Stability and composition of functional synergies for speech movements in children and adults

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Abstract

The consistency and composition of functional synergies for speech movements were investigated in 7 year-old children and adults in a reiterated speech task using electromagnetic midsaggital articulography (EMMA). Results showed higher variability in children for tongue tip and jaw, but not for lower lip movement trajectories. The contribution of lower lip to oral closures was smaller in children compared to adults, whereas in this respect no difference was found for tongue tip. The results support and extend findings of non-linearity in speech motor development and illustrate the importance of a multi-measures approach in studying speech motor development.

Introduction

The development of speech motor coordination essentially equates to the development of functional synergies of muscle activations (or coordinative structures). The degrees of freedom are reduced, which makes the control task simpler. Consequently, as the speech production system matures the dynamic coordination among orofacial structures becomes more consistent [1, 2].

Previous studies have shown infants' articulator movements (jaw, upper lip, and lower lip) to become more stable (less variability) over time and during linguistic/phonemic development [3, 4, 5, 6]. Furthermore, it as been shown that infants rely largely on the jaw in the realization of oral closures, where 6-7 year-olds show a more adult-like differentiation between lip and jaw, which still undergoes refinement from there on [7, 8].

Aim of the present study

To investigate both consistency and composition of functional synergies for speech movements in 7 year-old children and adults.

- The stability of speech motor execution was assessed by calculating *cyclic* spatiotemporal variability index (cSTI) of the movement trajectories of jaw, lower lip and tongue tip, which captures the variability of direction specific, cyclic movement patterns [9, 10].
- The composition of synergies was assessed by the amplitudes of the movement components of tongue tip and lower lip in the realization of the constrictions for respectively the /s/ and the /p/. Additionally, we investigated the amplitude of jaw opening during the /a:/.

Predictions

- Higher variability of articulatory movement trajectories for the 7 year-olds than for adults.
- Smaller contributions of lower lip and tongue tip to oral closures for children compared to adults.

Method

Participants

- Six children (3 females and 3 males, 6;4-9;8 yrs;mnths, mean 7.5 SD 1.2) and eight adults (6 females and 2 males, 21;3-27;2 yrs;mnths, mean 23.7 SD 2.2).
- All participants displayed speech, language, oro-motor and auditory abilities within the normal range.

Task

- Repeat /pa:s/ and /spa:/ at a normal speaking rate.

Data collection

- Electro-Magnetic Midsaggital Articulography (Carstens AG100).

Data analysis

- Functional synergies for tongue tip and lower lip closing and jaw opening movements:
- stability: cSTI (cyclic spatiotemporal variability index;Fig. 1 [9, 10]) of movement trajectories;
- composition: the unique contributions of articulators for achieving a constriction. Lower lip and tongue tip signals were corrected for jaw movements using an estimate of jaw rotation based on the principal component of the mandible coil trajectory [9, 10, 11].

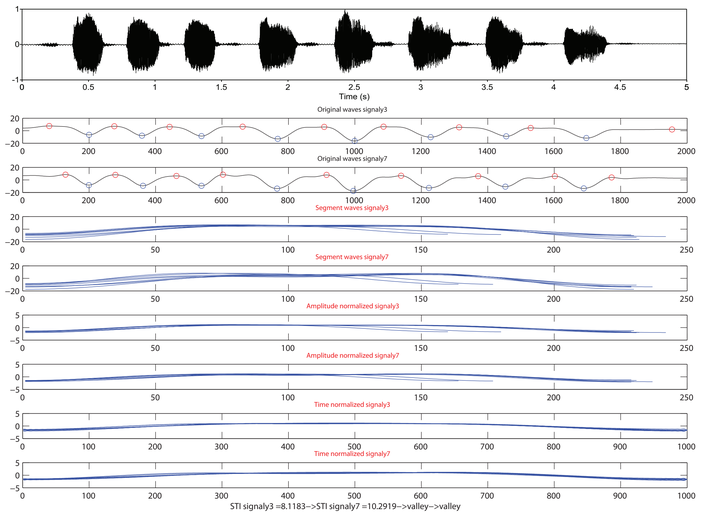

FIGURE 1: Example of an cSTI analysis for tongue tip (y3) and lower lip (y7) data, showing the associated waveform in the top panel, both the original and filtered signals (as used for the analysis), and the individual cycle specific information (original, amplitude, and time normalized).

Results

Variability of movement trajectories (Fig. 2)

- Higher variability for children compared to adults for movement trajectories of tongue tip [$F(1,26) = 6.740$, $p < .05$] and jaw [$F(1,26) = 10.219$, $p < .01$];
- No significant difference for variability the lower lip movement trajectories.

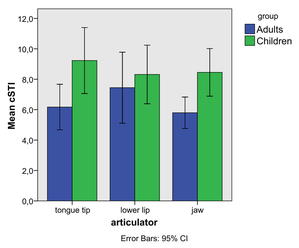

FIGURE 2: Mean variability (cSTI) of movement trajectories of tongue tip, lower lip, and jaw in the words /pa:s/ and /spa:/ in children vs. adults.

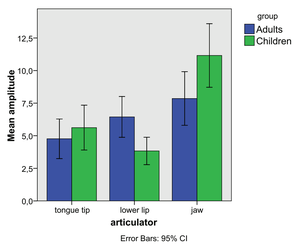

FIGURE 3: Mean amplitudes of the movement components of tongue tip and lower lip in the realization of the constrictions for respectively the /s/ and the /p/, and the amplitude of jaw opening during the /a:/ in the words /pa:s/ and /spa:/ in children vs. adults.

Composition of functional synergies (Fig. 3)

- Smaller contribution of lower lip to the closure for the /p/ for children compared to adults [$F(1,26) = 7.627$, $p < .01$].
- Larger amplitude of jaw opening during the /a:/ for children compared to adults [$F(1,26) = 5.034$, $p < .05$];
- No significant difference for tongue tip in the realization of the constriction for the /s/.

Discussion

In summary, results showed a higher variability of jaw and tongue tip movement trajectories in 7 year-old children compared to adults. The children also exhibited a smaller amplitude component of lower lip in the realization of oral closures and a larger amplitude of jaw opening movements. Overall, these results corroborate earlier results, and support and extend findings of non-linearity in speech motor development [3, 4, 5, 6, **?**, 7, 8].

Lower lip-jaw synergy

Whereas in terms of stability of the lower lip-jaw synergy at the level of individual movement cycles, speech motor development approaches adult-like qualities at the age of 7-8, a close inspection of kinematic variables shows that in fact children at this age still differ from adults in the relative contribution of lower lip in bilabial closure gestures.

Tongue tip-jaw synergy

Results showed an adult-like composition of the tongue tip-jaw coordinative structure in 7 year-old children compared to adults, but with higher variability.

Future research

At the level of individual movement cycles, speech motor development appears to follow different trajectories for different articulators. However, data on the tongue tip-jaw functional synergy earlier in development is needed to infer whether and how the developmental trajectory of the tongue tip-jaw synergy is qualitatively different from the lower lip-jaw synergy. Obtaining data of tongue tip movements in younger children constitutes a challenge for further research.

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