Sensorimotor Adaptation to Temporal Auditory Feedback Perturbation and its Relation to Motor Variability in General Timing Tasks

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Coupling sensory percepts with feedforward predictions is a mandatory mechanism in human attempts to precisely execute complex motor actions. In speech production, speakers attempt to reach speech targets that comprise predictions about spectral and somatosensory properties of sounds (Guenther *et al.*, 2003). Additionally, it can be assumed that predictions of speech must include information about the timepoint and timeframe for the particular motor action (Kotz and Schwartze, 2010; Oschkinat and Hoole, 2019). Real-time perturbation of spectral properties in auditory feedback (AF) indicated a link between feedback and feedforward mechanisms in speech production and reinforced the idea of speech targets when subjects compensated for applied shifts (Mitsuya *et al.*, 2011; Villacorta *et al.*, 2007). In the much newer field of *temporal* AF perturbation it was shown that speakers also compensate for temporal alterations of AF, providing evidence that speech targets must also comprise predictions about temporal properties of speech sounds (Oschkinat and Hoole, 2019).

In research on the perception-production interplay it was shown that subjects with a higher perceptual auditory acuity compensated more in spectral AF perturbation (Villacorta *et al.*, 2007). However, the reaction to feedback perturbation is not merely a matter of perceptual acuity but is also certainly affected by the ability to predict and produce precise motor action. This interplay between prediction, perception and motor execution seems to be crucial for timing of speech, as well as the timing of non-speech motor actions. Indication for a link between speech and non-speech motor timing abilities arises from investigations on people who stutter (PWS). Falk *et al.* (2015) found timing deficits in PWS not only in speech execution but also in non-verbal beat-alignment tasks that demand precise timing predictions.

The present study aimed at drawing a link between predictive timing mechanisms in speech and non-speech motor action, investigating how general motor timing abilities influence speech execution when it comes to an auditory distractor. Therefore, reactions of 23 subjects to temporally perturbed AF and profiles of their general rhythmic performance in production and perception were assessed. In the first step of this investigation we probe whether rhythmic production capacities of subjects are linked to compensatory behavior in temporal real-time AF perturbation; this link has scarcely been investigated before and could give new insight into similar underlying timing mechanisms for speech timing and general motor timing.

Rhythmic profiles were compiled with selected tests of the BAASTA tapping battery (Dalla Bella *et al.*, 2017) including unpaced spontaneous finger tapping, paced tapping to an external beat and tapping to a musical stimulus. The temporal AF perturbation paradigm (previously described in Oschkinat and Hoole (2019)) comprised stretching and compressing of sounds with respect to syllable position (onset+vowel (CCV) perturbation vs. vowel+coda (VCC) perturbation). Subjects were shown to compensate and adapt for all perturbed segments and directions except for CC in the onset+vowel perturbation condition. This finding indicates that updating of feedforward models over the quite short time span of a typical perturbation experiment also extends to temporal properties of speech sounds. However, prosodic structures such as syllable onsets that are often assumed to show higher stability (e.g. in Task Dynamics/Articulatory Phonology) are more resistant to temporal manipulations of AF.

In the current study, compensation magnitudes of the vowel+coda perturbation (that elicited an overall greater reaction) were correlated with motor variability in the three selected BAASTA tapping tasks (unpaced, paced by beat, paced by music). We expected subjects with a greater variability in general motor timing tasks to show a greater compensation magnitude, since a less stable motor pattern should also be more malleable when it comes to an auditory distractor.
Linear models were calculated with compensation magnitude as dependent variable and the coefficient of variation of the inter-tap-interval (CV of the ITI) as independent variable for each of the tapping tasks. We found correlations for all of the three tasks, showing that a higher variability in inter-interval tapping is associated with a greater compensation to temporally perturbed AF (Figure 1). This finding indicates that subjects who established more stable motor execution patterns (those who show lower motor variability) produce speech timing patterns that are also less malleable when it comes to an auditory distractor. Further, these results underline the assumption that motor timing abilities in speech, non-speech and music may follow similar underlying predictive timing mechanisms. Moreover, articulatory adjustments as a reaction to AF perturbation seem to be not only dependent on the perceptual acuity of a speaker, but are also dependent on the stability and execution ability of their feedforward model. Further results incorporating the link between perception and perturbation will be presented at the conference.

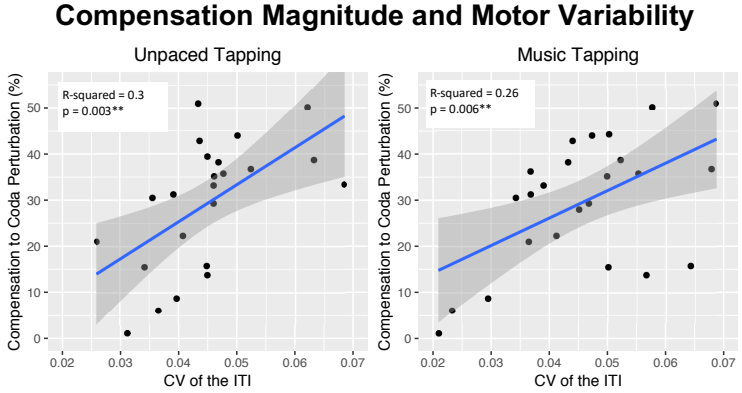

Figure 1. Correlations of compensation magnitude to temporal real-time AF perturbation and the coefficient of inter-tap-intervals (CV of the ITI) of 23 subjects for unpaced tapping (left panel) and paced music tapping (right panel), paced metronome tapping not shown.

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