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Schötz, Susanne; Frid, Johan; Löfqvist, Anders

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Age-related differences in repetition variability: Analysis of lip movements using functional data analysis

Susanne Schötz[1], Johan Frid[12], Anders Löfqvist[3]
[1]: Lund University Humanities Lab, [2]: Centre for Languages and Literature, Lund University,
[3]: Haskins Laboratories, New Haven, USA and Lund University

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 (1) if children with atypical language development differ from typically developing children in terms of articulatory variability and (2) the possible relationship with cerebellar function as assessed by the blink reflex.

Movements were recorded of the upper and lower lips along with a microphone signal using the Carstens Articulograph AG500. To obtain as large movements as possible of the lips, 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 the 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 procedure involves the following steps: (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. These results thus indicate that the younger subjects tend to be more variable in amplitude than in the temporal domain. 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 index by 0.04. For amplitude variability, the effect is rather noticable and statistically significant ($p = 0.0231$). For phase variability, the effect is smaller and statistically insignificant.

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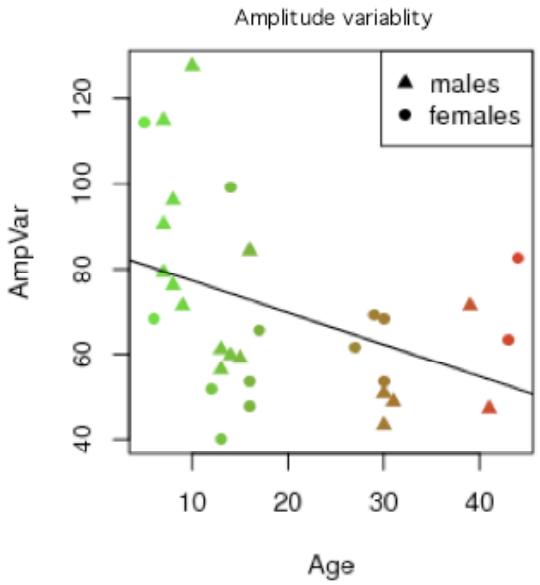
Amplitude variablity
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females
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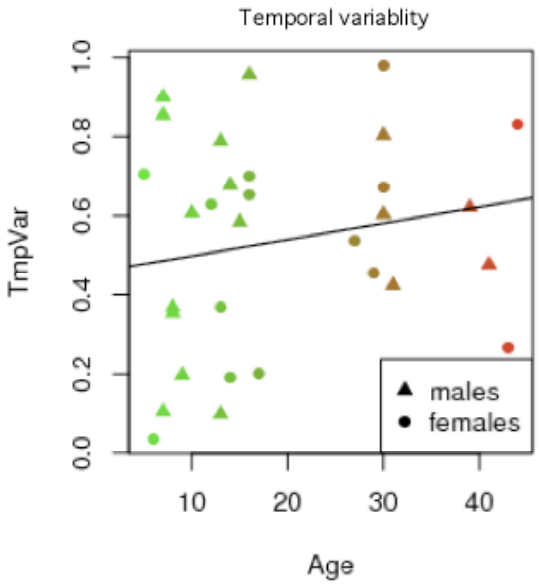
60
80
100
120
10
20
30
40


Temporal variablity
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females
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40