

Decoding dynamics in complete facial paralysis: Articulatory coupling and decoupling

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Background: Complete facial paralysis profoundly impacts speech motor control mechanisms through the absence of independent lip movement, entailing changes in coordination between articulators. While previous research has documented different kinematic mechanisms [1,2], the coupling and decoupling mechanisms remain poorly understood. Moebius syndrome (≈ 0.0002 to 0.002% of the world's population), characterized by congenital bilateral facial paralysis, provides a unique window into these coordination dynamics. Phase plane analyses reveal articulatory dynamics including movement magnitude, pattern quality, cycle-to-cycle consistency, and inter-articulator interactions [3,4].

Methods: Three French speakers with Moebius syndrome and intact speech intelligibility (M1 = 41 years, M2 = 43 years, M3 = 27 years) and one French control speaker (46 years) produced fast syllable repetitions (diadochokinesis, DDK) of /pa/ (bilabial), /ta/ (alveolar), and /ka/ (velar). Data was collected with Electromagnetic articulography (AG501), capturing the movements of jaw, upper/lower lips (UL, LL), tongue tip (TT), and tongue body (TB). Phase plane analyses (y-dimension) were done over ten repetitions (discard of 1st syllable).

Results: Fig. 1 presents phase plots for all articulators during DDK tasks, comparing three individuals with Moebius (IwM) with the control speaker. The control generally exhibits more consistent and elliptical trajectories, while the IwM show greater variability and irregularity.

Jaw-LL coupling: Control demonstrated flexible coupling with task-specific velocity independence (/pa/: jaw 337 mm/s vs. LL 493 mm/s) and variable velocity-position correlations (0.65-1.53). IwM showed increased passive biomechanical coupling with rigid position-velocity relationships: M1 exhibited remarkably consistent jaw-LL ratios (1.10-1.13 across all tasks), M2 showed moderate coupling (ratios 1.09-1.48), and M3 demonstrated coupling rigidity reflected in nearly identical jaw-LL ratio for /ka/ (1.01).

TT-TB decoupling: Control speaker demonstrated synergistic coupling with velocity ratio modulation across tasks (0.32-2.35), whereas IwM exhibited distinct decoupling patterns: (1) M1: Inverse support coupling: for /ta/, TB velocity with 99 mm/s (vs. control 125 mm/s) less support of TT elevation; (2) M2: Fragmented decoupling: /ta/, TT velocity 98% of control but with disorganized circular patterns; /ka/ severe range-velocity dissociation (TB 201% position range but only 60% velocity); (3) M3: Rigid coupling: TB/TT velocity ratios constant (1.25-1.48); excessive TB activity in /pa/: 347 mm/s vs. control 84 mm/s).

Position-velocity dissociation: IwM demonstrated preserved position ranges (64-87% for jaw/LL in /pa/) but severe velocity deficits (30-67%), with M3 showing most extreme reduction.

Velocity paradox (high velocity despite small positional change): IwM exhibited complex velocity patterns: (1) reduced velocity for primary articulators (/pa/ jaw/LL: 30-67% of control), (2) excessive velocity for tongue in labial DDK (/pa/ tongue: 147-412% of control), (3) compensatory increases in supporting articulators (/ta/ and /ka/ jaw/LL: up to 36-86% higher than control), and (4) high velocity with disorganized patterns (M2 /ta/ TT: 98% of control velocity but with ballistic, circular patterns).

Discussion: The control speaker demonstrates flexible, task-specific coordination with efficient TT-TB synergy. In contrast, all IwM exhibit the velocity paradox: reduced velocities in primary articulators, excessive or compensatory velocities in others, and altered coupling patterns, increased passive jaw-LL coupling and TT-TB decoupling. Our findings show high but disorganized velocities. This study reveals that intelligible speech can be achieved through fundamentally different articulatory dynamics, demonstrating how the human speech motor system flexibly reorganizes in the face of biomechanical constraints. Further analysis with more controls will be presented at the conference.

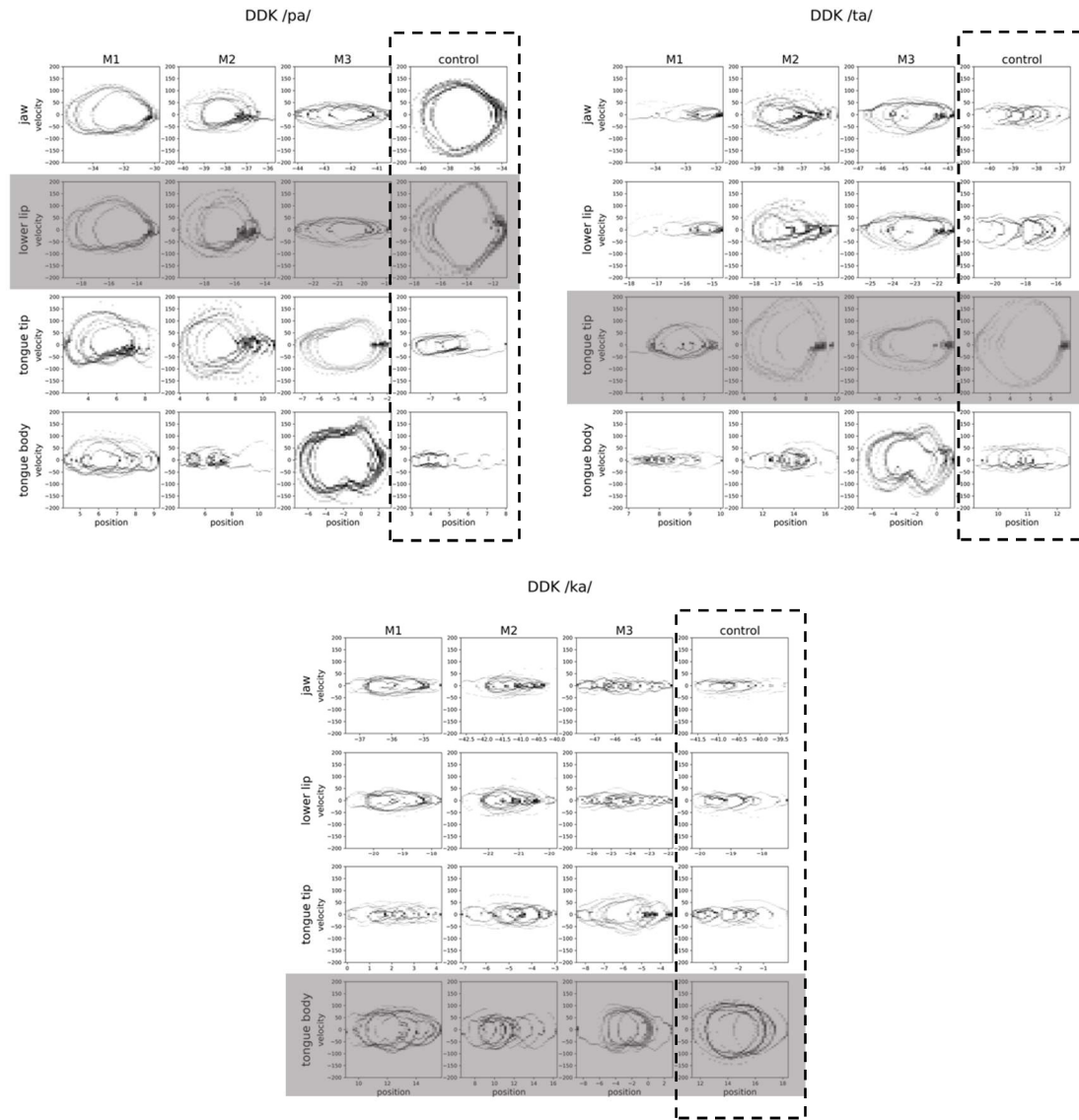


Fig. 1. Phase plots (vertical velocity, vertical position) for Moebius speakers (M1, M2, M3) and control speaker for different DDK tasks, /pa/, /ta/ and /ka/ for jaw, lower lip, tongue tip and tongue body. Primary articulatory is marked with grey box. Control speaker marked with dashed boxes.

References

- [1] Hermes, A., Didirková, I., Buech, P., Vannuscorps, G. (2025) Acoustic similarities, articulatory uniqueness: Speech production mechanisms in individuals with congenital lip paralysis. *Proc. Interspeech 2025*, 3728-3732, doi: 10.21437/Interspeech.2025-281.
- [2] Hermes, A., Didirková, I., Buech, P., & Vannuscorps, G. (2024). Compensatory Strategies in Individuals with Moebius Syndrome: A Case Study. *13th International Seminar on Speech Production*.
- [3] Kelso, J. S., Vatikiotis-Bateson, E., Saltzman, E. L., & Kay, B. (1985). A qualitative dynamic analysis of reiterant speech production: Phase portraits, kinematics, and dynamic modeling. *The Journal of the Acoustical Society of America*, 77(1), 266-280.
- [4] Kuberski, S. R. (2019). Fundamental motor laws and dynamics of speech. *Doctoral dissertation*, Universität Potsdam.