Do children with complex SSD process their self-produced auditory signal not as their own?

− SimpleDIVA modeling of speakers' responses to formant perturbations suggest:

- the auditory signal is processed as an external cue
- preventing online compensation to perturbations
- hindering the successful use of auditory feedback as a teaching signal for the acquisition & adaptation of speech motor programs

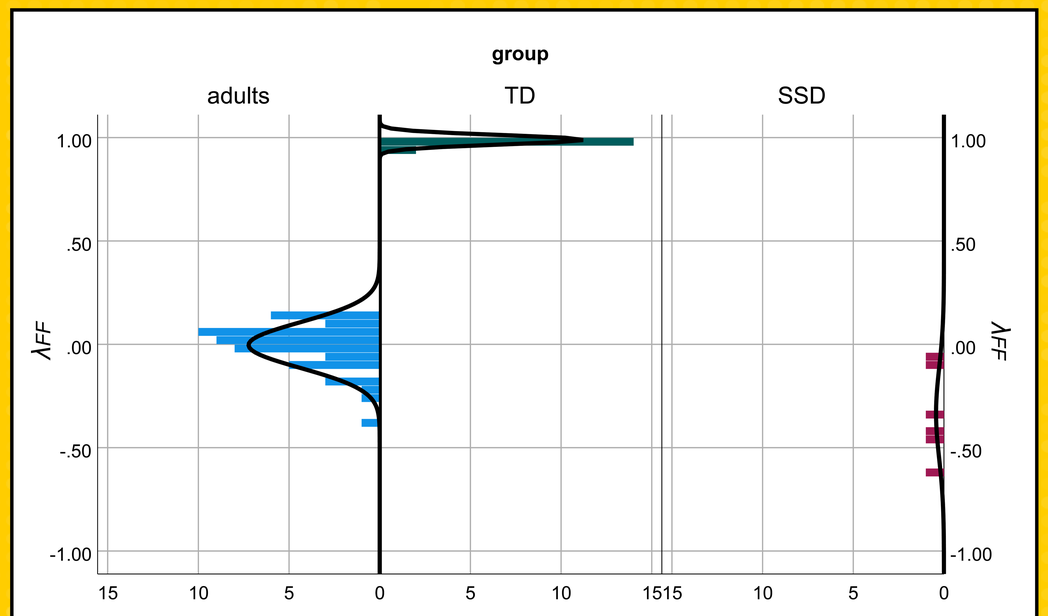

Figure 1: Binned SimpleDIVA feedforward control gain/learning rate (λ_{FF}) parameter estimates for individual speakers across groups (blue: adults; red: [TD] children; green: children with SSD). Bars indicate the number of speakers per bin.

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Introduction

Background

Previous studies indicated children with Speech Sound Disorders (SSD) show following, enhancing responses to formant perturbations [1], where typically developing (TD) children and adults show a compensatory response [1-6].

Our hypothesis explaining this perturbation-following behavior is that the implemented formant shifts have caused a "target drift", i.e., the sensory motor system interprets the formant shifts as adjustments of the intended auditory outcome [cf. 1, 7]. The auditory targets are then updated accordingly, and the shifted formant settings become the target for the next trial.

Aim of the present study

Evaluate possible underlying mechanisms causing differences in responses to auditory perturbation in children with SSDs using the SimpleDIVA application [8, 9].

Materials and Methods

SimpleDIVA modeling

SimpleDIVA is a 3-free-parameter computational model that estimates contributions of feedback and feedforward control mechanisms (auditory feedback control [α_A], somatosensory feedback control [α_S], and feedforward control/learning rate [λ_{FF}]) by modelling the produced formant values along with the perturbation trajectory [8, 9].

Model equations:

$$F_{produced}(n) = F_iFF(n) + \Delta F_iFB(n)$$
$$\Delta F_iFB(n) = \alpha A * (F_iT - F_iAF(n)) + \alpha S * (F_iT - F_iSF(n))$$
$$F_iFF(n+1) = F_iFF(n) + \lambda FF * \Delta F_iFB(n)$$

Description of dataset [1, 6]

- 50 adults: 32 f, 18 m; age 19 - 29 years, M = 22.3 y
- 17 TD children: 8 f, 9 m; age 4;0 - 6;7 y;m, M = 5;3 y;m
- 6 children with SSD: 3 f, 3 m; age 4;8 - 6;7 y;m, M = 5;5 y;m
- All participants were native speakers of Dutch
- Audapter software [5] was used for auditory feedback perturbation of target vowel /ɪː/ in CVC words
- F1 was raised 25% and F2 was lowered 12.5%
- Trials involved a baseline – ramp – hold – end paradigm
- Total of 102 trials for adults and 66 trials for children

Analysis

Speakers' behavior was modeled individually and the three model parameters (λ_{FF}; α_A; α_S) were compared across groups.

Results

Figure 1: negative feedforward control/learning rate (λ_{FF}) in all children with SSD, while approximating 0 in adults and 1 in TD children.

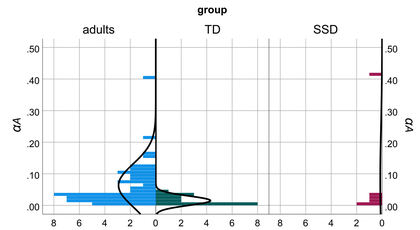
Figure 2: patterns of auditory and somatosensory feedback control gains (α_A & α_S) similar for TD children and adults, whilst a binomial distribution in the group of children with SSD.

Discussion

With respect to mechanisms underlying SSD, it is speculated that the auditory signal might be processed as an external cue.

Future research should assess how children with SSD process efferent signals and evaluate a possible role of speaking induced suppression mechanisms.

Auditory feedback control gain (α_A)



Somatosensory feedback control gain (α_S)

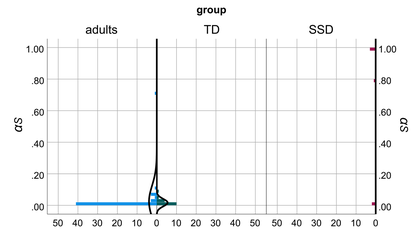


Figure 2: Binned SimpleDIVA parameter estimates (left panel: auditory feedback control gain [α_A]; right panel: somatosensory feedback control gain [α_S]) for individual speakers across groups (blue: adults; red: [TD] children; green: children with SSD). Bars indicate the number of speakers per bin.

Example individual results (SSD4)

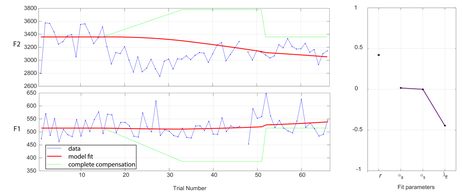


Figure 3: Left panel: produced formant values during the perturbation experiment of participant SSD4 (blue), along with model fit (red) and reference for complete compensation (yellow). Right panel: SimpleDIVA parameter estimates for this speaker.

References

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