Language experience affects predictive processing of rhythmic sound sequences

According to Predictive Processing models of auditory perception, the auditory system constantly extrapolates the rules governing recent input and uses such knowledge to generate predictive models of incoming sensory events. This operation is central to tracking meaningful structures during auditory rhythm perception. It is currently debated whether this mechanism relies only on short-term memories or can be shaped by experiential factors like language experience. In the present study, we investigate whether life-long exposure to certain linguistic patterns impacts neural predictive processing of rhythmic sound sequences.

We compare magnetoencephalography (MEG) data from native speakers of Spanish (N = 20) and Basque (N = 20) who performed a rhythmic version of the alternation paradigm with omission responses. Spanish and Basque are two languages that differ in their syntactic/prosodic structure, thus providing an ideal model to study the effect of linguistic experience on auditory predictive processing. In Spanish, a functor-initial language, short events (i.e., function words; e.g., *la*, the) normally precede long events (i.e., content words; e.g., *casa*, house), thus forming "short-long" phrasal chunks – a so called iambic pattern. By contrast, in Basque, a functor-final language, short events (i.e., function words; e.g., *bat*, the) normally follow long ones (i.e., content words; e.g., *etxera*, house), resulting in "long-short" grouping units – a so called trochaic pattern.

We hypothesize that the auditory system extrapolates abstract schemes underlying the phrasal structure of language, and use such knowledge to generate high-level predictions about incoming sound sequences. To test this hypothesis, we present subjects with 30s rhythmic sequences of two tones alternating in duration (short tone = 250ms; long tone = 435ms) at fixed intervals (20ms). In each sequence, two to six tone omissions occur pseudo-randomly. MEG responses to omitted sounds are recorded.

We predict that the omission of a short tone represents the violation of two predictions in Spanish, but not in Basque: a local prediction, based on the transitional probabilities of previous stimuli, and a high-level, language-induced prediction based on the regularities of Spanish syntax/prosody. The opposite pattern is expected in the Basque group (See Fig. 1).

Results show that unexpected omissions elicited a sharp "Mismatch Negativity" (MMN) – an event related field (ERF) response putatively associated to cortical prediction error. Importantly, the amplitude of the MMN varied orthogonally depending on the individual's linguistic background: the omission of a short tone elicited a larger MMN in Spanish compared to Basque native speakers, while the omission of a long tone elicited a larger MMN response in the Basque compared to the Spanish group (See Fig. 2). This prediction error signal occurred around 100ms from deviant onset, and had its locus in auditory regions.

These findings suggest that the auditory system recycles coding schemes employed to parse linguistic information to implement hierarchical predictive models of non-linguistic sound sequences. These results provide support for the proposal that shared computational resources underlie speech, sound, and music processing.

Figures

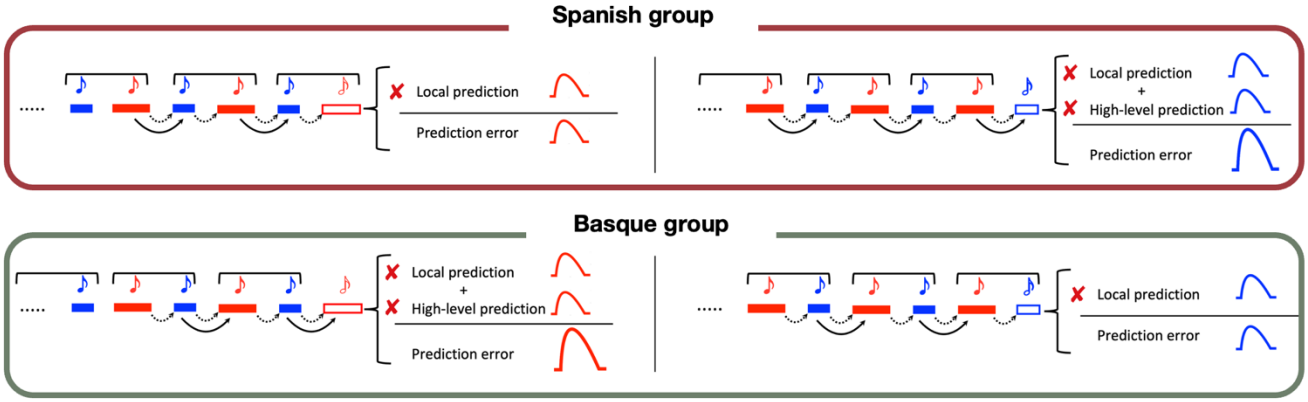

Figure 1. Experimental design and predictions of the study. Square brackets above the tones indicate the grouping structure for the two languages. Dotted lines refer to local predictions; solid lines indicate higher-level, language induced predictions.

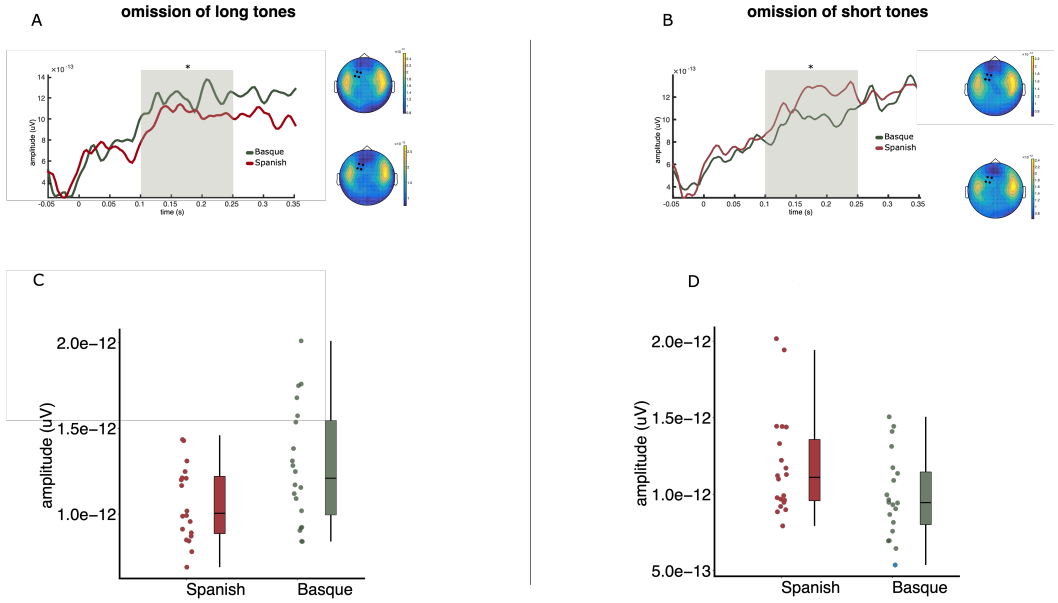

Figure 2. Panels A and B show ERF elicited by the omission of long (A) and short tones (B) in the Spanish and Basque group. Grey shadow part indicates the time-window of interest (100ms – 250ms). The topography of the MMN is reported on the right. Marked channels indicates the cluster in which the interaction between language experience and omission type was significant, as emerged from a cluster-based permutation test. Panels C and D show box plots reflecting the effect of language background on long and short tone omissions over the channels belonging to the significant cluster and time-window of interest.