

Explicit Action Perception Shares Resources with Music Syntax: A Controlled Behavioral Study

Eleanor Harding¹, Daniela Sammler², Alessandro D'Ausilio³, Angela Friederici², Luciano Fadiga^{3,4}, & Stefan Koelsch⁵

¹ Minerva Research Group "Neurocognition of Rhythm in Communication," Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

² Department of Neuropsychology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

³ Italian Institute of Technology, Genoa, Italy – ⁴ University of Ferrara, DSBTA – Section of Human Physiology, Ferrara, Italy

⁵ Freie Universität Berlin, Cluster of Excellence "Languages of Emotion", Berlin, Germany

harding@cbs.mpg.de



MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

Introduction

Like language, music and action may both be described by formal models of generative grammar, espousing their respective syntactic structures [1, 2]. This theoretical connection is supported by neuropsychological evidence: Broca's area activation is common to language, music, and action [3, 4, 5], and ERP patterns are similar in language and music [6, 7] even overlapping when elicited by respective syntactic violations in language and music (ERAN) [8]. Considering the need for ERP research in action-perception, and an as-of-yet unexplored connection between music and action syntax, this study used EEG and behavioral methods to seek a cross-domain syntactic resource. Music was coupled with pictorial human action se-

quences, and importantly, the study also paired the action sequence with an auditory control in a frequency oddball paradigm (known ERP effects: MMN, P3, RON). If music and action share syntactic resources, we *hypothesized* that

- 1) Perception of syntactic violations in both domains should evoke similar ERP's (early negativity)
- 2) These ERP's should interact when violations are presented simultaneously in both music and action domains, and not when actions are paired with non-syntactic auditory deviances.

Methods

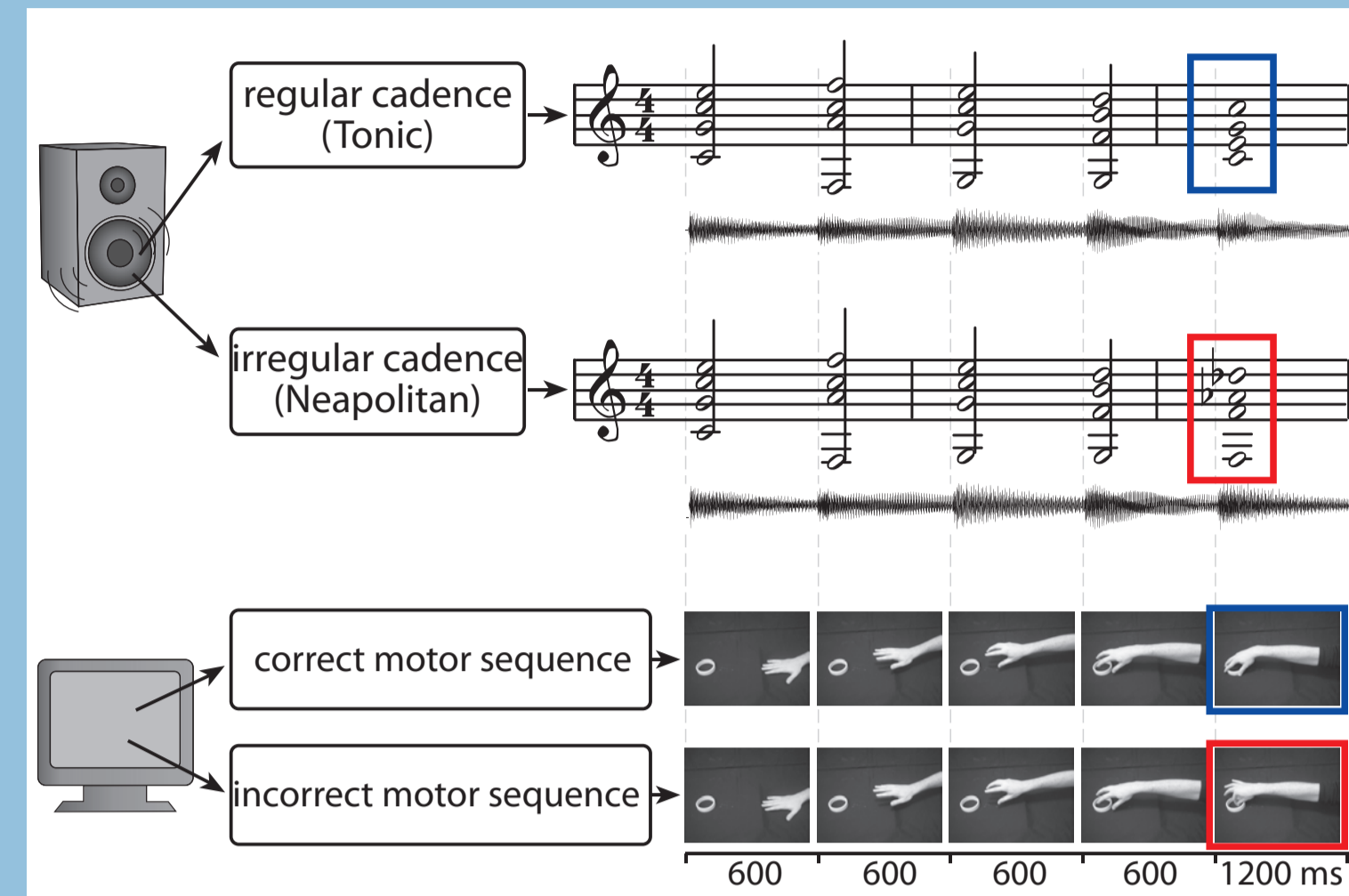


Figure 1 Materials and Design Full 2x2 design with factors Chord (regular/irregular) and Grasp (correct/incorrect). In control experiments, chord sequences were replaced by tone sequences in an oddball paradigm presenting pitch standards or deviants at sequence end position.

Participants

Non-musicians were within-subject for both EEG (N = 30, 15 female, mean age 25 yrs) and behavioral (N = 29) studies.

Task EEG

Subjects were uninformed of condition, paid attention to changes in object or sound timbre.

Task Behavioral

In the Visual task (N = 14) participants judged whether final grasp was able to pick up object (correct) or not (incorrect). In the Auditory task (N = 15, not reported here) participants judged whether final chord was regular or irregular or whether tone was standard or deviant.

Results

EEG CHORDS

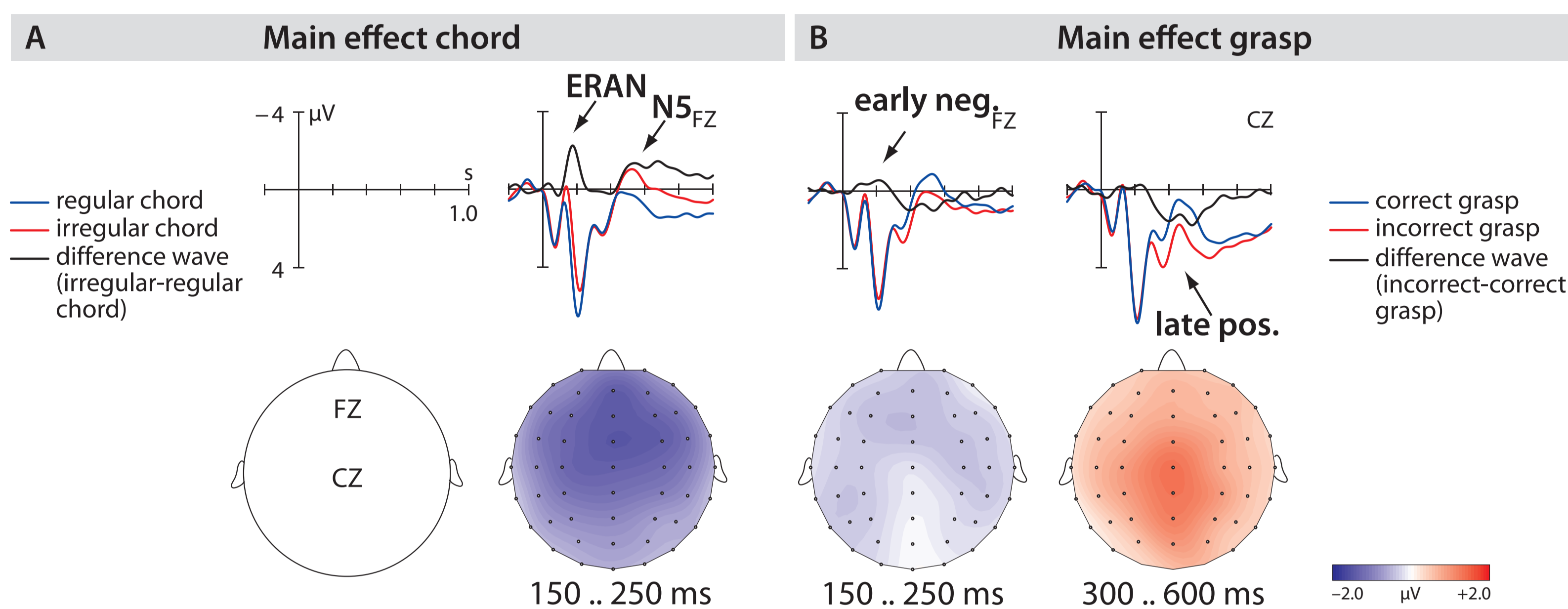


Figure 2 (A) Music effects: Irregular chords elicited an early right anterior negativity (ERAN, 150-250 ms) and an N5 (450-750 ms). **(B) Action effects:** Incorrect grasps elicited an early anterior negativity (150-250 ms) and a late centroparietal positivity (300-600 ms).

EEG TONES

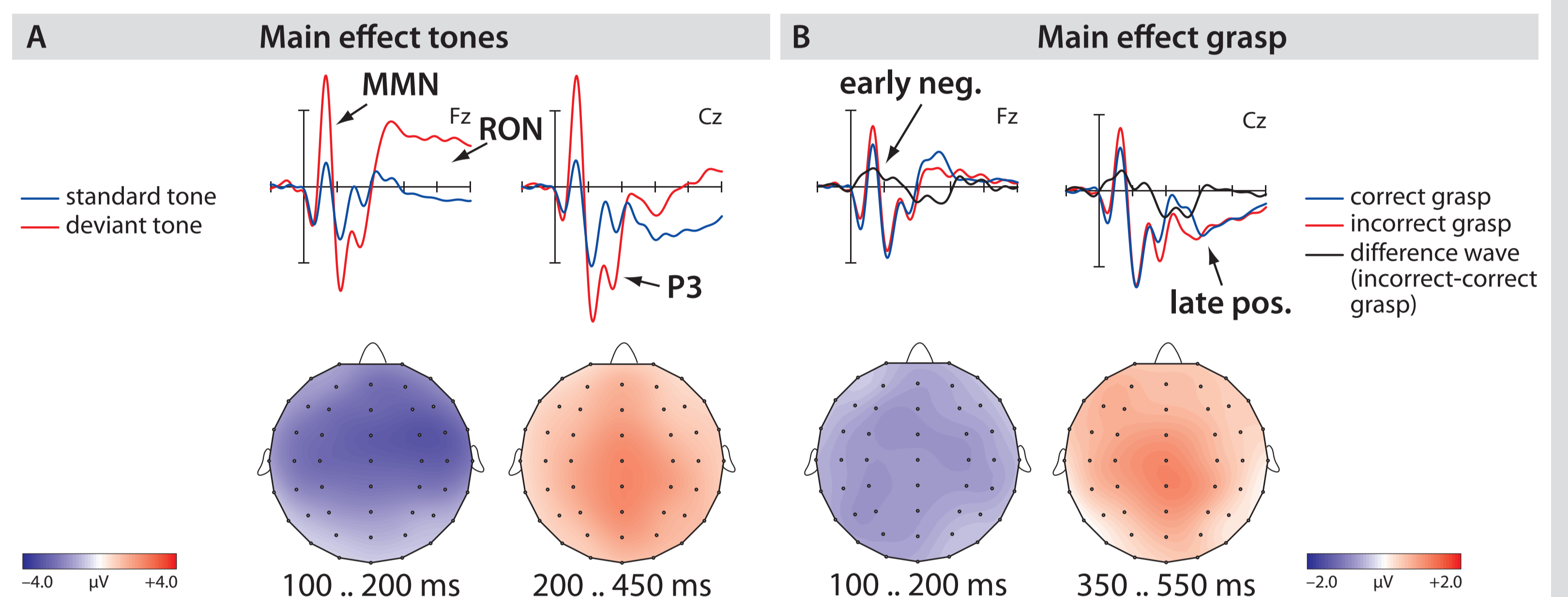


Figure 4 (A) Tone effects: Deviant tones elicited the expected MMN (100-200 ms), RON (450-700 ms), and P3 (200-450 ms). **(B) Action effects:** Incorrect grasps replicated the early anterior negativity (100-200 ms) and late centroparietal positivity (350-550 ms).

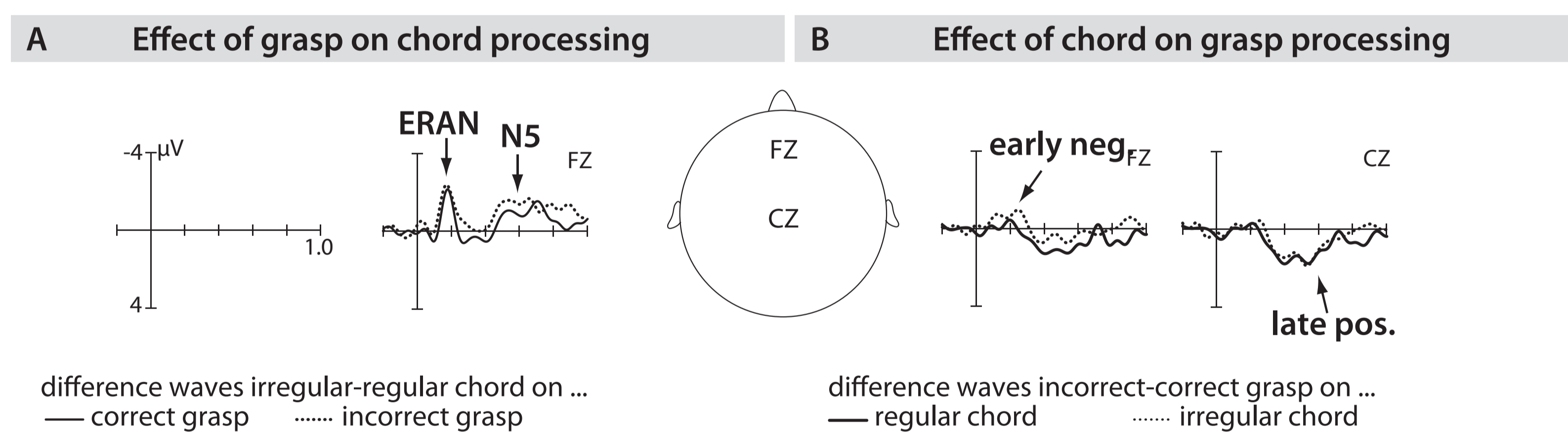


Figure 3 No interaction of effects was found.

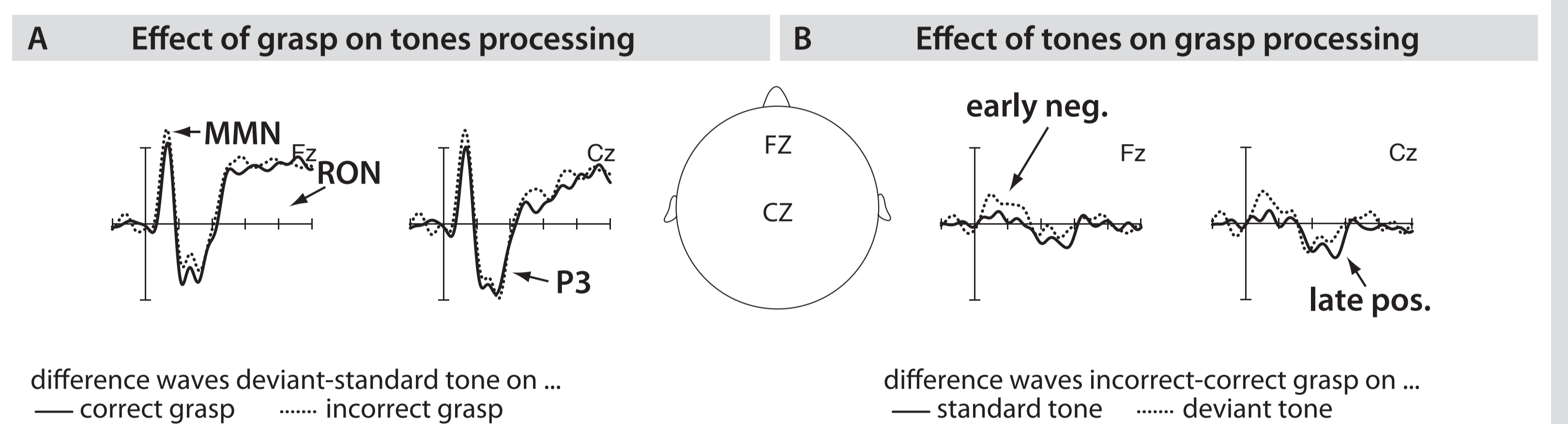


Figure 5 No interaction was found.

BEHAVIORAL CHORDS

Correctness-of-Grasp Judgment

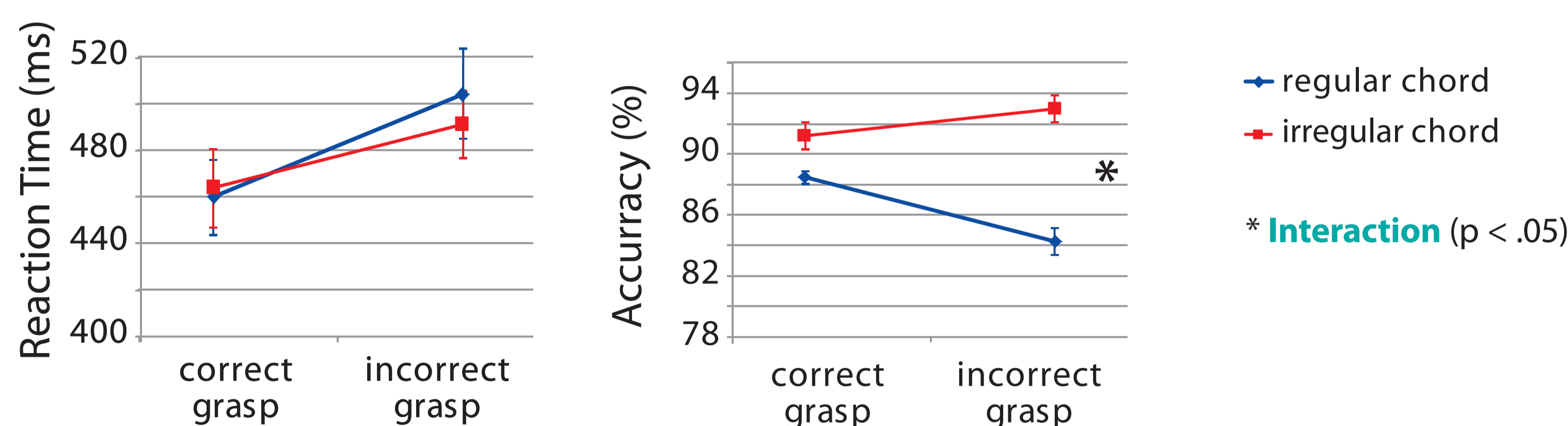


Figure 6 Music-action interaction ($p < .05$) Participants had greater task accuracy when music- and grasp-sequences matched in regularity/correctness. This was not found in the ERP study, suggesting that an explicit task is necessary to reveal an interaction between music- and action-syntax resources.

BEHAVIORAL TONES

Correctness-of-Grasp Judgment

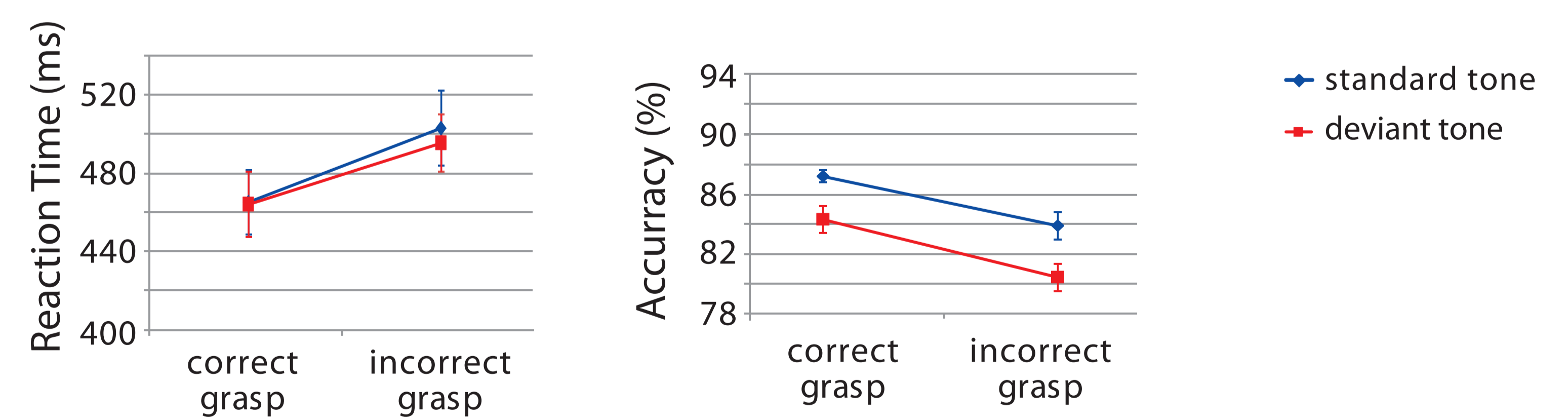


Figure 7 No interaction of tones and action, demonstrating that the syntactic structure of sound is needed to interact with the action sequences in an explicit task paradigm.

Conclusion

The ERP pattern evoked by the action sequence is reminiscent of ERP's elicited by syntactic processes found in language [6] and music [7] studies. Although no interaction between music and action sequences was found, the syntactic composition of the chord sequences became relevant to processing during an explicit correctness-of-grasp judgment, interacting with the action-sequence perception. Furthermore, this explicit-perception interac-

tion was not present in an auditory deviance, pointing indeed to a syntactic resource which monitored the action and music sequences. This study was an important first step in investigating the music-action perceptive link and finding ERP components related to action syntax. Future studies need to specify action-syntax related components and their modulation by attention and task.

References

- [1] Lerdahl, F., and Jackendoff, R. (1983). *A Generative Theory of Tonal Music*. Cambridge: MIT Press.
- [2] Pastra, K., and Aloimonos, Y. (in press). The minimalist grammar of action. *Philosophical Transactions of the Royal Society of London*.
- [3] Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, 6, 78 – 84.
- [4] Maess, B., Koelsch, S., Gunter, T. C., & Friederici, A. D. (2001). Musical syntax is processed in Broca's area: an MEG study. *Nature Neuroscience*, 4, 540-545.
- [5] Johnson-Frey, S. H., Maloof, F. R., Newman-Norlund, R., Farrer, C., Inati, S., and Grafton, S. T. (2003). Actions or hand-object interactions? Human inferior frontal cortex and action observation. *Neuron*, 39, 1053 – 1058.
- [6] Hahne, A., and Friederici, A. D. (1999). Electrophysiological evidence for two steps in Syntactic analysis: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience*, 11(2), 194 – 205.
- [7] Patel, A. D., Gibson, E., Ratner, J., Besson, M., & Holcomb, P. J. (1998). Processing syntactic relations in language and music: An event-related potential study. *Journal of Cognitive Neuroscience*, 10, 717-733.
- [8] Koelsch, S., Gunter, T. C., Wittfoth, M., & Sammler, D. (2005). Interaction between syntax processing in language and in music: An ERP study. *Journal of Cognitive Neuroscience*, 17, 1565-1577.