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Re-visiting the electrophysiology of language

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ABSTRACT

This editorial accompanies a special issue of Brain and Language re-visiting old themes and new leads in the electrophysiology of language. The event-related potential (ERP) as a series of characteristic deflections ("components") over time and their distribution on the scalp has been exploited by speech and language researchers over decades to find support for diverse psycholinguistic models. Fortunately, methodological and statistical advances have allowed human neuroscience to move beyond some of the limitations imposed when looking at the ERP only. Most importantly, we currently witness a refined and refreshed look at "event-related" (in the literal sense) brain activity that relates itself more closely to the actual neurobiology of speech and language processes. It is this imminent change in handling and interpreting electrophysiological data of speech and language experiments that this special issue intends to capture.

Writing a guest editorial in "Brain and Language" poses a one-time opportunity to quote novelist William Burroughs with his famous proverb, "language is a virus from outer space". Continuing the jest of doing so, one could easily add "... and this virus surely has found a way of working the neural make-up of the human brain". I am only half-joking. Indeed, we all might be susceptible to thinking of language as something essentially "out-there" that inhabits the neural tissue rather than as a phenomenon that first and foremost is instantiated by neurophysiological processes.

Of course, speech and language do pose systems of signals, rules, and concepts that, devoid of any neural matter, are worth studying and have in turn motivated inspirational neuroscientific experiments. However, when neural data (i.e., deflections of an ERP or a hemodynamic contrast in a certain brain area) are approached with these specific preconceptions of language, the observed neural dynamics oftentimes become reduced to simplified "neural signatures" or "correlates" taken to support long-hypothesised cognitive concepts. Needless to say that the translation of neural data into a cognitive concept (and vice versa) can become quite slippery all too easily.

This present special issue instead promotes a view of speech and language as emergent properties, owed to and rooted in the complexities of human neural tissue and its complex dynamics. If you are willing to subscribe to this view—that the neurobiology of speech and language is what deserves to be studied and understood, and that such an understanding will promote progress in neuroscience and language science to equal extents (Obleser, 2014)—then you will hopefully welcome this special issue and the efforts it presents. And you will hopefully enjoy the contained articles, all authored by eminent as well as up-and-coming researchers in the neurobiology of speech and language.

All contributions to this special issue have been summoned under this renewed effort to characterise what could be termed the "electrophysiology of language". This title has been chosen to emphasise the re-fuelled interest in the neural dynamics that we measure as fluctuations of electrical neural signals—non-invasively from the scalp, or invasively directly from neural tissue. It is maybe noteworthy that this issue conjoins both approaches, yet reverses the usual method-to-species assignment: We here present scalp electroencephalography (EEG) data from behaving macaques (Attaheri et al., 2014) and invasive electrocorticography (ECoG) data from human patients undergoing epilepsy treatment (Nourski et al., 2015).

More generally, we deemed it about time to collect, under the umbrella of a special issue, recent approaches to the richness of neural electrophysiological signals and the question in how far they are able to provide us with a window into the neurobiology of speech and language and its non-verbal prerequisites such as auditory regularity detection and prediction.

Starting literally at the beginning, Kabdebon, Pena, Buiatti, and Dehaene-Lambertz (2015) provide us with evidence that, first, the rich neural dynamics already present in 8-month-old infants can be usefully analysed (here the authors look at signatures of neural entrainment). Second, neural entrainment not only occurs at the

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syllabic rate, but brief exposure to word-like statistical structure in the materials yields also signatures of the word rate. That is, electrophysiological measures akin to the ones used prominently in current auditory and speech research (e.g., Gross et al., 2013; Henry & Obleser, 2012; Lakatos, Karmos, Mehta, Ulbert, & Schroeder, 2008) can inform us also about infants' abilities to compute the statistical structure of language.

Next, Nourski et al. (2015) turn to the electrophysiological signal as it can be recorded directly from the cortical surface. The authors utilise the ECoG technique in neurosurgical patients and focus on syllable categorisation in the posterior superior temporal cortex. Their goal is to classify neural traces of different syllable percepts, and they compare how the power of Gamma oscillations (~70–150 Hz, which can be easily analysed yielding favourable signal-to-noise ratio in ECoG) performs in comparison to low-frequency local field potential fluctuations (more akin to the signals in non-invasive Magneto- or Electroencephalography [M/EEG] research). The authors conclude that the local field potential and the high-frequency Gamma envelope contain complementary information and should best be integrated when interpreting the results of ECoG-based speech and language signals.

Lewis, Wang, and Bastiaansen (2015) continue on the Gamma trail, and present a review article synthesising and re-interpreting the results thus far on Beta and Gamma oscillations in language comprehension. Complementing the syllable-level results by Nourski et al., they focus mostly on EEG evidence from the sentence and discourse level. They propose that Gamma power changes are a neural means to convey a prediction signal, at least in these specific sentence comprehension contexts. This claim might spur some controversy—not least because reconciling this view with more general notions of Gamma oscillations conveying a neural feed-forward prediction-error signal (Bastos et al., 2015; Friston, 2010) will pose an interesting challenge.

While sticking to the topic of prediction, Bendixen, Schwartze, and Kotz (2014) shed new light on an old workhorse of electrophysiology, the mismatch negativity (MMN), when they study in how far verbal (syllables) and pre-verbal (i.e., tone) patterns adhere to the same neural principles of contingency extraction. Surprisingly, they find that the (passive) extraction of contingencies from verbal materials is the relatively slower process and thus requires longer "exposure" to a contingency before violations thereof can be registered using the MMN oddball approach. This result poses a timely warning that generalisations of results across the domains of auditory cognition in general versus speech and language specifically can be premature.

Using a very comparable design that also tests contingency extraction, Attaheri et al. (2014) provide us with a non-invasive, nonhuman primate model of (artificial) grammar acquisition. They report a frontally-distributed deflection in the ERP around 200 ms, which is potentially homologous to the human violation–indicating MMN response. As a major asset, the macaque scalp-EEG approach provides a bridge between the rich literatures on invasive electrophysiology in primates and non-invasive EEG in humans, respectively. Also, the authors face the intricate problem of analysing comparisons based on a sample size quite typical for nonhuman primate studies ($N = 2$) but unusually small by standards of a human ERP studies. The statistical solutions they utilise (e.g., confidence interval exceedance of difference waveforms) should be taken as an encouragement to re-assess and circumvent our field's null-hypothesis significance testing rituals (see e.g., Cumming, 2014).

Furthermore, one might ask: What can we learn from experimentally interfering with the normal electrophysiological functioning of speech and language processes? To this end, Hartwigsen (2014) presents a concise review of non-invasive brain stimulation (NIBS) techniques and their application thus far to problems of speech and language comprehension. She charts for us a bright future ahead with more thorough combinations of stimulation and functional imaging techniques as well as new stimulation paradigms (e.g., transcranial random noise stimulation).

This special issue comes full circle and ends yet again at the beginning when it "sets the stage for communication by sound", to quote the title of this latest model by Winkler and Schröger (2015), two spearheads of research into the language-precursory processes of auditory pattern detection and prediction. The authors suggest that all audition-based communication relies on a common generative model of the auditory environment. While this rich framework of a unitary, predictive auditory event representation system (AERS) will require future specification pertaining to details of its neurophysiological implementation, it is offered here to the speech and language community nevertheless—not least as testimony to a long tradition of psychologists providing fruitful (i.e., testable) models on the neural bases of speech and language.

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