Overlapping Neural Networks of Music and Language Processing

Daniela Sammler[1], Stefan Koelsch[1], Markus Haerle[2], Armin Brandt[2] & Andreas Schulze-Bonhage[2]

[1]*Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany*
[2]*Epilepsy Center, University Hospital Freiburg, Germany*
sammler@cbs.mpg.de

Introduction

Music and language share a multitude of characteristics [1,2], for example the organization of discrete elements in hierarchically structured sequences according to a complex set of regularities, termed *syntax*. Previous EEG studies showed in both modalities that violations of syntactic expectations elicit similar negative ERP components around 200 ms, termed ERAN (early right anterior negativity) [3] in the music domain, and ELAN (early left anterior negativity) [4] in the language domain, considering the slightly differential scalp topography of both components. Functional imaging studies [5,6] provide evidence that ERAN and ELAN are generated in at least partly overlapping brain areas in the inferior frontal gyrus (IFG) and the anterior superior temporal gyrus (aSTG) bilaterally, but with different hemispheric weighting. However, the assumption of a functional similarity and a neuroanatomical overlap of musical and linguistic syntax processing is based on separate music and language studies and has so far never been validated in a within-subject design. In the present study, we pursued this issue by means of Electro-Corticogram (ECoG) data obtained from left fronto-temporal brain areas during the presentation of linguistic and musical material.

We hypothesized that:

- syntactic violations in music as well as in language would elicit a negative ERP component (ERAN/ELAN) at around 200 ms at electrodes over IFG and/or aSTG.
- amplitude maxima of ERAN and ELAN would emerge at the same electrode.

Methods

Participant

Signals were collected from an intracerebral 4x8 electrode array implanted in the left hemisphere of one right-handed male patient (K.H., 29 years) undergoing presurgical evaluation of a pharmaco-refractory epilepsy. Besides two years of piano lessons at the age of 11-12 years, K.H. did not have further musical training.

Stimuli

In the *music block*, K.H. was randomly presented with two types of six-chord piano sequences. The first five chord functions of both sequence types were identical (dominant – tonic – subdominant – subdominant – dominant). The last chord was either music syntactically regular (Tonic) or irregular (Neapolitan 6th chord; Fig.1). 96 sequences of each type differing in tonal key were presented.

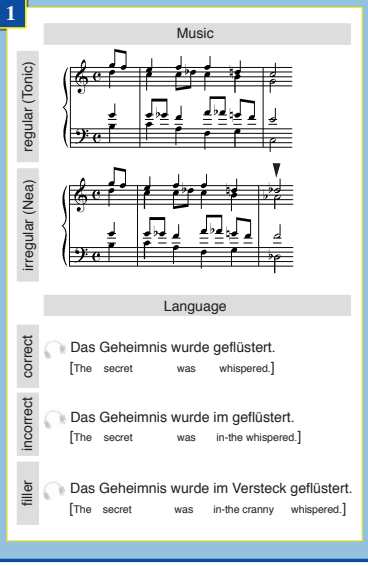
In the *language block*, K.H. listened to three types of German sentences in passive tense spoken by a female voice [4]. 96 short syntactically correct sentences and 96 syntactically incorrect sentences containing a phrase structure violation were presented. Additionally, the experiment comprised 48 syntactically correct 'filler sentences' (Fig.1).

In the music as well as in the language block, K.H. was asked to detect timbre changes, either of the musical instrument or of the speaker's voice.

Data Analysis

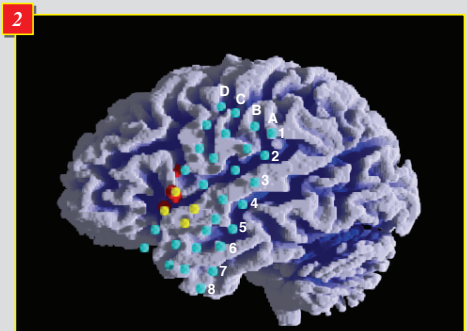
EEG data were recorded with Neurofile NT (IT-med) using a 256 Hz sampling rate. Four contacts (D5, D6, C5, C6; Fig.2) were chosen for analysis based on the functional mapping of the patient's cortex revealing the importance of this brain area in language processing. These contacts were (nearly) free of confounding epileptic activity. Artifact rejection (threshold ± 250 µV, visual inspection) and data analysis was done with EEGLAB 4.515 [7]. Repeated measurement MANOVAs with factors electrode and condition (regular/correct vs. irregular/incorrect) and subsequent *t*-tests were calculated separately for the language and the music block.

1



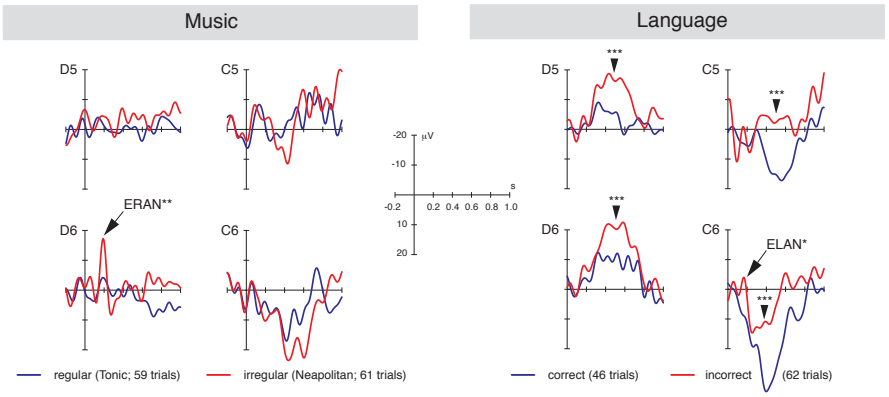
Results

2



Electrode positions of the 4x8 electrode grid mapped onto a standard brain using Talairach coordinates. Yellow marked contacts were language relevant as revealed by the functional mapping of the cortex. Red circles indicate activation foci of previous functional imaging studies on music syntactic processing [1]. This shows an overlap of language and music processing in the inferior part of the inferior frontal gyrus.

3



Average ERPs for music syntactically regular (blue) and irregular (red) final chords (baseline: -200..0 ms). Signals at electrode D6 located in IFG display a statistically significant ERAN ($p = .002$) within a time window from 170 to 210 ms after the onset of the irregular chord (asterisks indicate significance level; $p < .05$*, $p < .01$**, $p < .001$***).

Average ERPs for syntactically correct (blue) and incorrect (red) participles (baseline: 0..100 ms). Incorrect participles elicited a significant ELAN ($p = .041$) at electrode C6 within a time window from 150 to 190 ms as well as a significant sustained negativity ($p < .001$) at all four electrodes within a time window from 350 to 700 ms after onset of the participle.

Discussion

As hypothesized, syntactic violations in both music and language elicited early negativities (ERAN and ELAN) in the left fronto-temporal cortex. The peak localizations of ERAN and ELAN were close but not identical. The ERAN appeared over IFG, whereas the ELAN was found over aSTG. This observation is in line with MEG source localizations revealing temporal and frontal dipoles in both modalities, though with different weighting: Dipoles of the ELAN were found to be stronger within aSTG [6], whereas dipoles of the ERAN were reported most prominently within IFG [5]. This difference may be attributed to a more automatic processing of linguistic compared to musical irregularities, which is supported by studies showing that syntax processing in second language speakers [8] as well as in young children with less linguistic expertise [9] involves most prominently the IFG.

The localizations of the ELAN and of the late sustained negativity following linguistic syntax violations cover fronto-temporal language relevant electrodes as indicated by the functional mapping of the patient's cortex. This shows that both ERP components are linked to the processing of speech based information, however, the exact function of the late effect remains to be clarified.

Most interestingly, one of these language relevant electrodes displays an ERAN following music syntactic irregularities, demonstrating that language and music processing involve overlapping neural resources.

Conclusion

- In patient K.H., left IFG serves the processing of musical syntax, underlining that left (and not only right) hemisphere brain areas are to a certain degree involved in the processing of music.
- The localizations of ERAN and ELAN are close but not identical, probably due to the differential expertise of K.H. in the processing of musical and linguistic syntax.
- The localization of the ERAN lies within language relevant brain areas as revealed by the functional mapping and overlaps with the localization of the sustained negativity elicited by linguistic syntax violations, showing that language and music processing share common neural resources.

References

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