iScience, Volume *26*

Supplemental information

Neural oscillations and speech processing at birth

Maria Clemencia Ortiz-Barajas, Ramón Guevara, and Judit Gervain

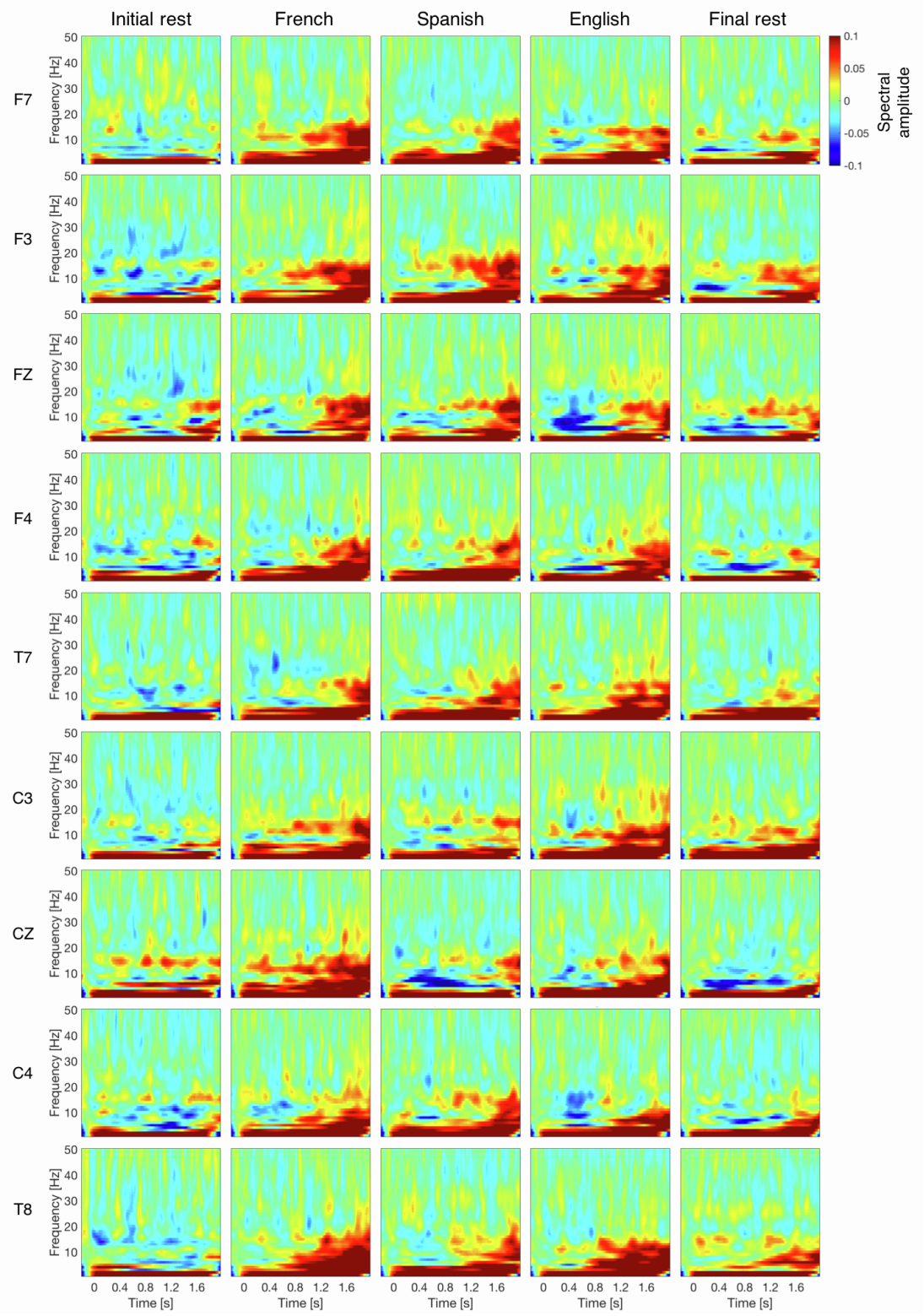

Fig. S1 | The average time-frequency response for each tested condition, related to Figure 1d. The time-frequency maps illustrate the mean spectral amplitude per condition from 1-50 Hz.

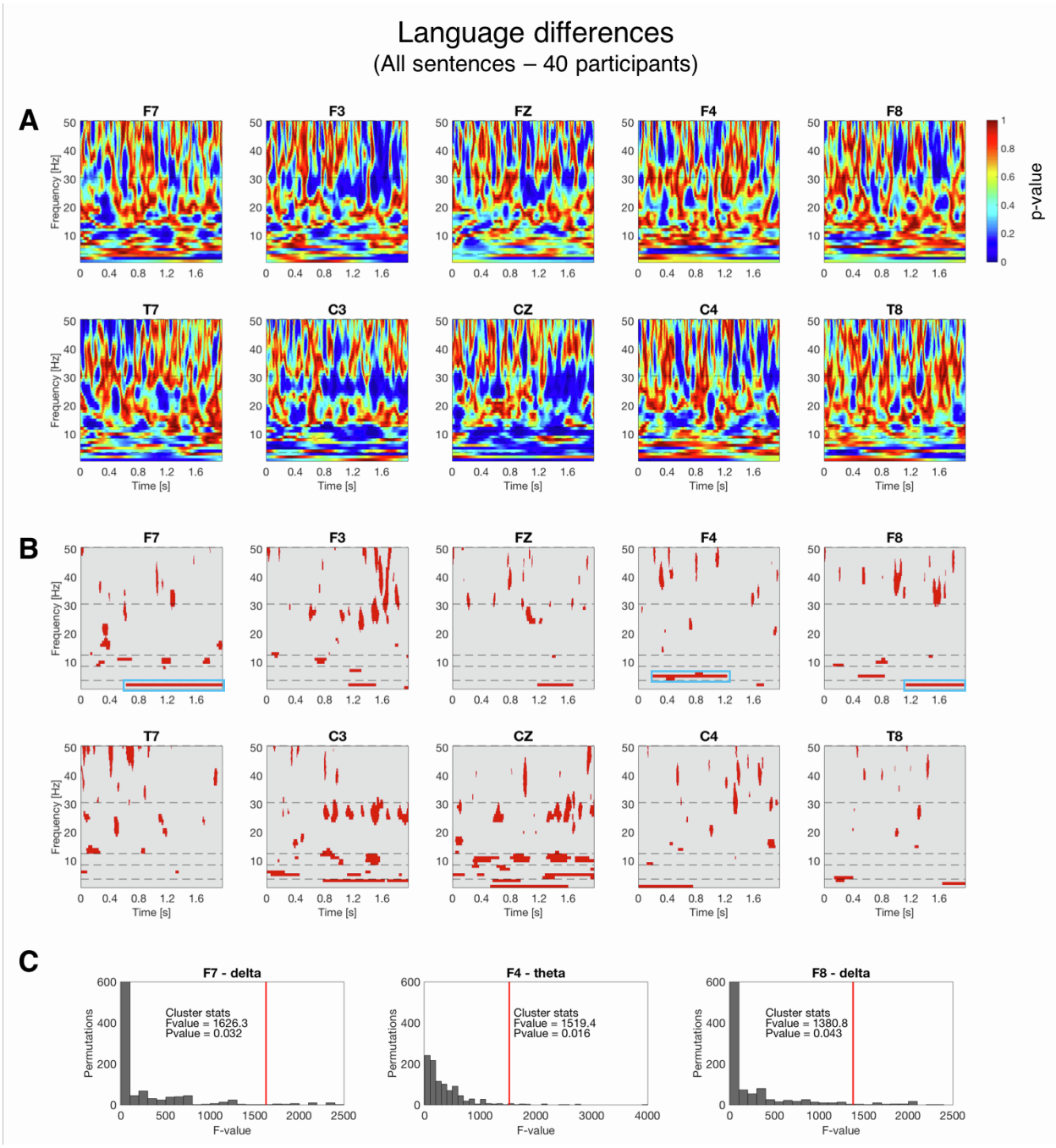

Fig. S2 | Language comparison for all participants, related to Figures 2 and 3, as well as to the STAR methods. (A) *P*-maps obtained by submitting the time-frequency responses to the three language conditions to repeated measures ANOVAs with the within-subject factor Language (French/Spanish/English). (B) Time-frequency regions where the results from the ANOVAs exceed the critical threshold (*F*-value > 3.114). The blue rectangular boxes indicate the clusters exhibiting significant language differences (F7 and F8 in the delta band; F4 in the theta band). (C) Permutation distributions for the significant clusters found, in channels F7, F4 and F8, following the methodology described by Maris and Oostenveld [S1]. The red vertical lines indicate the *F*-value of the given cluster.

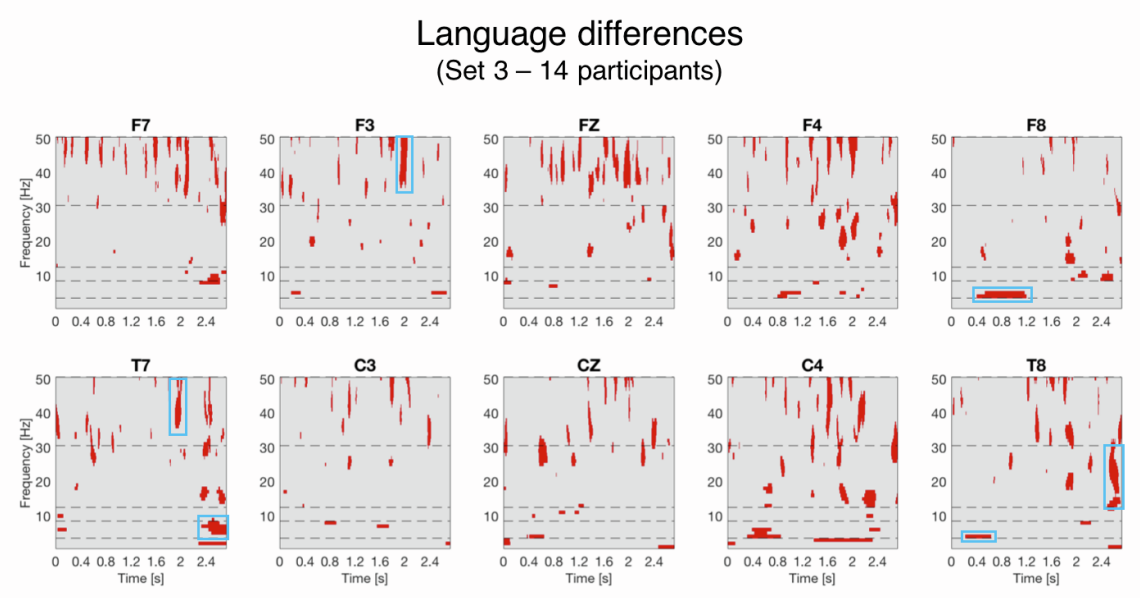

Fig. S3 | Language comparison for the participants who listened to the sentences in Set 3, related to the STAR methods. Time-frequency regions where the results from the repeated measures ANOVAs, with the within-subject factor Language (French/Spanish/English), exceed the critical threshold (F-value > 3.369). The blue rectangular boxes indicate the clusters exhibiting significant language differences (F8, T7 and T8 in the theta band; T8 in the beta band; and F3 and T7 in the low-gamma band).

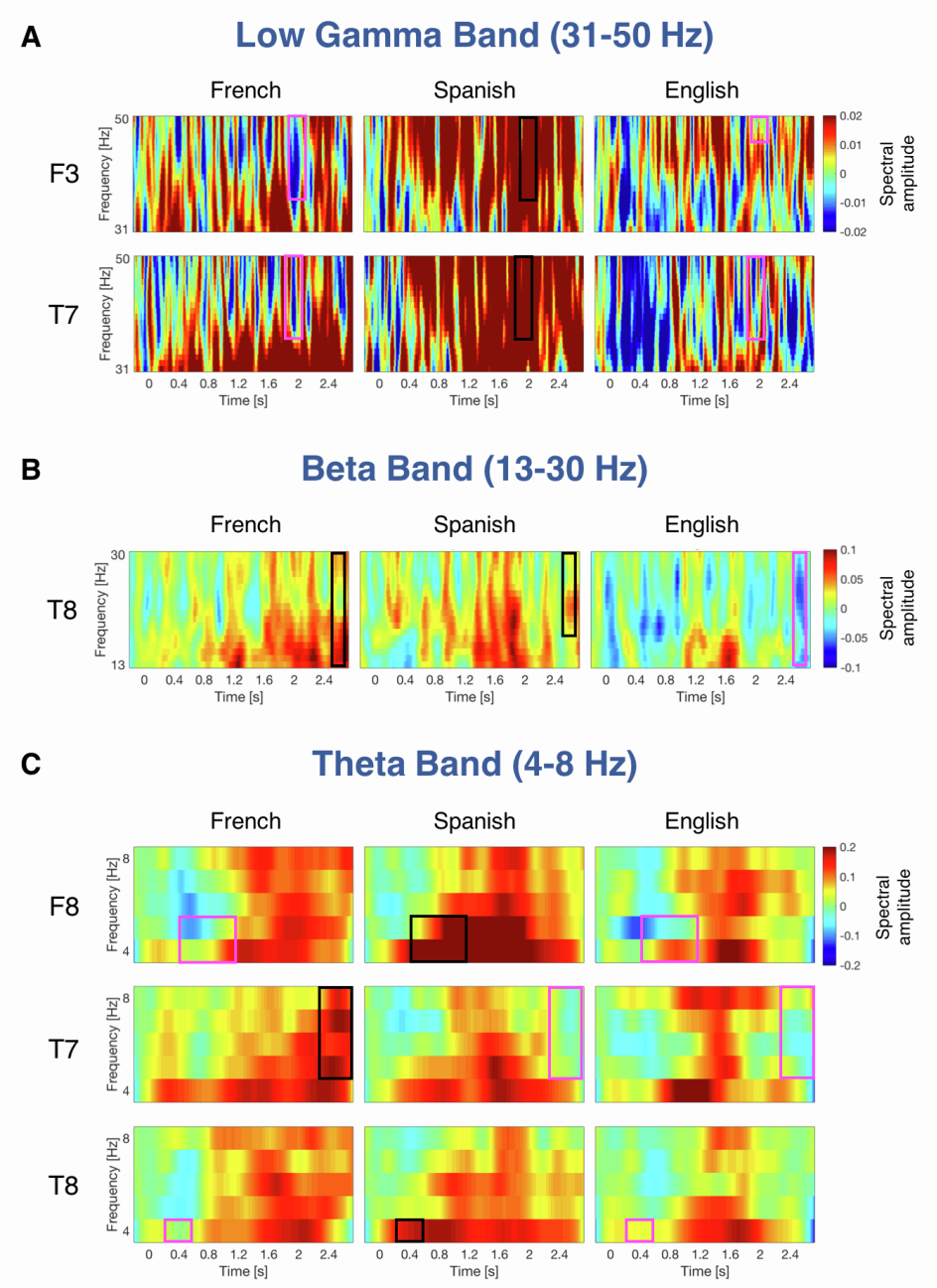

Fig. S4 | Time-frequency response for the participants who listened to the sentences in Set 3, related to the STAR methods. (A) Channels F3 and T7 exhibit significantly higher activation for Spanish than for French and English in the low-gamma band (31-50 Hz), in the time and frequency ranges indicated by the black rectangular boxes (magenta boxes indicate significantly lower activation). (B) Channel T8 exhibits higher activation for French and Spanish than for English in the beta band (13-30 Hz). (C) Channels F8 and T8 exhibit significantly higher activation for Spanish than for French and English in the theta band (4-8 Hz); while channel T7 exhibits higher activation for French than for Spanish and English. Plotting conventions as before.

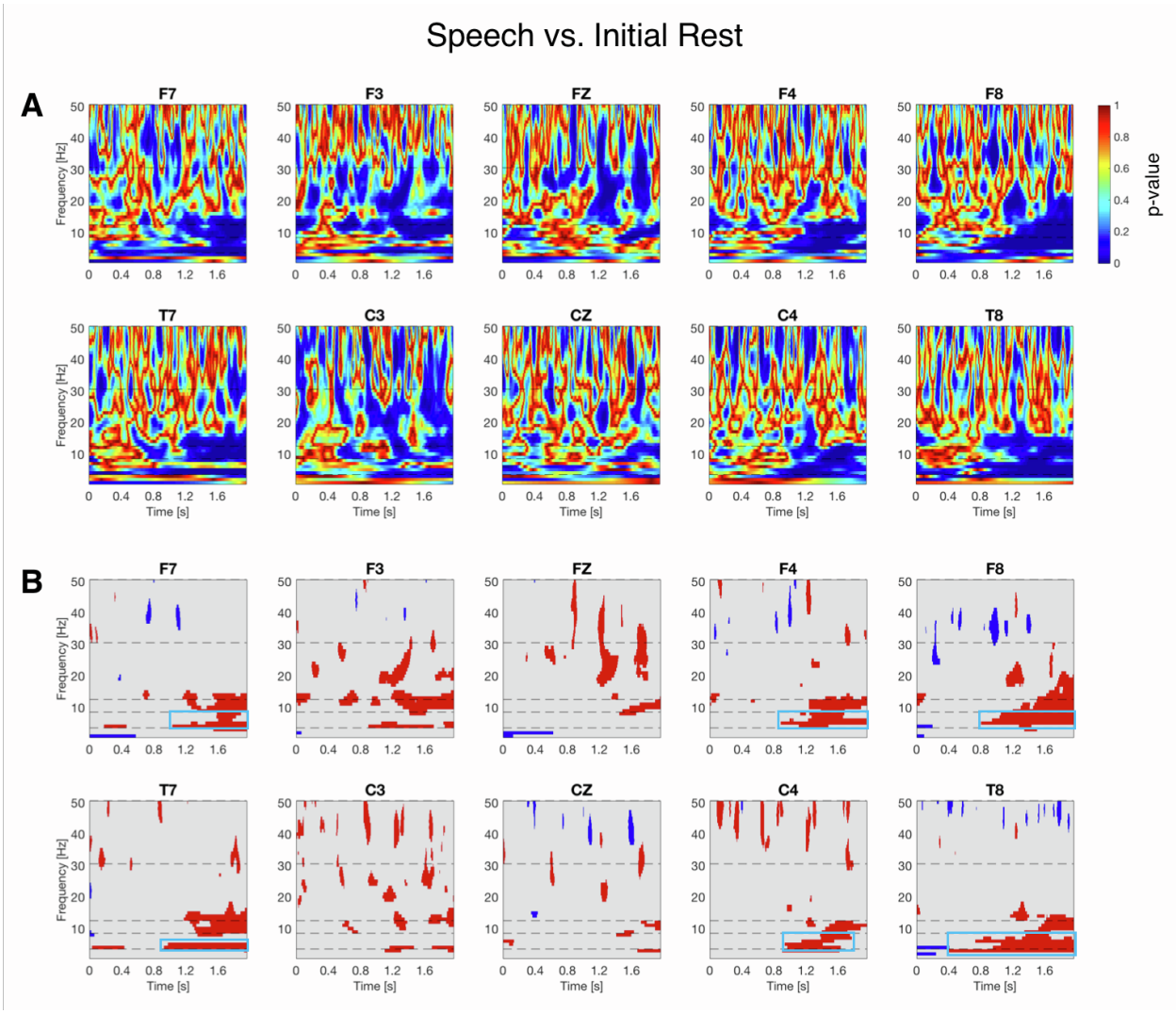

Fig. S5 | Resting state vs. speech processing comparison, related to Figure 4 and to the STAR methods. (A) *P*-maps obtained by submitting the time-frequency responses to the initial resting state condition and the speech stimulation condition to two-tailed paired-samples t-tests. (B) Time-frequency regions where the absolute *T*-values exceed the critical threshold (|*T*-value| > 2.030). Red regions indicate higher activation during speech processing, while blue regions indicate higher activation during resting state. The blue rectangular boxes indicate the clusters exhibiting significant differences between the two conditions (T8 in the delta band; F7, F4, F8, T7, C4 and T8 in the theta band).

.

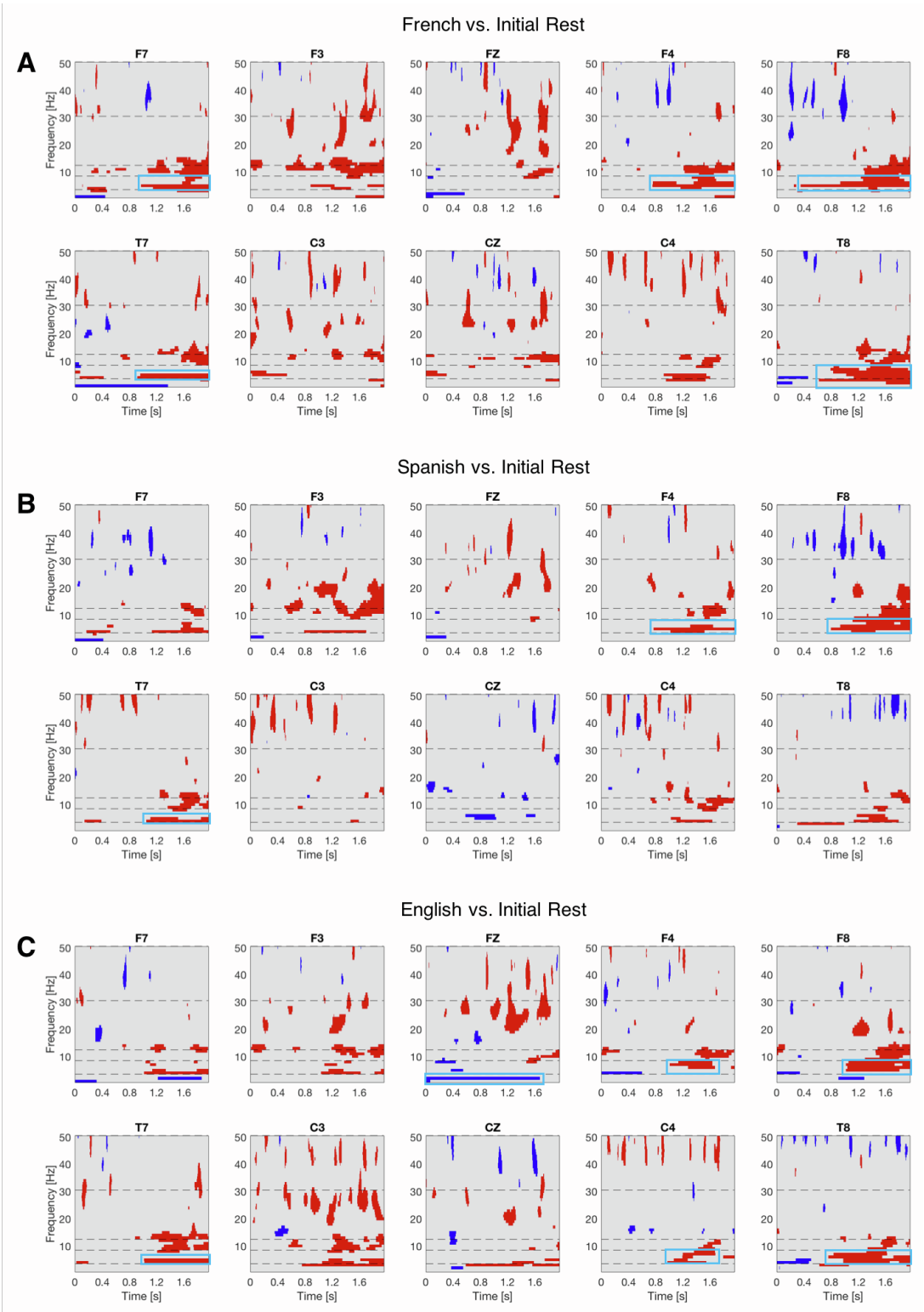

Fig. S6 | Time-frequency comparison between each language and the initial resting state condition; related to the STAR methods. (A) French vs. Initial Rest. (B) Spanish vs. Initial Rest. (C) English vs. Initial Rest. Plotting conventions as before.

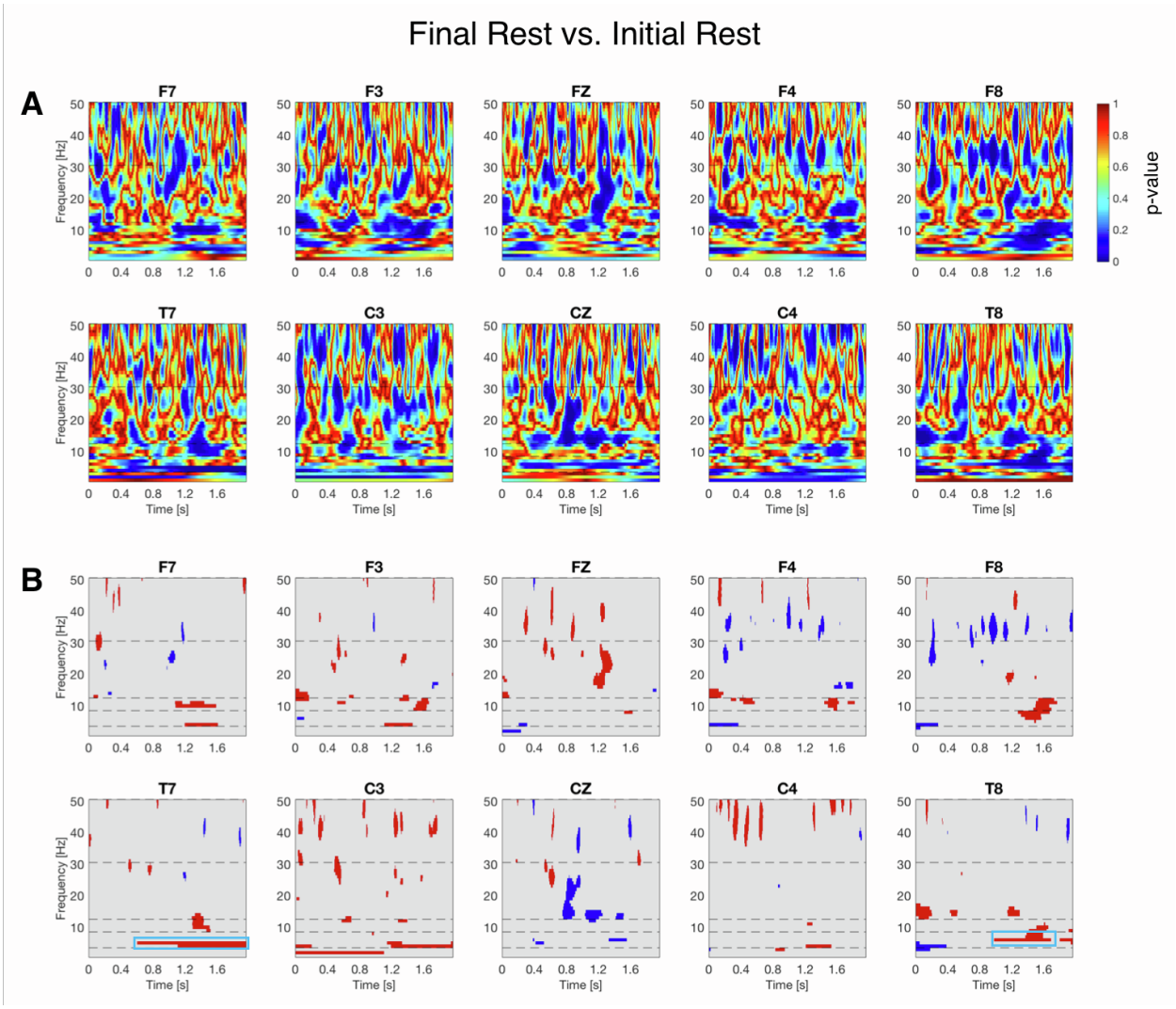

Fig. S7 | Final vs. initial resting state comparison, related to Figure 4 and to the STAR methods. (A) *P*-maps obtained by submitting the time-frequency responses to the initial and final resting state periods to two-tailed paired-samples t-tests. (B) Time-frequency regions where the absolute *T*-values exceed the critical threshold (|*T*-value| > 2.030). Red regions indicate higher activation during the final resting state condition, while blue regions indicate higher activation during the initial resting state condition. The blue rectangular boxes indicate the clusters exhibiting significant differences between the two conditions (T7 and T8 in the theta band).

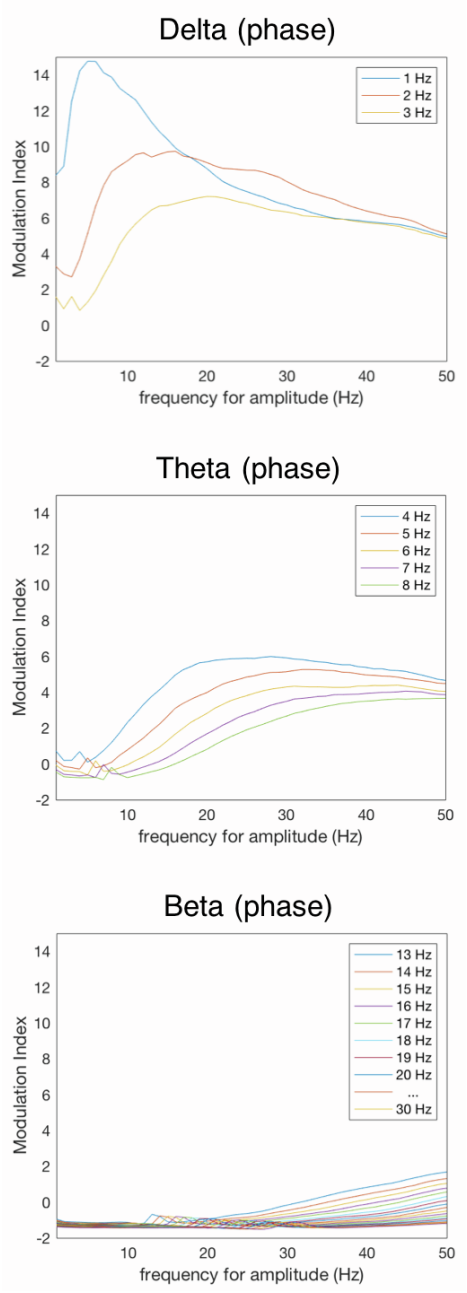

Fig. S8 | Modulation index as a function of analytic phase (1 – 30 Hz) and analytic amplitude (1 – 50 Hz) for French at channel F8, related to Figure 5. Each subplot represents a range of frequencies for phase corresponding to the frequency bands of interest (delta, theta and beta). Larger modulation index values indicate stronger cross-frequency coupling. Highest MI values are present for phase in the delta band and amplitudes in the 3 to 20 Hz range (delta, theta and beta bands).

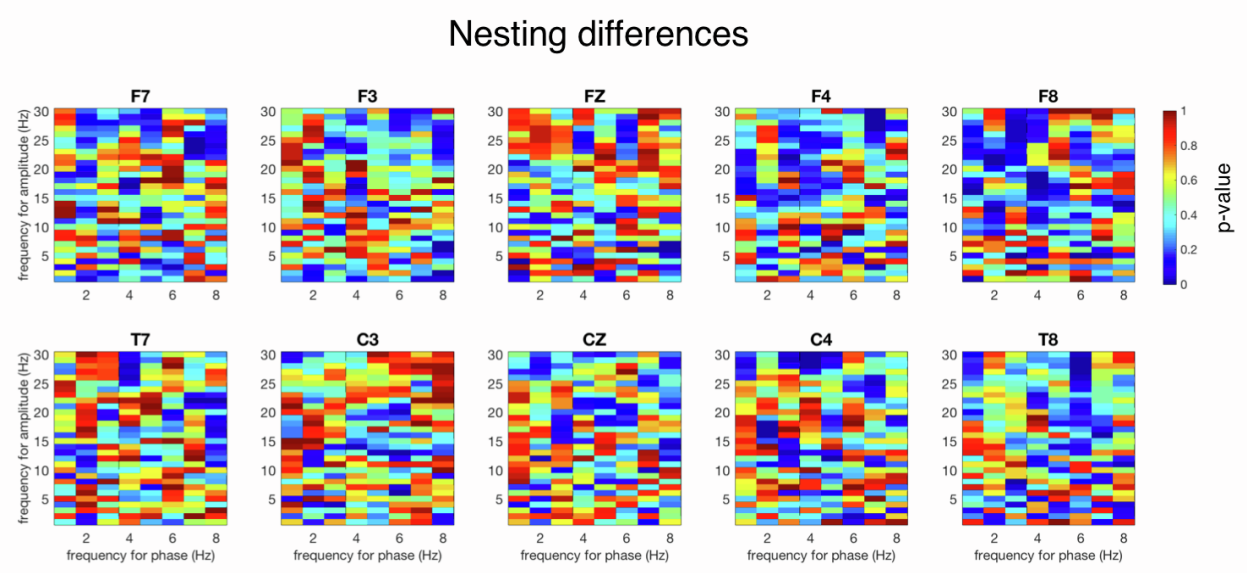

Fig. S9 | Nesting comparisons across conditions, related to the STAR methods. *P*-maps obtained by submitting the modulation index values from the three language conditions and the two resting state periods to repeated measures ANOVAs with the within-subject factor Condition (InitialRest/French/Spanish/English/FinalRest).

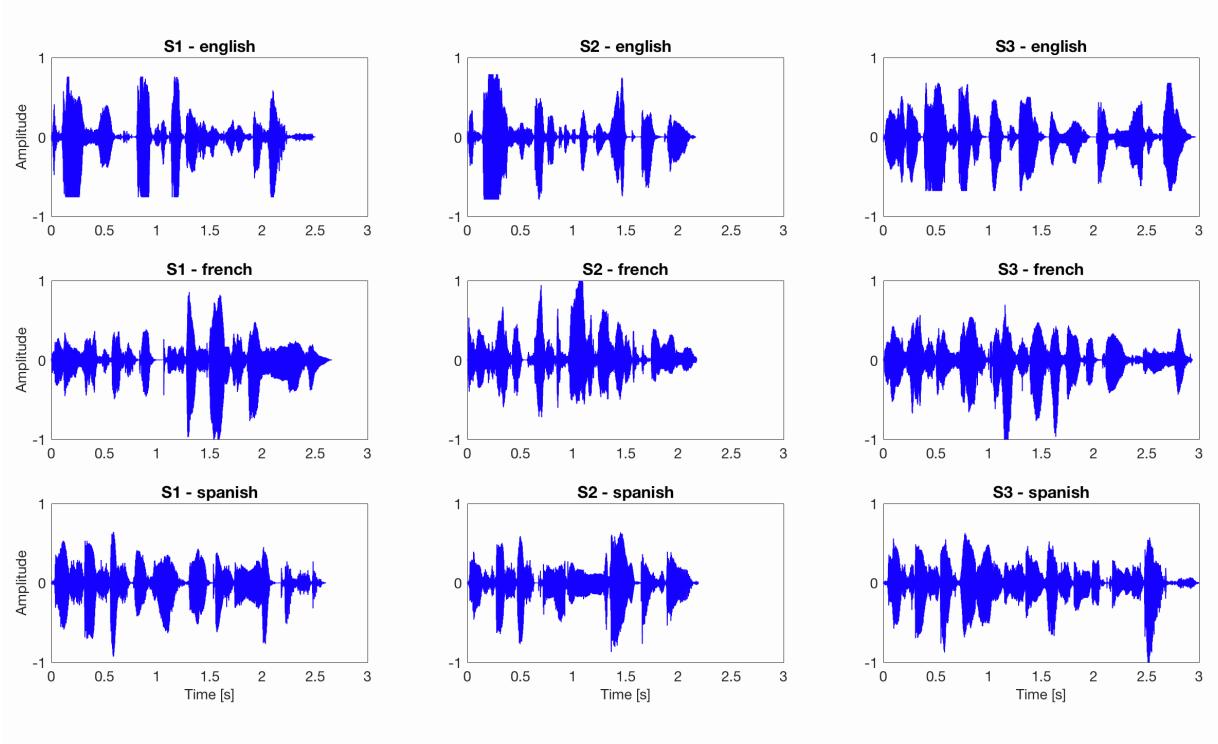

Fig. S10 | Time series for the nine utterances used as stimuli, related to the STAR methods.

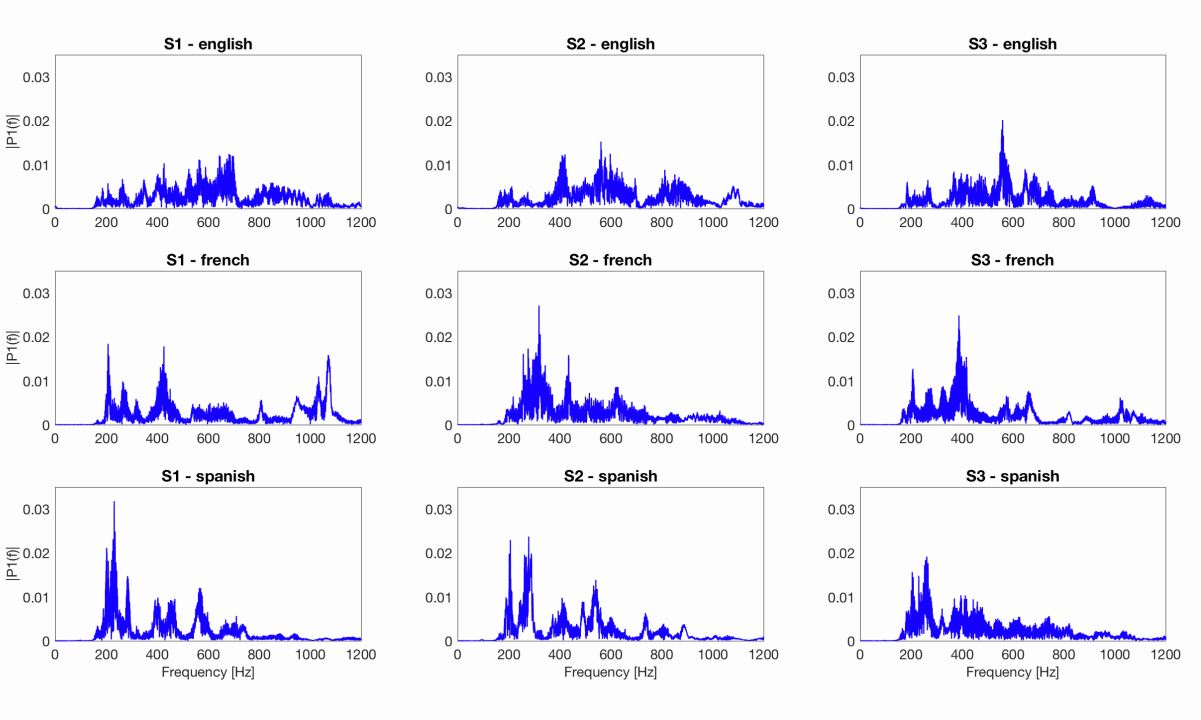

Fig. S11 | Frequency spectra for the nine utterances used as stimuli, related to the STAR methods. These frequency spectra were obtained using the Fast Fourier Transform function in Matlab (fft).

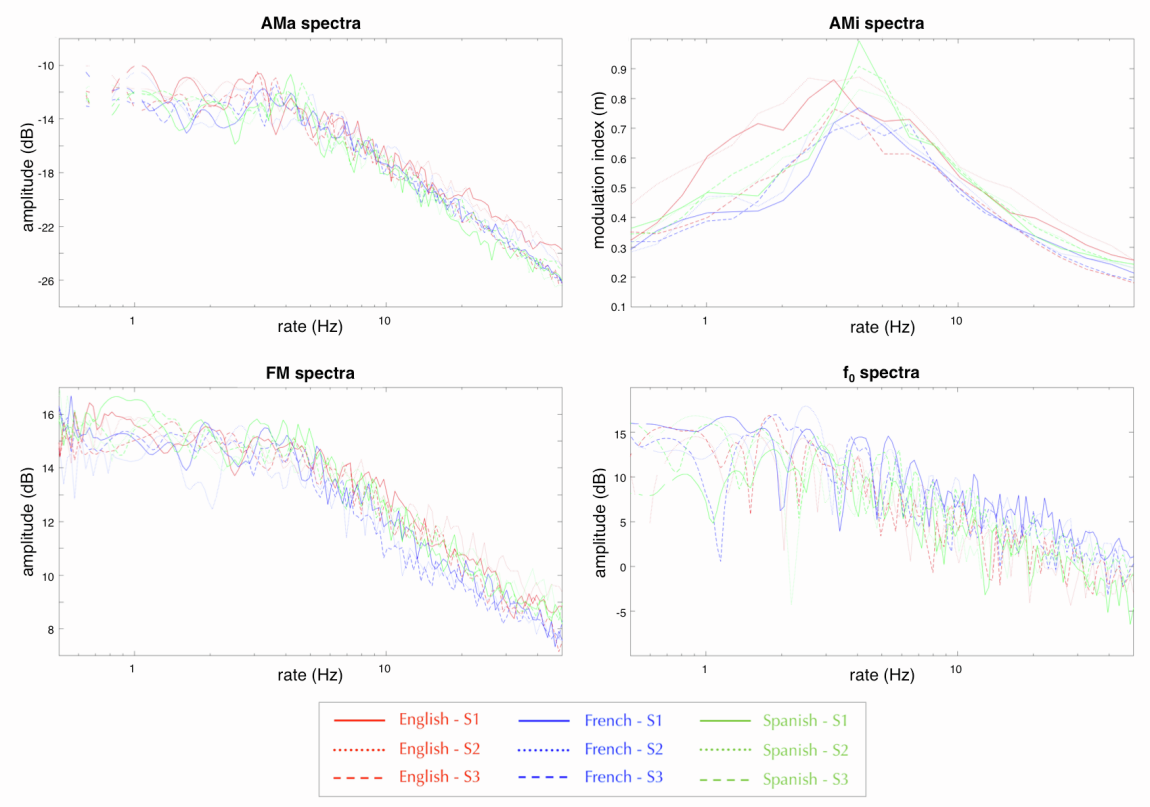

Fig. S12 | Amplitude and frequency modulation spectra for the nine utterances used as stimuli, related to the STAR methods. Red lines: English utterances; blue lines: French utterances; green lines: Spanish utterances. These modulation spectra were obtained following the methodology described by Varnet and colleagues[S2]. Figure taken from Ortiz Barajas et al.[S3]

	Set 1	Set 2	Set 3
English	*The bears lived all together in a beautiful house* Syllables: 13 Duration: 2,50 s Syllabic rate: 5 Hz Pitch_min: 142,5 Hz Pitch_max: 700,8 Hz Pitch_range: 558,3 Hz Pitch_mean: 303,4 Hz	The bears decided to take a walk that day Syllables: 11 Duration: 2,16 s Syllabic rate: 5 Hz Pitch_min: 181,2 Hz Pitch_max: 400,2 Hz Pitch_range: 219,0 Hz Pitch_mean: 261,8 Hz	The little bears saw that their chairs were used by the naughty girl Syllables: 15 Duration: 2,96 s Syllabic rate: 4 Hz Pitch_min: 171,2 Hz Pitch_max: 735,9 Hz Pitch_range: 564,7 Hz Pitch_mean: 322,1 Hz
French	Les ours habitaient tous ensemble dans une maison Syllables: 13 Duration: 2,66 s Syllabic rate: 4 Hz Pitch_min: 195,6 Hz Pitch_max: 556,5 Hz Pitch_range: 360,9 Hz Pitch_mean: 307,6 Hz	Les ours décidèrent d'aller se promener Syllables: 11 Duration: 2,17 s Syllabic rate: 4 Hz Pitch_min: 99,7 Hz Pitch_max: 342,3 Hz Pitch_range: 242,6 Hz Pitch_mean: 224,7 Hz	Les ours virent que leurs chaises avaient été utilisées Syllables: 15 Duration: 2,93 s Syllabic rate: 6 Hz Pitch_min: 95,7 Hz Pitch_max: 263,2 Hz Pitch_range: 167,5 Hz Pitch_mean: 190,1 Hz
Spanish	Los osos vivían juntos en una casa Syllables: 13 Duration: 2,60 s Syllabic rate: 4 Hz Pitch_min: 164,4 Hz Pitch_max: 287,3 Hz Pitch_range: 122,9 Hz Pitch_mean: 219,8 Hz	Los osos tomaron un gran paseo Syllables: 11 Duration: 2,19 s Syllabic rate: 3 Hz Pitch_min: 178,2 Hz Pitch_max: 423,5 Hz Pitch_range: 245,3 Hz Pitch_mean: 245,9 Hz	Los osos vieron sus sillas siendo utilizadas Syllables: 15 Duration: 3,00 s Syllabic rate: 4 Hz Pitch_min: 99,0 Hz Pitch_max: 420,8 Hz Pitch_range: 321,8 Hz Pitch_mean: 260,0 Hz

Table S1 | Stimulus information, related to the STAR methods. Three sets of sentences were used during the study. Each set contained one sentence translated into the three languages. The translations were slightly modified in order to match sentence duration across languages within the same set. The duration, syllabic rate, and pitch details are included for each sentence. Table taken from Ortiz Barajas et al.[S3]

Audio S1-S9 | Audio files (.wav) for the nine utterances used as stimuli, related to the STAR methods. Nine utterances were used as stimuli, where Audio S1, S2 and S3 correspond to the utterances in French; Audio S4, S5 and S6 correspond to the utterances in Spanish; and Audio S7, S8 and S9 correspond to the utterances in English.

References

S1. Maris E, Oostenveld R. 2007. Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods* **164**(1):177–190. doi:10.1016/j.jneumeth.2007.03.024

S2. Varnet L, Ortiz-Barajas MC, Guevara Erra R, Gervain J, Lorenzi C. 2017. A cross-linguistic study of speech modulation spectra. *The Journal of the Acoustical Society of America* **142**(4):1976–1989. doi:10.1121/1.5006179

S3. Ortiz Barajas MC, Guevara R, Gervain J. 2021. The origins and development of speech envelope tracking during the first months of life. *Developmental Cognitive Neuroscience* **48**:100915. doi:10.1016/j.dcn.2021.100915