speech error research. We discuss methodological issues and present first data from a project pioneering the acoustic analysis of spontaneously occurring speech errors in large speech corpora. We use the Bavarian Archive for Speech Signals (BAS) comprising acoustic recordings of more than 1000 speakers (Verbmobil I+II, SmartKom). These corpora were transcribed orthographically for speech technology research at the time of data collection and 'errors' were labelled during the transcription process. We have filtered out the sublexical errors among the errors identified by the orthographic transcribers, and explore to what extent an acoustic error analyses is viable. Importantly, since speakers correct themselves in over 90% of cases, the recordings contain a sample of both the errorful and the intended utterance by the same speaker. Particular potential for analysis lies in vowel errors, which have received almost no attention in laboratory-based speech error research involving healthy adult speakers. First results suggest that about 50% of the errors identified in our data affect consonants, while about 25% are vowel errors. Syllable omission or addition errors amount to about 10%. We discuss the feasibility of acoustic analyses of speech errors in these kinds of data, and present the potentials and limitations of this approach. Analysing spontaneously occurring error in speech corpora will provide an important additional resource to the error collection methods employed so far.

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ROLE OF SENTENCE-FINAL PARTICLES IN DECODING COMMUNICATIVE INTENT

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This study was aimed at demonstrating the role of prosody and sentence-final particles in decoding communicative intent of Mandarin speakers. Prosody, being extrasegmental component of the language, typically reflects affect/attitude of a speaker. In English, intonation serves a grammatical function, playing an important role in conveying a speaker's communicative intent — e.g., a question is differentiated from a statement by a rising tone toward the end of a sentence. In Mandarin Chinese, lexical tone (a tonal pattern assigned in the lexicon, Schack, 2000) is often used to differentiate word meaning. Mandarin tonal structure includes neutral tone (flat), 1st tone (high pitch), 2nd tone (rising), 3rd tone (falling-rising), and 4th tone (falling). Unlike English, Mandarin Chinese expresses communicative intent, beliefs and attitudes differently by using communication-oriented particles (e.g., ma, ba, de, le, etc.). According to Leung (2008), these are morphemes that occur at the end of a sentence, which are known as 'sentence-final particles' (SFPs). A major use of SFPs in Mandarin is to signal a speaker's attitude, to register or pragmatic effects rather than linguistic modality, and serve as an interpersonal function (Lu, 1997).

Twenty subjects (12 Monolinguals, 8 Bilinguals) aged 21 to 48 (X= 26 ± 6.4) with no knowledge or backgrounds in any Chinese language or culture took part in this study. All subjects participated in a training consisting of seven sets of short Mandarin phrases with four commonly used SFPs and a XnoX structure conveying the following communicative intents: General question, Yes/no question, Rhetorical question, Statement, and Completion. The presentations of the stimuli were randomized among 7 sets of phrases that varied in their semantics-e.g., hao3ma0 (Is that OK?), dui4ma0 (Is that right?), hui4ma0 (Do you know how to do it?), lai2ma (Are you coming?) and qu4ma0 (Are you going?). Two-tail paired sample t-tests revealed significant differences in accurate decoding of communicative intents between pre-and post-trainings for all SFPs at .01 level: XnoX [t (19) = –12.861*], ma [t(19) = –14.457*], ba [t (19) = –7.150*], de [t (19) = –3.365*], le [t (19) = –10.899.*]. No gender or age effects were found. Language background was also not found to contribute the differences in training effects. The study results yield support for using sentence-final particles in decoding communicative intents of Mandarin Chinese speakers.

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EFFECTS OF PRACTICE SCHEDULES ON SPEECH MOTOR LEARNING

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Researchers in the field of limb motor learning have long been interested in how to optimize learning by manipulating practice schedules. Practice schedules such as blocked practice (i.e., different targets practiced in separate successive blocks) and random practice (i.e., different targets intermixed in each practice block) have received much attention in the past. The general findings are that, relative to random practice, blocked practice leads to better performance during the acquisition phase but poorer performance in retention tests. However, there is evidence to suggest that optimal learning is achieved by introducing a mixed practice schedule (i.e., both blocked and random practice are included during the learning phase) relative to either blocked practice or random practice being introduced alone.

Recently there is renewed interest in whether and how principles of limb motor learning can be applied to speech motor learning (Maas et al., 2008). Some studies have investigated the effects of blocked practice and random practice on speech motor learning. However, none of them has examined the possible interaction between the two. Therefore, the present study was conducted to investigate this issue using a novel speech task.

Participants were asked to learn to produce a Cantonese phrase (with six CV-syllables) over a specified duration of 2500ms or 3500ms (Adams & Page, 2000). Participants were randomly assigned to one of four groups: 1) blocked practice only, 2) random practice only, 3) blocked practice followed by random practice, and 4) random practice followed by blocked practice. Feedback on utterance duration was given after each learning trial. Retention tests without feedback were introduced immediately and two days after the learning phase. Also, a transfer test, in which participants were asked to do a secondary distracting task simultaneously with the speech task, was given after the second retention test. Preliminary results suggest that Group 2 (i.e., random learners) showed the least improvement during learning. Furthermore, although the groups did not differ from each other in retention tests, participants from Groups 3 and 4 (i.e., mixed learners) showed more stable performance relative to those from Groups 1 and 2 during the transfer test. These results, which are consistent with those from limb motor learning research, suggest that mixed schedules lead to more stable change in speech motor performance than either blocked practice or random practice alone.

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DICHOTIC AND SINEWAVE PROCESSING IN PERSONS WITH STUTTERING: A PRELIMINARY STUDY

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The notion that auditory processing in persons with stuttering (PWS) is not normal has received research attention from studies spanning at least 4 decades. One line of inquiry has used dichotic listening to reveal potentially abnormal laterality in auditory processing of language in PWS. In normal controls this paradigm revealed a right ear advantage or left hemisphere laterality for speech processing. Deviations from this performance pattern have not been shown consistently in studies with PWS, in part due to methodological differences. A left ear preference PWS was shown by Curry and Gregory (1969), Quinn (1972) and Brady (1975) but not by Rosendfield and Goodglass (1980) and Blood (1986). The latter study found, however, reduced processing in PWS if attention was directed to the left but not the right ear, a decrease that was not present in normal controls. More recently, Foundas et al. (2004) found that 50% of left-handed male PWS failed to show a LE advantage but that it was unremarkable in right handed participants. The mixed results obtained using the dichotic listening paradigm point to a need for further investigation if not also other methodologies that could complement this line of inquiry. Sinewave speech (SWS) analogs if presented monaurally with or without contralateral masking could hold promise in this regard. Developed by speech scientists to investigate the processing of sound as speech, these ambiguous stimuli can involve left- or right-lateralized processing strategies pending on whether they are perceived as speech or non-speech. The purpose of this study was to explore auditory processing in PWS and a control group using dichotic listening and sinewave speech paradigms. It was predicted that if PWS who stutter use less left lateralized brain strategies as is suggested by dichotic listening tests their response to sinewave speech might be different as well. Participants included six PWS (4 were right dominant, 2 left, mean age 38.5 (SD = 15.8)) and six normally fluent persons (5 right dominant, 1 mixed, mean age 37.8 (SD = 10.5)). They were given a CVC dichotic word test with and without directed attention and a SWS test. Stimuli in the latter task (trials = 142; 1 syllable: consonant or vowel initiated) were administered monaurally to the left or the right ear with or without masking (40 dB). Results reveal that handedness was predictive of ear preference. Furthermore, directed attention affected dichotic listening differently in the groups. As for SWS, accuracy across groups ranged from 80.36 to 95% with PWS being more accurate than normal controls (89.91 vs. 87.5%). Accuracy was better if syllables were consonant initiated, delivered to the right ear and not accompanied with masking contralaterally. Interestingly, PWS unlike normal controls made fewer errors in the masking than in the non-masking condition.

IDENTIFYING THE LEVEL THAT ERRORS ARISE IN ACQUIRED SPEECH IMPAIRMENT

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Introduction

Articulatory errors may arise in acquired phonological impairment in phonemic paraphasia (PP) or motor speech impairment as in Apraxia of Speech (AOS), with the latter associated with prosodic abnormalities and distortions (McNeil et al., 2009). Given high rates of comorbidity of PP and AOS, the following question arises: for individuals with both PP and AOS, can we identify whether specific errors arise before motor planning (PP) or during motor planning (AOS)?

Method

P1 and P2 were both diagnosed with PP and AOS by an SLP. Each individual made frequent /s/-deletion errors in words with /s/-initial onset clusters (P1: 51%; P2: 20%). Due to lexical access impairment, participants were tested with repetition tasks designed for this study. Intact auditory speech perception was verified with minimal pair discrimination tasks.

VOT. Participants repeated /s/-stop clusters (spill~still~skill), and control words with voiceless (pill~till~kill) and voiced stops (bill~dill~gill). In unimpaired speech, the stop in clusters is unaspirated, with a VOT equivalent to the English voiced stop. Thus, if /s/ is deleted after generating context-specific timing, the resulting stop should be unaspirated (as in clusters); in contrast, if /s/ is deleted before generating context-specific timing, the resulting stop should be aspirated.

Nasal duration. Participants repeated /s/-nasal clusters words (smear, sneer) and control words with singleton nasals (mere; near). In unimpaired speech, nasals are shorter in clusters than as singletons. Thus, if /s/ is deleted after generating context-dependent for the cluster, the resulting nasal should be shorter than singletons; in contrast, if /s/ is deleted before timing is generated, no differences should be obtained.

Results

VOT. P1's /s/-deletion in /s/-stop clusters yielded VOTs significantly longer than the voiced stop, consistent with a singleton voiceless stop. In contrast, P2's deletion errors yielded VOTs significantly shorter than voiceless stops, similar to the voiced stops; thus, P2's productions were consistent with the timing of a cluster.

Nasal duration. P1's /s/-deletion errors did not yield significantly different nasal durations than singleton nasals. In contrast, when P2 deleted /s/ from /s/-nasal clusters, the resulting nasal was significantly shorter than the nasal in control words.

Discussion and Conclusion

These data revealed consistent differences between two types of /s/-deletion. For P1, the output following /s/-deletion reflected the articulatory timing of a singleton onset (and not a cluster). For P2, the output reflects the articulatory timing associated with an /s/-initial cluster, even when /s/ was deleted from the output form. These two patterns, consistent with deletion at context-independent and context-specific levels respectively, indicate that we can determine where errors arise from their articulatory properties.

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CLASSIFYING CHILDREN WHO STUTTER AND CHILDREN WHO DO NOT STUTTER: EVALUATION OF THE 3% STUTTERING LIKE DISFLUENCIES CUTOFF

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Objective
Three % stuttering-like disfluencies (SLD) seems to become an accepted cutoff criterion for distinguishing children who stutter (CWS) and children who do not stutter (CWNS). In the absence of a gold standard for assessing stuttering, Bloodstein & Bernstein Ratner (2008) recommend expert perceptual judgment as the best estimate of the presence of stuttering. To evaluate the 3% SLD cutoff point, this classification criterion was compared with expert severity scaling. To enable a broader discussion, also a 'weighed SLD score' of 4 and 3% Syllables Stuttered (SS) were included as reference points for classifying CWS and CWNS.

Methods
Twenty experts in stuttering rated stuttering severity in 300-syllable audio speech samples of 17 preschool children whose parents were concerned about possible stuttering by using an 8 point scale (1 = severe stuttering, 6 = borderline stuttering, and 7 = normally fluent). Two trained raters computed % SLD, weighted SLD and % SS for the same 17 speech samples.

Results
Using the mean expert severity rating as a criterion, a cutoff point of 3% SLD resulted in wrong identification of three out of 17 children, just as the cutoff point of a weighed SLD of 4. However, a cutoff point of 3% SS led to the same classification as the mean expert severity rating.

Conclusion
Prudence is suggested in applying the 3% SLD cutoff point as a grouping factor classifying stuttering and normally fluent children for research purposes. Three percent SS is yet to be preferred as a cutoff measure to classify CWS and CWNS for research purposes.

NEURAL SUBSTRATES FOR SPEECH PRODUCTION IN NORMAL AND DEVELOPMENTAL STUTTERING SPEAKERS

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A dual-route cascaded model of visual word recognition and reading aloud (DRC) has been proposed based on the word familiarity effects (Coltheart M, et al., Psychol Rev. 200;108:204–56), and is given support from functional brain imaging (e.g. fMRI) in that Broca's area is activated by reading silently unfamiliar and pseudo-words, as part of the indirect route (Ischebeck A, et al., J Cogn Neurosci. 2004;16:727–41). Since the gray matter volume of Broca's area has been found smaller in people who stutter (PWS) than in people who do not stutter (PWNS) (Chang SE, et al., Neuroimage. 2008; 1:39:1333–44), the functionality of the indirect route for reading could be compromised in PWS.

Methods

We employed an overt reading task of high- and low- familiarity and pseudo- words presented visually in Katakana, (1) in order to investigate the neural word-familiarity effects in PWNS, and (2) to compare the results with those from PWS. We used an event-related sparse-sampling design of fMRI, in which subjects read words aloud during scanning intervals. This allowed normal auditory feedback and reduced head motion artifacts due to articulation. High- and low- familiarity Japanese words with four or five syllables (morae) long were chosen from "Lexical properties of Japanese" (Amano N, et al, 1999). Pronounceable pseudowords of the matching lengths were generated by randomly ordering letters. The cloze rates of understandability for high-, low-familiarity and pseudowords were 100, 0, and 0%, respectively.

Results

(1) In PWNS, Broca's area showed a word-familiarity effect with which low-familiarity words activated the area more strongly than familiar words. While reading pseudowords activated the Broca's area, as previously shown, it also activated the left motor area, which was not observed in previous silent reading or lexical decision tasks. (2) PWS failed to activate Broca's area significantly for reading low-familiarity and pseudo- words even though they did not stutter during the fMRI sessions. This suggests that there is little or no word-familiarity effect in this area for PWS, contrary to the prediction of the DRC. Instead, they showed stronger activation in the left motor cortex for all word categories.

Conclusions

(1) We propose a third route including the left motor cortex, in addition to DRC, for overt reading of words that do not conform to the syllable (mora) sequences in natural words. The Broca's area and the posterior lexicon presumably encode native syllable sequences for efficient articulation without significantly activating the motor cortex in PWNS. (2) The elevated activation of the motor cortex for all word categories in PWS is likely due to an enhanced recruitment of this area to compensate dysfunctional Broca's area, which, however, may imply less efficient articulation of even native words in PWS.

DYSFUNCTIONAL INTRACORTICAL NETWORKS IN THE PRIMARY MOTOR TONGUE REPRESENTATION IN ADULTS WITH PERSISTENT STUTTERING

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Neurons of the primary motor cortex receive influential input from frontal cortex regions, the basal ganglia, and the cerebellum. Their descending output innervates coordinated, voluntary movements. Intracortical inhibitory and excitatory networks of the primary motor cortex promote the selection and initiation of target movements and suppress undesirable synergisms (Stinear et al. 2009). Current knowledge about the efficiency of these intracortical networks in stuttering relies mainly on imaging studies, reporting for instance hyperactivity in the primary motor cortex during speech production but diminished activity during speech perception (Chang et al. 2009). However, the aberrant haemodynamic responses as quantified by functional magnetic resonance imaging provide only hints towards an imbalanced intracortical excitability modulation. The method of choice to investigate intracortical excitability modulation in human is transcranial magnetic stimulation. We here present the first study of intracortical excitability of a speech muscle in persistent stuttering. In 12 adults who stutter and in 14 control subjects, we examined motor threshold, motor-evoked potential (MEP), the MEP input-output curves (i.e. the amount of MEP-amplitude increase with rising TMS stimulus intensity), short-term intracortical inhibition and intracortical facilitation, by adopting the procedure of Muellbacher et al. (2001), who delivered the sole data of intracortical excitability in ipsilateral and contralateral human motor cortex representations of the tongue in non-stuttering adults. Motor thresholds did not differ between groups. Control subjects showed a paired-pulse induced inhibition of the MEP-amplitude at short inter-stimulus interval and a paired-pulse induced facilitation of the MEP-amplitude at long inter-stimulus intervals. In comparison, adults who stutter showed a reduced short-term intracortical inhibition in the right hemisphere and a reduced intracortical facilitation in both hemispheres. Contrastingly, the amount of MEP-amplitude increase with rising TMS stimulus intensity was steeper in adults who stutter. Our data suggest that stuttering is associated with an impaired facilitation in response to activation of cortical interneurons, but an excessive cortico-bulbar energization, particularly in response to voluntary muscle contraction. These results provide novel insights into pathomechanisms and a potential role of transcranial magnetic stimulation in understanding speech induced excitability modulations and pharmacological treatment responses in stuttering.

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NEURONAL CORRELATES OF AFFECTIVE AND LINGUISTIC PROSODY IN STUTTERING SHOWN WITH FMRI AND EFFECTS OF THERAPY AND RECOVERY

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Introduction

With respect to speech prosody, affective and linguistic prosody are distinguished. Previous neuroimaging studies on speech prosody have mainly investigated perceptive aspects (Kotz et al., 2003, Mitchell et al., 2003). They have shown mainly left-hemispheric activations during linguistic prosodic tasks and either right-hemispheric or bilateral brain activation during affective prosodic tasks in the temporal cortex, the peri-sylvian cortex, in the frontalen operculum, and in the basal ganglia. All these regions show either abnormal activations or abnormal morphology in persons who stutter (PWS) compared to non-stuttering control subjects (PWNS). An effective stuttering therapy should normalize the disturbed speech prosody in PWS. On the other hand, therapy approaches such as fluency shaping methods exploit prosodic cues for therapeutic aims for example by practising special voice onsets or speech bows.

The aim of this study was the examination of the brain activations during speech motor tasks performed with neutral, linguistic, and affective prosody by PWS before and after an effective fluency shaping therapy compared with those of PWNS.

Method

An fMRI speech production experiment was performed with 13 male PWS (mean age 27 years, range 18–39, mean handedness score 50, SD = 54) before and after an intensive course of the Kassel Stuttering Therapy and 13 males who had recovered from stuttering spontaneously (Kell et al., 2009).

Results

PWNS activated mainly in the left-sided anterior insula, inferior frontal gyrus, and supramarginal gyrus as well as in the right cerebellum. There were no remarkable activation differences between affective and linguistic prosodic tasks. PWNS were not able to activate this network before therapy. However, directly after therapy the activation of PWNS for affective prosody already normalized compared with that one seen in PWNS. Contrasting, a normalization of the activation for the linguistic prosodic task was not observed at that time but one year after finishing the therapy. The activation changes were paralleled by a normalization of prosody parameters.

Conclusion

The cerebral activations shown in the controls seems to reflect the prosodic network in normal speaking subjects The described activation changes in PWS may be attributed to local insular and left inferior frontal trainee effects which are accompanied by subcortical overactivation.

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STIMULATION OF THE SUBTHALAMIC NUCLEUS IN PARKINSON'S DISEASE CHANGES THE RELATIONSHIP BETWEEN REGIONAL CEREBRAL BLOOD FLOW AND SPEECH RATE

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High frequency electrical stimulation of the subthalamic nuclei (STN), commonly referred to as deep brain stimulation (DBS), has become a widely used therapy in movement disorders but its therapeutic mechanism is not understood. DBS improves levodopa responsive motor problems in Parkinson's Disease (PD) but speech does not benefit and can be adversely affected (Klostermann et al., 2008). DBS is believed to reorganize neurophysiological activity within the basal ganglia while local field effects can produce side-effects. We have been using Positron Emission Tomography (PET) to study the effects of DBS on cerebral blood flow (CBF) during speech tasks in PD subjects. Seven right-handed PD subjects with bilateral STN-DBS underwent CBF studies using H215O PET while speaking. Complete studies (12 whole-brain scans) were obtained on different days for STN-DBS on and off. All studies were conducted at least 12 hrs after the last dose of levodopa. Regions of interest (ROIs) were obtained with a template derived from a composite of 166 images. Speech tasks were recorded for subsequent analyses. A performance-based analysis was conducted to determine if relationships among brain areas predicted speech rate (Sidtis et al., 2007). Increased speech rate was significantly modeled in the STN-DBS off condition by an increase in left inferior frontal gyrus rCBF and a decrease in the right caudate nucleus rCBF [$F(2,24) = 14.15$; $p < 0.001$]. In the STN-DBS on condition, this relationship was absent. Compared to the DBS off condition, DBS on produced an abnormal left/right hemispheric asymmetry in the inferior frontal gyri and a symmetry in the caudate that was not present in the off condition. However, with DBS on, speech rate was predicted by a combination of increases and decreases in the left sensori-motor strip. On a regional basis, the cortical-subcortical interaction associated with speech rate previously reported in normal and ataxic speakers (Sidtis et al., 2007) was present when STN-DBS was turned off, but was absent when STN-DBS was turned on. These results suggest that bilateral stimulation of the STN may disrupt both cortical and subcortical asymmetries normally present during speech, even when cerebellar ataxia or PD is present. This reorganization of cortical and subcortical activity during speech may account for both subjective complaints and objective findings of speech changes following DBS (Sidtis, D. et al. 2010).

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SCREENING PHONOLOGICAL ACCURACY, EFFECTS OF ARTICULATORY RATE ON PHONOLOGICAL ENCODING

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An assessment instrument specifically developed and validated to assess speech motor on word level "the Screening Phonological Accuracy" (Van Zaalen et al., 2009a) adds differential diagnostic speech characteristics between people who clutter (PWC) or persons who stutter (PWS). While stuttering is known as a motor disorder (Van Lieshout, Hulstijn, & Peters, 1996), it is hypothesized that cluttering is a fluency disorder in which phonological encoding can be disturbed in a fast speech rate, resulting in errors in metrical frame generation, slot construction or segmental spell out. In the first part of this research project in an elicitation procedure, repetitions of complex multi-syllabic words at a fast speech rate, were obtained from 374 Dutch speaking participants (47 dysfluent participants (mean age 24.3; SD=10.3 yrs; range 14.2–47.4 yrs) and 327 controls (mean age 25.6; SD = 8.5 yrs; range 14.3–50.1 yrs). Speech production was judged on articulatory accuracy (distortion or voicing), smooth-flow (coarticulation, flow and sequencing) and articulatory rate (Webster, 1986). Results from PWS or PWC were compared to normative data based on the control group data. PWC produced significantly more flow and sequencing (i.e. phonological encoding) errors compared to PWS.

In the second part of the research project results of the Dutch research population were compared to results of 105 native English speaking participants (83 controls, without fluency or intelligibility complaints and 22 participants with fluency disorders) on the translated version of the SPA in an attempt to gain normative data for the English speaking population. Results show that both the SPA Dutch version and the SPA English version differentiated between persons with or without phonological errors at a fast speech rate. Results tentatively suggest that a test on phonological encoding deserves its place in the standard assessment protocol of speech disorders.

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