Oscillatory tracking of syntactic structure across languages

Jordi Martorell (BCBL), Simona Mancini (BCBL), Nicola Molinaro (BCBL, Ikerbasque) &
Manuel Carreiras (BCBL, Ikerbasque, University of the Basque Country UPV/EHU)
j.martorell@bcbl.eu

Recent findings suggest that neural oscillations support the grouping of words into multi-word syntactic structures. Specifically, using the frequency-tagging paradigm, it has been shown that low-frequency oscillations track different syntactic units (e.g., phrases and sentences) by synchronizing to their rhythmic presentation frequency during continuous speech perception (Ding et al., 2016). Although this syntax-driven oscillatory tracking has been replicated testing similar constructions in distinct languages (Ding et al., 2016; Makov et al., 2017; Sheng et al., 2018), it has not been determined yet what is the impact of cross-linguistic typological differences that are syntactically relevant for grouping. A notable aspect of cross-linguistic variation in this respect is word order: some languages are head initial (e.g., objects follow verbs) while others are head final (e.g., objects precede verbs), thereby grouping equivalent syntactic structures in the reversed order.
In this magnetoencephalography (MEG) study, we investigate the phenomenon of oscillatory tracking of syntactic structure from a cross-linguistic perspective. Our aim is to assess how it is modulated by the typological characteristics of head-initial and head-final languages like Spanish and Basque, respectively. Moreover, we test such cross-linguistic differences within the same group of Spanish-Basque bilinguals. To do so, we implement the frequency-tagging paradigm in the visual modality by rhythmically presenting sequences of written words to be combined into certain structures at different frequencies. We aim to replicate previous findings in both languages, providing cross-linguistic evidence for oscillatory tracking of syntactic structure. In addition, we explore whether such effects have distinct topographic distributions over the classical left-hemisphere fronto-temporal language network.

Spanish-Basque bilinguals (n = 39) were visually presented with trials composed by 12-second sequences of 24 words (500 ms per word: 300 ms display + 200 ms blank screen; word presentation frequency: ~ 2 Hz). Words presented in each trial repeatedly corresponded to three grouping types: 1 word (frequency of interest: ~ 2 Hz), 2-word phrases (~ 1 Hz), and 3-word sentences (~ 0.67 Hz). Moreover, each grouping type was presented either in Spanish or Basque, thus resulting in 6 conditions (see Table 1). Participants performed a probe-recall task after 25 % of the trials. Following the procedure in Ding et al. (2016), first we averaged neural activity across participants for each condition and then computed frequency-domain power analysis for MEG sensors (frequency resolution: 1/12 = 0.083 Hz).

We present preliminary results in Figure 1. As shown in the power spectrum averaged across sensors (Figure 1a), power peaks at ~ 2 Hz are observed in all conditions, confirming that our method successfully detects neural responses driven by the word presentation rate. Moreover, regarding syntactic grouping effects, power peaks at ~ 1 Hz and ~ 0.67 Hz are also observed in the 2-word and 3-word conditions, respectively, for both languages. This suggests that oscillatory tracking at the frequency of syntactic phrases and sentences emerges regardless of how such words are specifically grouped. Concerning the topographic distribution of these effects (Figure 1b), word-frequency peaks concentrate over occipital and left-temporal sensors, probably corresponding to visual and word-level language-related regions. In addition, as expected, phrase- and sentence-frequency effects in general extend to left fronto-temporal sensors, likely involving the classical language network. However, certain differences between languages are also apparent within this fronto-temporal network. For example, the effects at the frequency of phrases in Basque and sentences in Spanish seem to be particularly concentrated in a cluster of temporal sensors. Future analysis will consider how individual variability in bilingual proficiency modulates such effects. Overall, our preliminary results seem to replicate in two typologically different languages the main findings on syntax-driven tracking reported in previous frequency-tagging studies.

Language / Grouping	Spanish	Basque
1 word (~ 2 Hz)	| una casa | un texto | un acto | un tren |… | *a house* | *a text* | *an act* | *a train* |…	| etxea | liburua | eguna | trenea |… | *house.a* | *book.a* | *day.a* | *train.a* |…
2-word phrases (~ 1 Hz)	| vender | una casa | subrayar | un texto |… | to.*sell* | *a house* | to.*highlight* | *a text* |…	| etxea | saldu | liburua | irakurri |… | *house.a* | *to.sell* | *book.a* | *to.read* |…
3-word sentences (~ 0.67 Hz)	| hemos | vendido | una casa | hemos |… | *we.have* | *sold* | *a house* | *we.have* |…	| etxea | saldu | dugu | liburua |… | *house.a* | *sold* | *we.have* | *book.a* |…

Table 1. Example materials for the 6 conditions in the experiment (English translations in italics), showing a representative trial with only 4 words. Words appearing within symbol "|" represent the material that was presented at once on the screen. Frequencies of interest (Hz) are specified in parenthesis for each grouping type.

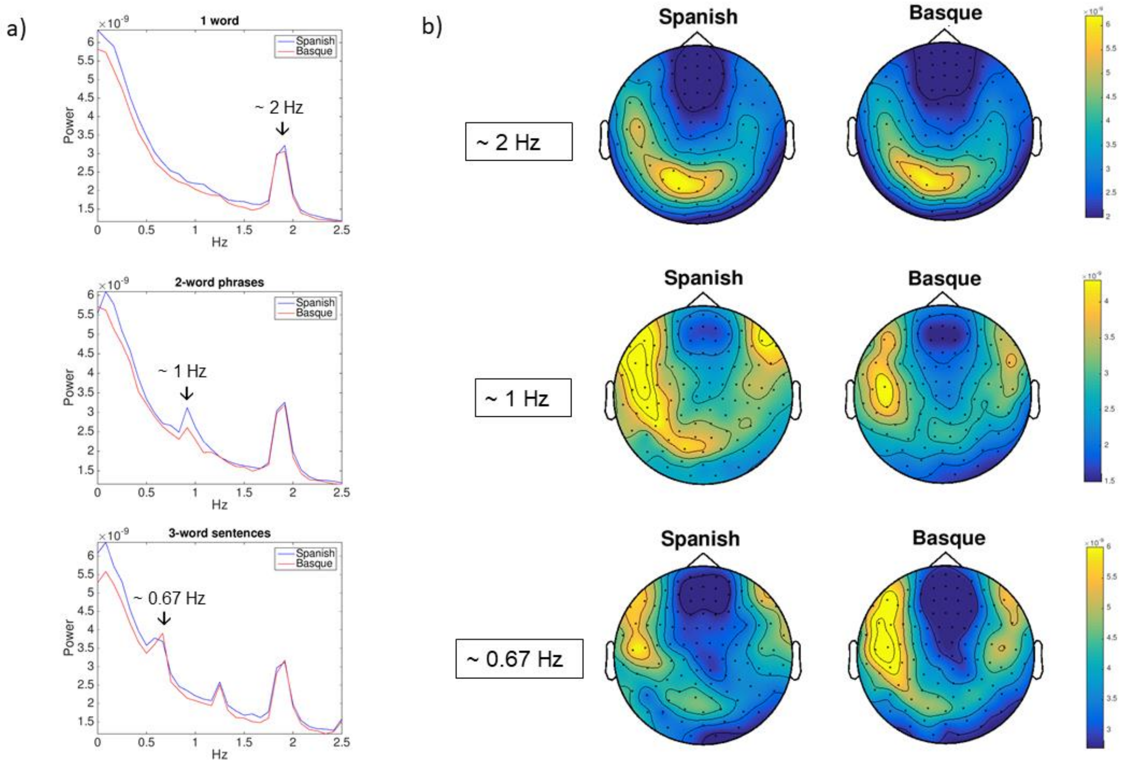

Figure 1. MEG sensor-level preliminary results of the experiment, showing the three grouping types ordered vertically (1 word, 2-word phrases and 3-word sentences) in both a) and b) panels. a) Power spectrum averaged across sensors for each grouping type and language (Spanish = blue, Basque = red). Peaks at frequencies of interest given the grouping type are marked with an arrow. b) Sensor-level topographic distribution of the effects marked in the power spectrum in a) for their corresponding grouping type in each language.

References:

Ding, N., Melloni, L., Zhang, H., Tian, X., & Poeppel, D. (2016). *Nature Neuroscience*, *19*(1), 158–164. https://doi.org/10.1038/nn.4186

Makov, S., Sharon, O., Ding, N., Ben-Shachar, M., Nir, Y., & Zion Golumbic, E. (2017). *The Journal of Neuroscience*, *37*(32), 7772–7781. https://doi.org/10.1523/JNEUROSCI.0168-17.2017

Sheng, J., Zheng, L., Lyu, B., Cen, Z., Qin, L., Tan, L. H., … Gao, J.-H. (2018). *Cerebral Cortex*, *29*(8), 3232–3240. https://doi.org/10.1093/cercor/bhy191