Review

Future perspectives in neurobiological investigation of language

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\textbf{Abstract}

Studying language as an object of the biological world requires the resolution of the mind-brain problem. While contemporary theoretical linguistics has addressed the problem adopting a dualistic approach (in which the representational and algorithmic nature of linguistic knowledge can be investigated independently by brain activity), cognitive neuroscience has privileged an anti-dualistic perspective (in which the direct observation of the brain can reveal the higher-level cognitive properties of the language faculty). These different epistemological views generated incommensurable ontologies that at the moment prevent the fertile integration of linguistics and cognitive neuroscience. The aim of this special issue is to redraw attention to unresolved shortcomings adopting an interdisciplinary perspective by comparing different research traditions, approaches and methods. The contributions come from linguistics, cognitive neuroscience, neurophysiology, computational neuroscience and computer science and discussed topics related with different aspects of the language faculty. We have tried to blend experimental works with theoretical contributions from linguistics addressing questions that can fruitfully join experimental evidence with abstract theorization. We conclude by outlining some future scenarios under the theme of integration that, although stimulated on the basis of the linguistic-cognitive neuroscience interface, represent general challenges for all interdisciplinary approaches in cognitive neuroscience.

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1. Introduction

Language is our unique feature, an exclusively human cognitive ability. According to contemporary theoretical linguistics, the language faculty represents a particular object of the biological world (Berwick & Chomsky, 2011; Jenkins, 2000). This view emerged during the last fifty years thanks to the so-called “cognitive revolution”, for which a central focus in the study of the mind is represented by the study of the biological bases of language. A main goal of this perspective is to understand how human beings acquire, comprehend and produce natural languages and their specific structures. To reach this goal we need to account for the representations and computations related to our ability to reason, speak, perceive, and interact with the world. Thus, a commitment to the resolution of the mind-brain problem is implied: it requires that we search for the manner in which these processes and representations are correlated with brain activity.

The classical generative approach addressed this problem by following a model traditionally adopted by physical sciences, in which the construction of a theoretical model precedes the testing of its validity. Assuming that there exists a language faculty – a component of the mind-brain that yields knowledge of a language given appropriate environmental stimuli – one can use behavioural data from native speakers (for example, grammatical judgements) within a formal apparatus to infer the abstract characterization of the mental computations underlying language. That is to say, the study of the faculty of language can reveal the complexity of the mind and brain.

Into this scene, towards the end of the 20th century, cognitive neuroscience made its entrance. It aims to reveal the functioning brain in real time by adopting a strictly empirical approach. The basic assumption is that by studying how the low level information and computations are encoded in the neuroanatomy of the brain, one can work upwards towards the understanding of the higher-level cognitive properties of language faculty. Using performance measures from an impressive array of neuroimaging and neurophysiological methodologies (PET, fMRI, EEG, MEG, NIRS and TMS), cognitive neuroscience has been characterized by the effort to correlate specific aspects of language processing with specific brain regions. Although these techniques present some limits because of the nature of signal captured, the physiological basis exploited and of the experimental design and analysis required, they constitute a scientific advance in addressing old questions in new ways (see Fedorenko & Kanwisher, 2009; Lancker Sidtis, 2006; Logothetis, 2008; Poeppel, 1996; Poldrack, 2010; Yarkoni, Poldrack, Essen, & Wager, 2010).

While the two above outlined approaches share an interest in disentangling the relation between the mind and brain with regard to language faculty, they differ in the way of reaching the goal: that is, a dualistic perspective is opposed to an anti-dualistic one. Generative grammar, by separating the study of linguistic representations from the study of the neurophysiological processes producing them, has mainly pursued the objective of formally capturing abstract structures of mental phenomena. This has led linguistics to gradually distance itself from much of the rest of cognitive (neuro)science (but see Marantz, 2005 for a discussion of this issue).

Meanwhile, in the last fifty years the positivist belief that the study of the brain will reveal aspects of the structure of linguistic knowledge has produced an impressive amount of studies from the cognitive neuroscience perspective. As is well-known, this kind of research dates back to the connectionist approach that gave the birth to the Broca–Wernicke–Lichtheim model (revived by Geschwind, 1967; for a review, see Poeppel & Hickok, 2004). Observations in language disorders and brain lesions were correlated to how brain damage can be expected to affect language performance. This intuitive theory aimed at understanding the physical foundations of language (e.g., an injury in area x results in impairments in cognitive function y, therefore, area x is involved in cognitive function y) by abstracting principles of cognitive function.

The tenets underlying this model have been largely reevaluated notwithstanding the possibility to study the brain in vivo and the awareness that it is clearly no longer sufficient. Actually, new data coming from a wide range of language levels (phonetic/phonemic perception and production, morphology, syntax, semantics, etc.) have led the development of large scale brain-language models bound on the assumption that Broca and Wernicke areas are involved in language processing (Friederici, 2002; Hickok & Poeppel, 2004a,b; Indefrey & Levelt, 2004; Price, 2000). Although these new models are clearly anatomically and linguistically more sophisticated than previous ones and attempt
to reach generalizations and explanations of language phenomena, they are still limited to restricted
domains (but see Ben Shalom & Poeppel, 2008 for an interesting effort to discuss the salient properties
and limitations of each model and at the same time to integrate across the frameworks).

However, the conclusions deduced from the studies at the base of these models are inherently
localizationistic in nature. In other words, they describe linguistic-cognitive functions as being local-
ized in focal brain regions. Namely, brain activity in a defined brain region x is involved in specific
linguistic-cognitive functions y (see for example Sahin, Pinker, Cash, Schomer, & Halgren, 2009).
Furthermore, it is tacitly assumed that categories, notions and principles developed within theoretical
linguistics can be validated through neurophysiological and neuroimaging methods: i.e., that onto-
logical entities such as ‘phoneme’, ‘phrase’, ‘recursion’, ‘syntax’, etc., can neurobiologically be
measured. These insights are surely appealing, because they suppose the existence of real correlation
between language and the biological world. However, the clear limits of such an approach are the lack
of an explanatory theory of the correlations and the risk of falling into a sterile reductionism (Poeppel &
Embick, 2005). Conversely, in our view, linguistic ontologies that are stable elements within a theo-
retical framework should be employed as a means to explore neural computations and processing and
not to simply confirm them.

Unfortunately, linguistics has developed a powerful theoretical apparatus verifiable through
empirical procedures that are not neurocognitive in nature. On the contrary, in the domain of cognitive
neuroscience, a theoretical model is generally developed after the observation and the interpretation of
a multitude of empirical data (as, for example, happened for the Broca–Wernicke–Lichtheim model).
Clearly, the observation of the world from different perspectives produces epistemological effects,
which in turn, cause mismatches both at the conceptual and ontological level (see Poeppel &
Embick, 2005). For instance, the idea that starting from phonemes one can increasingly form complex units and
generate syntactic entities by means of transformational rules does not have immediate neural
correlates. At the same time, it is very difficult to directly correlate the ontological unit with a neuro-
biological one.

Thus, despite tremendous progress towards an understanding of the relationship between language
and brain, we face considerable obstacles in understanding this relationship in an explanatory way.
While we do not claim that the research program in language and brain is doomed to failure, we feel
that, in order to make significant progress, it is necessary that both linguistic and neurobiological
paradigms reshape their perspective by searching for the key intersecting points between the two
approaches.

According to the most recent models of brain organization, complex cognitive processes are not
localized in isolated brain regions (as already hypothesized, for example, by Hebb, 1949; Lashley, 1950).
Rather, cognitive abilities emerge from functional relations that are subserved by widespread cortico-
cortical and subcortical connections, differentiated in space and time of activation (Fuster, 2003;
Schnelle, 2010). Such networks are based on and are connected to organized modules of elementary
sensory and motor functions. This intricate relationship of discrete neuronal aggregates and the
possibility of myriad aggregate combinations can generate specific cognitive processing and compu-
tation. Thus, as the more important distinction between our brain and that of our ancestors is not size
but the neuronal connectivity (Edelman, 1989, 1992), cognitive functions probably grow out of func-
tional interactions within and between cortical networks.

In line with this view, we need to assume that linguistic representation and computations are
executed in the brain in real time. Specifically, we do not need to operate with antonymous concepts
such as mind reality vs. neurophysiological reality, since they can be considered as the same thing
traditionally described from different point of views. Furthermore, we cannot think of distinct levels of
language (phonetics vs. phonology vs. syntax vs. semantics, etc.) as being isolated computational
entities. Crucially, this implies that we have to avoid to neurobiologically validating linguistic concepts
and ontologies per se. We do not need neuroimaging taxonomy of cognitive processes related with
linguistic notion. Linguistics concepts and ontologies need to be taken into account as elements of
a theory that allows the study of how they are correlated with spatial and temporal brain processes (see
for example Pallier, Devauchelle, & Dehaene, 2011, who identified a neural network where activation
increases parametrically in both amplitude and phase with the integration of words into hierarchical
structures during on-line language comprehension).

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Such a framework may be helpful to give more explanatory power to conclusions such as, for example, “acoustic-phonetic analysis of words is conducted in the superior temporal sulcus”. In parallel, such a model may also highlight the conditions necessary to achieve integration between the Chomskyan tradition and the cognitive neuroscience approach. This suggests an ongoing conceptual change in both domains of inquiry (Poeppel & Hickok, 2004). Within this integrated perspective, the theory could be better refined accordingly to experimental data and might reach an explanatory level in term of neural functions. On the other side, cognitive neuroscience would avoid the sterile accumulations of data and could reach a predictive level that currently is still limited. Thus, to achieve a neurobiological explanatory level of analysis about brain linguistic structures, it is necessary to elaborate explicit hypotheses about how particular linguistic processes are executed in the brain (see Poeppel, Idsardi, & van Wassenhove, 2008 concerning speech perception). If brain constraints on abstract computations could be observed, we would be able to move closer to the biological properties of the faculty of language by developing a neural theory of language.

2. The present volume

The present collection of papers comes to grips with these issues by comparing different research traditions, perspectives and methods. The aim is to assess the current situation in respect to a possible theoretical and methodological integration in the study of language and brain, and hence to redraw attention to unresolved shortcomings. Contributions were included from the fields of linguistics, cognitive neuroscience, neurophysiology, computational neuroscience and computer science. Such diversity derived from the heterogeneity of the topics debated: i.e., the unified representations for speech and action, the perception–production interface, the lexical competence and semantic processes, and the natural and artificial structures of language and communications.

Predictably, the variety of papers collected in this issue fell short of the goal we had in mind. However, one of the merits of the present volume, we submit, lies in the balanced blend of pure experimental works with theoretical contributions from linguistics aiming to address questions that can fruitfully join experimental evidence with abstract theorization. Thus, we are confident that the articles here published can further sensitize the potential readers to intensify the dialogue among scholars of different disciplines as a means of pursuing an integrated approach in the study of neurobiological basis of language. Although the enterprise principally implicates the reciprocal collaboration and influence between linguistics and cognitive neuroscience (with the contribution of neuropsychology), we think that also tangential disciplines such as computer science and computational neuroscience might contribute to support in refocusing crucial questions for guiding the interpretation of experimental results and the developments of future directions.

This enterprise, we feel, should be placed on interdisciplinary foundations, incorporating theoretical and methodological approaches both across and within disciplines. Moreover, we hope that research in the cognitive neuroscience of language will progressively integrate the search of anatomical specifications with the investigation on what kind of computations in the brain forms the basis for linguistics representations and operations. That is to say, we need to abandon the opinion that sub-domains of language represent holistic parts that can be functionally localized, pursuing the building of an integrated theory grounded on neurobiological basis that it is able to make explicit predictions on linguistic representations and computations mirrored in functional anatomical networks.

Accordingly, the volume is opened by Grimaldi’s contribution aiming to explore the intersections between research in linguistics and cognitive neuroscience. Firstly, Grimaldi analyzes the main issues, questions, and concerns that limit the combined study of language and the brain, showing that they originate in the above-cited dualistic and anti-dualistic conflicting approaches. Then, stimulated by previous works of Hickok and Poeppel (2004a,b), Poeppel and Hickok (2004), Poeppel and Embick (2005), he discusses in detail the conceptual and ontological incompatibilities between the two disciplines. The author argues that classical notions of language processing (e.g., syntactic and semantic interface, hierarchical syntactic structures, recursion procedure, phonological processes and speech perception, etc.) can be reexamined in the light of recent neurocognitive data. Furthermore, these notions are connected with the processes of analysis, memorizations, retrieval of stored items and combinatorial operations and are correlated to the cortical areas traditionally hypothesized to be
involved in these processes (i.e., the frontal, temporal and parietal lobes). Finally, Grimaldi discusses a possible interdisciplinary program in order to achieve a theory capable of verifying theoretical assumptions and predictions based on real time neural constrains that characterize the functional-anatomic organization of language in the brain.

Three papers, D’Ausilio et al., Schwartz et al., and Calabrese, explore the neural correlates of speech perception from different point of views. D’Ausilio et al.’s paper stresses the view that language, like other complex cognitive processes, is suberved by neuronal networks based on organized modules of elementary sensory and motor functions. In particular, the authors present empirical evidence showing that the motor system plays an important role also in perception, suggesting the abandonment of the classical view claiming a clear-cut distinction between language production and perception. This approach is based on the Motor Theory of Speech Perception, which postulated that the intended articulatory gestures, rather than sounds, are critical for both production and perception of speech (Liberman at al., 1967; for a review see Galantucci, Fowler, & Turvey, 2006) and the perspective that sounds conveying speech could be a vehicle of motor representations shared by both the speaker and the listener, upon which speech perception could be based. Experimental evidence showing that a selective alteration of neural activity in speech motor centres impairs phonological perception in a specific way provides strong support to this view indicating a causal contribution of the motor system in the perception of speech sounds.

Conversely, Schwartz et al. aim to re-emphasize the role of perceptual shaping as opposed to the primary function attributed to motor properties in perception by motor theories. The main criticism comes from the observation that sometimes the relationship between gestures and sounds is many-to-one (various gestures for a single sound), and hence the gesture cannot be, in theory, recovered from the sound without additional pieces of information. This suggests that a gesture is characterised by its functional value and that gestures are not pure motor units, but rather perceptuo-motor units, gestures being shaped by perception. The paper presents in detail the so-called Perception-for-Action-Control Theory (PACT) aiming at solving the apparent never-ending loop constituted by the remark that action shapes perception and perception shapes action in return. PACT considers that speech perception is the set of mechanisms that enable not only the understanding, but also the control of speech, considered as a communicative process. Therefore, the perceptual system is intrinsically organised in reference to speech gestures, and in relation with the structure of the action system. Perception provides action with multisensory templates, which contribute to define gestures, providing them with objectives, organisation schemes and functional value. In PACT, the communication unit, through which parity may be achieved, is neither a sound, nor a gesture, but a perceptually-shaped gesture, that is a perceptuo-motor unit. It is characterised by both its articulatory coherence – provided by its gestural nature – and its perceptual value – necessary for it to be functional.

From a theoretical linguistic perspective Calabrese hypothesizes that a perceptual system is dedicated to the analysis, identification, and recognition of linguistic information in the acoustic inputs. Importantly, in Calabrese’s view, the system involves phonological computations of the same type as those found in production. To account for these kinds of computations, the author assumes that perception includes an analysis-by-synthesis component which analyzes linguistic material (in terms of distinctive features) by synthesising it anew through grammatical computations. Analysis-by-synthesis, however, is required only when the listener wants to be certain that the words or morphemes identified in the input signal correspond to those intended by the speaker who produced the signal. The author, then, hypothesizes two perceptual processes: phonemic perception where only the contrastive aspects of sounds associated with meaning differences are searched for, and phonetic perception where both contrastive and non-contrastive aspects of sounds are identified. Analysis-by-synthesis in the former process can generate ‘phonological’ illusion. A crucial element in Calabrese’s model is represented by the notion of echoic memory in which auditory representations of acoustic inputs can be stored. The articulated analysis of these assumptions leads Calabrese to explore recent neurocognitive research and to make key hypotheses on the questions related to the neural bases of perceptual processes and representations.

Two additional papers, based on a shared theoretical and empirical perspective, examine speech productions and the link with auditory and somatosensory processing. Perkell deals with questions regarding what the movement goals or targets are in the production of individual speech sounds and
sequences of speech sounds, and what the roles of feedback and feedforward mechanisms are in controlling those goal-directed movements. Motivated by the assumption that the speaker's objective is to produce sound sequences with acoustic patterns that are intelligible to the listener, based on the modelling work of Guenther and colleagues (c.f., Guenther and Vladusich, this issue) Perkell proposes that movement goals for speech movements are time-varying patterns of auditory and somatosensory sensation specified primarily in terms of sensory parameters (e.g., auditory trajectories). Evidence from experiments designed to test experiments based partly on Guenther's DIVA model, demonstrated that speakers with greater auditory acuity, i.e., who discriminate well between speech sounds with subtle acoustic differences, produce those sounds with greater contrast than speakers who discriminate the same sounds less well. Furthermore, fluently produced sound sequences are encoded primarily as feedforward commands, and feedback control serves to correct mismatches between expected and produced sensory consequences. These data support a theoretical framework in which fundamental control variables for phonemic movements are multi-dimensional regions in auditory and somatosensory spaces.

Guenther and Vladusich present a computational and neural framework called DIVA, that provides a quantitative account of the interactions between cortical motor, somatosensory, and auditory regions during speech output. In particular, they focus on a specific class of neurons (speech sound map), hypothesized to be present in the left ventral premotor cortex and posterior of Broca's area, active during both production and perception of specific motor actions. Since they provide a link between the sensory representation of a speech sound and the motor program for that sound, they are considered to resemble mirror neurons described in the F5 region of monkey premotor cortex (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Guenther and Vladusich summarize data from several brain imaging and behavioural studies which have provided support for the key functional predictions of the DIVA model, and suggest how this model can be used to further examine the functional properties of mirror neurons in the speech motor control system.

Two contributions, one by Pülfvermuller and the other by Panizza, focus on meaning at two different levels: i.e., the former privileges the lexical level where the latter prefers the logical one. Pülfvermuller addresses the problem of meaning in a radical way returning to its origin: i.e., to the notion of ‘sign’. In particular, at the core of Pülfvermuller’s investigations there is the well-known phenomenon for which the arbitrariness of the sign differs fundamentally between semantic categories. A question arises: is this specific feature of meaning reflected in precise neural patterns during the comprehension of different semantic word types? Classically, processing words activates the perisylvian language areas and sensory areas, especially higher visual, olfactory, somatosensory and auditory ones. However, if the meaning expresses action-related concepts, the brain’s motor system (cortical action–perception circuits involving cortical motor, sensory and multimodal areas) is activated when such words are processed. Also, the paper focuses on a range of different facets of semantics: i.e., affective-emotional (limbic system), abstract (anterior-temporal and perieto-temporo-occipital cortex), and combinatorial semantics (perisylvian cortex).

For his part, Panizza firstly reviews recent EEG, fMRI and MEG studies that have investigated linguistic mechanisms postulated by formal theories of meaning, concentrating his analysis on concepts such as truth value, compositionality, recursion, predication, logical entailment, and in particular on Negative Polarity Items. Then he discusses and compares some theories that challenge distinct neural substrates for these mechanisms. Finally, the author examines some semantics construals (such as modal subordination) that have been studied through neurocognitive methods. At the end, the work presents convincing evidence that our brain must implement certain representations necessary to understand language which are symbolic, abstract and grammar-driven. As Panizza highlights, the challenge for future research, then, will be to figure out how brain functions cooperate and interact with other cognitive systems, in dealing with this kind of information structure. On the whole, the two papers suggest that neurosemantics may open a new way of addressing old issues and theoretical concerns, offering the possibility to found a semantic theory on functional neuronal models.

Rizzi’s paper concentrates on the syntactic level. Dealing with linguistic computations and language variations within parametric and minimalist models, the author discusses some core ideas and formal devices of theoretical linguistics. Starting from the distinction between contentive lexicon (nouns, verbs, adjectives, determiners, etc.) and functional lexicon (characterized by more interpretive
properties such as tense, definiteness, declarative or interrogative force, etc.), Rizzi outlines the critical role that the latter actually play within syntactic theory. The functional elements are considered with respect to the fundamental computational processes of Merge, Search and Move that they trigger. Hence, functional elements are the locus of much of the syntactic action: That is, they express basic syntactic parameters (producing the main cross-linguistic variation in syntax), and give rise to very complex configurations. Then, Rizzi tries to formulate some coherent hypotheses to shed light on how both elemental pieces and abstract computational operations are performed in the brain forming syntactic representations. These suggestions may be useful for further neurocognitive investigation on the neural constrains that control such abstract computations.

A contribution coming from the field of computer science closes the issue. Guerra-Filho and Aloimonos propose a linguistic framework for the modelling and learning of human activity representations (Human Activity Language, HAL). Their starting point comes from the observation that infants acquire actions by observing and imitating the actions performed by others. Once basic actions are acquired, they learn to combine and concatenate simple actions to form more complex actions. The authors claim that this process is similar to speech, where we combine phonemes into words, and words into sentences. Guerra-Filho and Aloimonos take the hierarchical structure of natural language (e.g., phonology, morphology, syntax) as a framework for structuring not only the linguistic system that describes actions, but also the motor system, and demonstrate that there exists a language of human activity by empirically constructing one such language out of large amounts of data. In particular, in the present paper they extend HAL syntax to consider human interactions between two subjects, empirically showing that human interactions have a particular syntax based on the syntax of individual actions.

3. Conclusions and further remarks

Looking back, we feel that the contributions from heterogeneous fields forming this volume offer a reasonable picture, although incomplete, of the challenges that await research in the field of cognitive neuroscience of language in the future. We take this opportunity to outline some possible scenarios under the theme of integration, that, although stimulated on the basis of linguistic-cognitive neuroscience interface, are more general challenges for all interdisciplinary approaches in cognitive neuroscience.

First, we have to reflect on the fact that most functional imaging studies utilize univariate analyses, permitting only the independent assessment of activity within each brain region in isolation of all others. So, it is important to recognize that there has been the steady development of multivariate approaches to analyze neuroimaging data in a manner that more directly addresses the network model of cognitive processes (for example, Hampson, Peterson, Skudlarski, Gatenby, & Gore, 2002; Lin et al., 2003; Maguire, Mummery, & Buchel, 2000; Toni, Rowe, Stephane, & Passingham, 2002). Therefore, continued development of effective multivariate techniques seems necessary not just within the field of functional neuroimaging, but for all physiological methods. Second, a combination of the varied methodologies used to explore networks will be essential in order to take the chance to really take advantage of the respective strengths in spatial and temporal resolution of fMRI and ERP/MEG by coupling them in the same experiment (Bledowski, Prvulovic, Goebel, Zanella, & Linden, 2004; Schulz et al., 2004). Furthermore, while fMRI, ERP, and MEG are promising techniques that can identify network regions associated with cognitive processes, they are correlational methods that cannot on their own establish the necessity of component regions. To show that identified network nodes are functionally necessary, we will need to integrate these methods with those capable of inducing focal reversible lesions, such as TMS in humans with EEG (Miniussi & Thut, 2010; Taylor, Walsh, & Eimer, 2008; Thut & Pacual Leone, 2010) or cortical cooling in animals (Coomber et al., 2011), as well as to perform network studies on neurological/neurosurgical patients with chronic lesions. This will allow an assessment of the necessity of specific network regions for cognitive performance, as well as the plasticity of the network in response to their absence. Third, it is essential that we integrate the reductionist modular approach with the functionalist network approach. Also, parallel experiments should be planned from the onset to generate complementary information from these two approaches. By using data from both of these models to inform one another, we can hope to obtain a comprehensive
understanding of neural mechanisms underlying cognitive processes in general and those correlated with language in particular. Fourth, the increasingly integration of diverse research expertise focused on research projects is essential. This will require a new interdisciplinary education for a generation of scholars able to master linguistic, neurophysiological, and (neuro)psychological tools. Lastly, and perhaps most importantly for that which concerns linguistics and cognitive neuroscience, as described above, the progressive integration between linguistic and neuroscience concepts and ontologies is indispensable. This implies that starting from the large body of evidence already accessible on the essential basic neuroanatomy of language processing, we can formulate more detailed hypotheses about how assumptions and notions on linguistic levels of analysis may be grounded in the physical world. Subsequently, these hypotheses will be verified through integrated experimental methods in order to develop finalized predictions on how linguistic computation and processing are neurally assembled (i.e., functionally distributed in neural circuitries).

We are well aware that hard work is required and that there is still much to be done in order to get beyond empty promises of interdisciplinary cross-fertilization, because the risk of cross-sterilization is real (Poeppel & Embick, 2005). Overcoming mutual suspicions, misunderstandings and tensions between the disciplines will surely contribute to making the field of the cognitive neuroscience of language move persistently forwards towards a neural theory of language.

Conflict of interest

As authors of the manuscript “Future Perspective on Neurobiological Investigation of Language”, we declare, on our responsibility, that we have not actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence our work.

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