Linguistik Aktuell Linguistics Today 235

Biolinguistic Investigations on the Language Faculty

Edited by
Anna Maria Di Sciullo

John Benjamins Publishing Company

Biolinguistic Investigations on the Language Faculty

Linguistik Aktuell/Linguistics Today (LA)

ISSN 0166-0829

Linguistik Aktuell/Linguistics Today (LA) provides a platform for original monograph studies into synchronic and diachronic linguistics. Studies in LA confront empirical and theoretical problems as these are currently discussed in syntax, semantics, morphology, phonology, and systematic pragmatics with the aim to establish robust empirical generalizations within a universalistic perspective.

For an overview of all books published in this series, please see
http://benjamins.com/catalog/la

Volume 235

Biolinguistic Investigations on the Language Faculty
Edited by Anna Maria Di Sciullo

Biolinguistic Investigations on the Language Faculty

Edited by

Anna Maria Di Sciullo
University of Quebec at Montreal

John Benjamins Publishing Company
Amsterdam / Philadelphia

The paper used in this publication meets the minimum requirements of the American National Standard for Information Sciences – Permanence of Paper for Printed Library Materials, ANSI Z39.48-1984.

DOI 10.1075/la.235

Cataloging-in-Publication Data available from Library of Congress.

ISBN 978 90 272 5718 5 (HB)
ISBN 978 90 272 6630 9 (E-BOOK)

John Benjamins Publishing Company · https://benjamins.com

Table of contents

Biolinguistic investigations on the Language Faculty

Introduction

Anna Maria Di Sciullo
Université du Québec à Montréal

The papers assembled in this volume aim to contribute to our understanding of the human capacity for language, understood as a generative procedure that relates sounds and meanings via syntax. While theoretical hypotheses about this relation are part of the generative enterprise since its beginnings, recent developments address the issue in terms of the properties of the 'language organ'. Different hypotheses about the properties of the generative procedure, giving rise to the discrete infinity of language, are under discussion, and their connection with biology is open to important cross-disciplinary work. Advances have been made in human-animal studies to differentiate human language from animal communication. Contributions from neurosciences also point to the exclusive properties of the human brain for language. Studies in genetically based language impairments also contribute to the understanding of the properties of the language organ. This volume brings together contributions on theoretical and experimental investigations on the Language Faculty, language variation and language impairments. The following paragraphs present the gist of their content.

Section 1. Language Faculty

In this first section, the main questions and hypotheses of the Biolinguist program are restated as well as new Biolinguistic research is discussed. While the paper on the Biolinguistic program provides a broad coverage of the field, focusing on the properties of the Language Faculty, the other papers focus on phonology, language externalization and the organization of speech in auditory cortex in a biolinguistic perspective.

The first paper by Anna Maria Di Sciullo and Calixto Aguero, "The Biolinguistic Program: Questions and hypotheses", presents a comprehensive overview of the Biolinguistic research program. This program aims to provide explanatory accounts of the fundamental facts about human langue, that it is an unbounded

doi 10.1075/la.235.001int

recursive system, that language acquisition is rapid and universal irrespectively of geographical or cultural differences across the species. The authors identify the questions and the hypotheses that are at the core of the biolinguistic program in current developments of linguistic theory and biology. The Biolinguistic Minimalism (Chomsky 1993, 2007a, b, 2008, 2013) relies on the one hand on the hypothesis that human language is a part of human biology, as evidenced by the fact that language develops in the child through the same typical steps, independently of socio cultural parameters. Facts from natural development and language impairments provide evidence of the biological basis of human language. Furthermore the authors bring evidence that language diversity and historical change find resonance in the diversity and change of bipartite biological organisms (Palmer 2004, 2009). The generality of the biolinguistic questions makes it difficult for any single scholar to be able to pursue such topics exhaustively from within the methodological boundaries of a single discipline. For this reason, research in biolinguistics abstracting away from the aspects of the problems that are irrelevant to the domains in which the research takes place while recognizing that findings achieved in the other related disciplines, including biology, mathematics and physics, may have an impact in confirming or disconfirming the hypothesis that are postulated at the local levels.

Camila Matamoros and Charles Reiss' paper on "Symbol taxonomy in biophonology" is complementary both to work like that of Hornstein and Pietroski (2009), who explicitly exclude phonology in their discussion of a possible set of 'basic operations' for language; and to work like that of Mesgarani et al. (2014) who report finding evidence for phonetic/phonological feature encoding in the brain. The authors are interested in the combinatoric and syntactic properties of phonological computation. The paper is influenced by scholars like Poeppel (2012) who maintain that neuroscientists need theoreticians to tell them what primitives to look for in the brain: "The commitment to an algorithm or computation […] commits one to representations of one form or another with increasing specificity and also provides clear constraints for what the neural circuitry must accomplish. The kinds of operations that might provide the basis for investigation include concatenation, segmentation, combination, labelling, and other elementary (and generic) operations that could be implemented quite straightforwardly in neural circuits". Their discussion of basic notions like variables and functions and the combinatorics of phonological data structures built from atomic symbols is inspired by Gallistel and King (2009).

In ''Language externalization is not secondary: On the integration of speech and thought', Joana Rosselló points out that the importance of speech/sign for thought has been overly underestimated. The paper focuses on externalisation and provides different arguments in favour of the thesis that language externalization is not secondary, contrary to the classical Chomskian position (Chomsky 2007a, b, 2014) according to which the faculty of language matches optimally with thought, the Conceptual-Intentional system, rather than with externalization. Against this framework, the author provides different arguments in favor of her thesis, which reinforces the un-Cartesian view of language (Hinzen 2014). From a conceptual point of view, two arguments are developed. The first argument posits that language is the most complete faculty ever evolved in the sense that it embraces and interrelates a sensory system, which qualifies as an input/perceptual system (Fodor 1983), a cognitive system and a motor system, which crucially are all interdependent. That it is precisely the motor-cognitive – perceptual connection that is crucial is suggested by the openness of the externalization: the system can be oral-auditory or gestural-visual. The second argument shows that externalization can be vindicated without assuming that language evolution is crucially informed by animal communication (Bolhuis et al. 2014; Hauser et al. 2014). Once communication/externalization is restated, words and grammar are considered in its light. It is then argued that the communicative (sound/sign) and cognitive (meaning) dimensions of language go arm in arm irremissibly and are responsible of our species' mental and social profiles.

In "Neurobiological correlates of the temporal and spatial organization of speech in auditory cortex: A critical review," Mirko Grimaldi and Anna Dora Manca highlight that human speech processing shows a unique property: a high-resolution system for acoustic decoding and phonological encoding tied with ability for abstraction and a very efficient memory mechanism, both residing in high developed cortical (and sub-cortical) pathways. The authors point to the fact that in search for the neurobiological foundation of speech processing, studies have used Magnetoencephalography (MEG), a technique with good spatial and excellent temporal resolution, to investigate timing (tonochrony) and topography (phonemotopy) of the N1m – the magnetic counterpart of the N1 auditory evoked potential (AEP). Researchers want to know if the phonemotopic map is independent of the tonotopic map or, alternatively, whether phonemes are more simply represented according to their frequency content along tonotopic gradients in auditory cortex. To this end, investigators have mainly measured the cortical responses to vowel stimuli, a class of speech sounds differing acoustically each another on the basis of the distribution of F1-F2 formant frequencies. While these studies provide evidence that tonochrony and phonemotopy of the N100m may reflect differences in the quality of vowels, these findings require a number of caveats. First, the source locations described in these studies represent a single point in three-dimensional space in the cortex of the N100m response. As it is known that the N100 response has at least six separate cortical generators, the N100m sources can describe a simple cortical map representing a partial abstraction of the underlying anatomy and thus, they should not be viewed as an exact representation of the auditory maps well-described in animal. Finally, none of these studies have tested whether the cortical responses to the F1-F2 dimensions for nonnative vowel sounds show a similar sensitivity to native phonemes. Despite these limitations, these studies provide consistent evidence that a perceptually critical aspect of the formant structure of vowels, such as the ratio between F1-F2, is represented in a temporal and spatial map within the auditory cortex.

Section 2. Language variation

The papers included in this section relate language variation to variation in biology. They present a view of the Language Faculty as parallel to any other biological system, as well as they show that a biolinguistic understanding of human language and variation also has implications for comparative linguistics. While the first paper relates macro and micro parameters to deep properties of I-language, the second and third papers present explanatory approaches to language variation in terms of third factor principles reducing complexity.

In "Feature-values and the expression of variation" Pritha Chandra argues that feature-values (e.g. singular/plural; 1st/2nd/3rd person) are as varied for dialects and closely related languages as for typologically unrelated languages. In other words, the I-language systems of related and geographically close languages are sometimes quite disparate in their feature-value pools, contra suggestions of micro-variationists (Kayne 2005). In this sense, the language system mirrors the variation patterns observed in population genetics, where genetic variation within a population/race is as varied or even more varied than that observed between different populations/races. These claims are substantiated in the present work with a wide array of split-ergative patterns. At the descriptive level, cross-linguistic split-ergative patterns show person and number values independently effecting interesting similarities and differences both between closely related and unrelated languages. Pama-Nyungan language Dyirbal exhibits ergativity in third person pronominals, but not with first and second persons (Bitter & Hale 1996; Legate 2012), a pattern also evident in Indo-Aryan Punjabi and Marathi. However, its dialect Giramay has no such restriction and closely resembles Walpiri, a typologically related language. Similarities also exist between Giramay/Walpiri and typologically unrelated languages like Basque and Indo-Aryan Nepali while Nepali exhibits notable differences from typologically related Hindi-Urdu. Number values like singular and plural on the other hand, play significant roles in the ergative patterns in the Mayan language Tzotzil as well as the typologically unrelated Indo-Aryan Gujarati (Bhatt 2007). This paper goes on to demonstrate how feature-value pools have large-scale structural repercussions, just like what are expected of macro-parameters (Baker 2008). This leads the author to analyze them as reflections of deeper structural differences in I-languages than as mere values on functional heads.

The second paper brings to the fore parallels between language variation and variation in biology by considering the effect of natural laws, or third factor principles (cf. Chomsky (2005), on language diachrony. In "Object pronouns in the evolution of Romanian: A biolinguistic perspective", Anna Maria Di Sciullo and Stanca Somesfalean assume that the Language Faculty does not change through time, and that syntactic variation is the consequence of minimal changes in the feature structure of functional categories, which are brought about by language acquisition and languages in contact. They also assume that evolutionary developmental principles emerge in the historical development of languages as a consequence of natural laws reducing complexity. One consequence of such principles is the Directional Asymmetry Principle (DAP) according to which points of symmetry tend to be eliminated (Di Sciullo 2011). The authors provide further arguments for such symmetry breaking universals by considering the development of object pronouns in the diachrony of Romanian. Relying on the two notions of complexity proposed in Di Sciullo (2012), Internal and External complexity, the authors address the facts that clitics and strong pronouns differ in their level of complexity (Kayne 1991, 1994; Uriagereka 1995; Cardinaletti & Starke 1999; Sportiche 1999; Di Sciullo 1990, a.o). Internal complexity is derived by the operations of the Language Faculty and is measured in terms of length of derivations. Thus, a derivation of a linguistic expression that involves fewer operations will be preferred over a more 'costly' derivation on grounds of computational efficiency. External complexity is legible at the sensori-motor (SM) interface and is calculated in terms of density of representations, which is not limited to string linear measure, but includes supra-segmental material such as stress as discussed in Di Sciullo (2005). Thus, a representation that contains less SM material will be less 'costly' on grounds of representational efficiency. The authors propose that the change in the pattern of pronominal objects from Old Romanian to Modern Romanian is the result of a bi-fold complexity reduction mechanism, namely the reduction of both I-complexity, which is basically derivational, and the reduction of E-complexity, which is basically representational. Given these assumptions, the derivation of proclitic constructions involves fewer operations than the derivation of post-verbal pronoun constructions. Thus, in a fluctuation period such as the one observed in Old Romanian, the analysis predicts that given DAP and the fact that the derivation of post-verbal clitic objects is more derivationally costly, proclisis will be preferred.

The third paper of this section "The interplay of silent nouns and reduced relatives in Malay adjectival modification", Manuel Espagnol Echevarria discusses facts from Malay and focuses on the variation in the area of adnominal adjectival modification. The author develops the idea that silent categories may also play a role in parametric variation due to their featural properties. Cinque (2010) has shown that, in spite of the great deal of variation found in adjectival modification, it is possible to identify two main classes with clear-cut syntactic and semantic properties: direct and indirect modification. Working on a restricted subset of adjectival classes, namely intersective, subsective and evaluative adjectives, the author puts forward a general proposal aiming to characterize in a precise way the syntactic distinction between these two main types of adjectival modification. The proposal crucially involves the presence of silent/overt nouns, cf. Kayne (2005), and a possessive relation in the case of direct modification, and (reduced) relatives for indirect modification. Under the set of proposals put forward in this paper, variation will mostly follow from (a) externalization, cf. Berwick and Chomsky (2011), Chomsky (2010), Richards (2008), Di Sciullo (2015), and (b) the set of silent nouns available, a "lexical parameter" of a quasi-inflectional nature, cf. Chomsky (2001).

Section 3. Language Impairments

This section assembles three papers on language impairments. The first paper considers a particular case of Specific Language Impairment, the second is on autism and the last on schizophrenia. In each case theoretical and empirical arguments as well as experimental data support the biological nature of the human Language Faculty.

The founder effect, whereby genetic drift occurs when a new population is established by a very small number of individuals, is an important source of information on genetics and phenotypic variation both in human and non-human populations. In "A study in Spanish SLI and the founder effect", Anna Gavaro and Myriam Cantú-Sánchez report an instance of the founder effect in a Pacific Spanish-speaking population associated in the genetic literature to a high incidence of Specific Language Impairment (SLI). According to Villanueva et al. (2008), the incidence of SLI in the child population of Robinson Crusoe Island, in Chile, is around 35%; that is, 5 to 7 times higher than its incidence in the continental population. This is explained as a consequence of the founder effect: 75% of the impaired subjects were descendents of two founder brothers and have been identified with a genetic abnormality with its main locus on chromosome 7q

(Villanueva et al. 2011). While the genetic profile of the population is well investigated, no detail is provided in any of the publications as to its linguistic performance. The goal of the authors is to start filling this gap and consider the linguistic performance of the current child and adolescent population. They designed and administered nine language tests to 45 children in the island, 31 descending from the original founder families, the other 14 of continental origin and with no consanguinity ties with the islanders. The overall results do not show any contrast as a function of the origin (continental vs. islander) of the subjects; they do show some age effect. At most three islander children tested may meet the criteria for a diagnosis of SLI, since they perform below their age peers in use of determiners, grammaticality judgment and/or sentence repetition. This result does not challenge the findings regarding the chromosomal abnormality affecting a sizeable proportion of the population of the island; rather it questions the relation between that affectation and a specific language impairment. This preliminary conclusion is in line with observations by Grodzinsky (2002) in connection to the KE family and the role of FoxP2.

In "Syntax and its interfaces at the low and high ends of the autism spectrum", Arhonto Terzi, Theodoros Marinis and Konstantinos Francis discuss the language abilities of individuals with Autism Spectrum Disorders (ASD/autism). Research in this field has focused until recently on pragmatics and prosody, presumably because these are the areas afflicted the most cross-linguistically in autism. Recent research, in English primarily, has also targeted morphosyntax (Roberts et al. 2004; Perovic et al. 2012, 2013). The study by Terzi et al. (2014) looked at 5–8 year old high-functioning Greek-speaking children with ASD, discovering that they fall behind their language and age matched controls with typical language development (TD) on both production and interpretation (i.e., binding) of pronominal clitics. Given the profile of ASD, and the fact that clitics: (a) are an interface phenomenon, hence, their accurate comprehension and production involves discourse/pragmatics, syntax, and prosody (Anagnostopoulou 1997; Mavrogiorgos 2010, a.o.) and (b) constitute an area of grammar known to be problematic in impaired language (e.g. Jakubovic et al. 1998; Stavrakaki & Tsimpli 1999; Chondrogianni et al. 2014 on SLI), the above finding raises several questions. What is the source of the weakness on clitics that this particular population exhibits? Can the attested behavior possibly tell us something more about clitics in grammar? The study reported here investigates the difficulties that high-functioning ASD children have with (pronominal) clitics, by testing the contribution of discourse, syntax, and intonation on producing clitics and understanding their reference. Taken together, the findings indicate that children with ASD do not differ from TD children in the comprehension and production of clitics when demands are increased within the domain of syntax, or when other criteria (such as given information) are offered by the experiment. However, ASD children are less successful than TD childrenin deciding on when to use a clitic, conceivably failing something like the *Prominence Condition* (Heim 1982). An additional difficulty they seem to have involves the prosody-syntax interface, in particular, to the processing of the prosodic cues of focused DPs, with repercussions for syntax.

In "Communication in schizophrenia, between pragmatics, cognition and social cognition", Marta Bosia, Giorgio Arcara, Mariachiara Buonocore, Margherita Bechi, Andrea Moro, Roberto Cavallaro, and Valentina Bambini point out that recent research describes language disruption in schizophrenia in terms of impairments at the pragmatic level, i.e., in the ability to match language and context. Importantly, pragmatics is acknowledged as resulting from the interplay of a number of cognitive abilities, spanning from Theory of Mind to executive functions, known to be compromised in schizophrenia. The present study aims at specifically assessing pragmatic skills with a newly developed protocol (Assessment of Pragmatic Abilities and Cognitive Substrates, APACS) on a sample of 39 patients with schizophrenia and 32 healthy controls, and to analyze relationships between communication-related skills and neuropsychological measures, especially focusing on aspects of social cognition. Patients performed significant worse than controls in all subtests, especially those assessing the comprehension of figurative language. Several cognitive and social cognition domains correlated significantly with the pragmatic tasks. Their data confirm that linguistic deficits in schizophrenia include specific pragmatic abilities that may be at the base of communicative dysfunction. Their findings also suggest that communicative behavior in patients is largely depending on cognitive and social cognition components. A deeper understanding of the interplay of the different components may thus lead to the development of new and effective therapeutic strategies.

Most of the papers assembled in this volume were selected from the conference on The Biolinguistic Investigations on the Language Faculty organized by the International Network in Biolinguistics and the NeTS Center at IUSS Pavia, and held 26–28 January 2015 in Pavia, Italy. We thank the audience of this conference for their questions and comments. We also thank the reviewers of the papers assembled in this volume, including Wolfram Hinzen, Dana Isac, James Idsardi, Dimitris Michelioudakis, Bert Vaux and Ken Wexler. We thank Brill for permission to reprint Di Sciullo and Somesfalean's paper, that appeared in a collection of papers on *Formal approaches to DPs in Old Romanian* in 2015. Finally, we thank the Biolinguistic Network and the Fonds de recherche du Quebec for providing the financial support to the Dynamic Interface Project ⟨www.intefaceasymmetry.uqam.ca⟩, ⟨www.biolinguistics.uqam.ca⟩.

References

Anagnostopoulou, E. 1997. Conditions on clitic doubling in Greek. In van Riemsdijk (ed.), 761–798.

Baker, M.C. 2008. The macroparameter in a microparametric world. In *The Limits of Syntactic Variation* [Linguistik Aktuell/Linguistics Today 132], T. Biberauer (ed.), 351–374. Amsterdam: John Benjamins. doi:10.1075/la.132.16bak

Berwick, R.C. &. Chomsky, N. 2011. The Biolinguistic Program: The current state of its development. In Di Sciullo & Boeckx (eds), 19–41.

Bhatt, R. 2007. Ergativity in the Modern Indo-Aryan languages. Handout of talk given at the MIT Ergativity Seminar. ⟨http://people.umass.edu/bhatt/papers/mit-nov2007-handout.pdf⟩

Bittner, M. & Hale, K. 1996. Ergativity: Towards a theory of a heterogeneous class. *Linguistic Inquiry* 27: 531–604.

Bolhuis, J.J., Tattersall, I., Chomsky, N. & Berwick, R.C. 2014. How could language have evolved? *PLoS Biology* 12(8): e1001934. doi:10.1371/journal.pbio.1001934

Cardinaletti, A. & Starke, M. 1999. The typology of structural deficiency: A case study of the three classes of pronouns. In *Clitics in the languages of Europe*, van Riemsdijk (ed.), 145–235. Berlin/New York: Mouton de Gruyter.

Cinque, G. 2010. *The Syntax of Adjectives*. Cambridge MA: The MIT Press. doi:10.7551/mitpress/9780262014168.001.0001

Chomsky, N. 1993. A minimalist program for linguistic theory. In *The View from Building 20: Essays in Linguistics in Honor of Sylvain Bromberger* [Current Studies in Linguistics 24], K. Hale & S.J. Keyser (eds), 1–52. Cambridge MA: The MIT Press. Reprinted in Chomsky, N. 1995. *The Minimalist Program* [Current Studies in Linguistics 28], 167–217. Cambridge MA: The MIT Press.

Chomsky, N. 2001. Derivation by phase. In *Ken Hale: A Life in Language,* M. Kenstowicz (ed.), 1–52. Cambridge MA: The MIT Press.

Chomsky, N. 2005. Three factor in language design. *Linguistic Inquiry* 36: 1–22. doi:10.1162/0024389052993655

Chomsky, N. 2007a. Approaching UG from below. In *Interface+recursion=language?*, U. Sauerland & H.-M. Gartner (eds), 1–29. Berlin: Mouton de Gruyter.

Chomsky, N. 2007b. Of mind and language. *Biolinguistics* 1: 9–27.

Chomsky, N. 2008. The biolinguistic program: Where does it stand today? Ms, MIT.

Chomsky, N. 2010. Poverty of stimulus: Unfinished business. In *Universals and Variation: Proceedings of GLOW in Asia VIII 2010,* M. Gao (ed.), 1–17. Beijing: Beijing Language and Culture University Press.

Chomsky, N. 2013. Problems of projections. *Lingua* 130: 33–49. doi:10.1016/j.lingua.2012.12.003

Chomsky, N. 2014. The Biology of Language. Royal Dutch Academy of Sciences (KNAW), Amsterdam. ⟨https://www.youtube.com/watch?v=H-fRSrfr2L0⟩

Chondrogianni, V., Marinis, T., Edwards, T. & Blom, E. (2014). Production and on-line comprehension of definite articles and clitic pronouns by Greek sequential bilingual children and monolingual children with Specific Language Impairment. *Applied Psycholinguistics* 36(5): 1155–1191. doi:10.1017/S0142716414000101

Di Sciullo, A.M. 1990. Sur la Définition des Variables. In *Binding in Romance. Canadian Journal of Linguistics*, A.M. Di Sciullo & A. Rochette (eds), 19–41. Cambridge University Press.

Di Sciullo, A.M. 2005. *Asymmetry in Morphology*. Cambridge MA: The MIT Press.

Di Sciullo, A.M. 2011. A biolinguistic approach to variation. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 305–328. Oxford: OUP.

Di Sciullo, A.M. 2012. Perspectives on morphological complexity. In *Morphology. (Ir)regularity, Frequency, Typology,* F. Kiefer, M. Ladanyi & P. Siptar (eds), 105–135. Amsterdam: John Benjamins. doi:10.1075/cilt.322.06sci

Di Sciullo, A.M. 2015. On the domain specificity of the human language faculty and the effects of principles of computational efficiency: Contrasting human language and mathematics. *Revista Linguistica* 11(1): 28–56.

Fodor, J.A. 1983. *The Modularity of Mind. An Essay on Faculty Psychology.* Cambridge MA: The MIT Press.

Gallistel, C.R. & King, A.P. 2009. *Memory and the Computational Brain: Why Cognitive Science Will Transform Neuroscience*. Chichester: Wiley-Blackwell.

Grodzinsky, Y. 2002. Neurolinguistics and neuroimaging: Forward to the future, or is it back? *Psychological Science* 13(4): 388–393. doi:10.1111/j.0956-7976.2002.00470.x

Hauser, M.D., Yang, C., Berwick, R.C., Tattersall, I., Ryan, M.J., Watumull, J., Chomsky, N. & Lewontin, R.C. 2014. The mystery of language evolution. *Frontiers in Psychology* 5(1): 401.

Heim, I. 1982. The Semantics of Definite and Indefinite Noun Phrases. Ph.D. dissertation, MIT.

Jakubovic, C., Nash, L., Rigaut, C. & Gérard, C.-L. 1998. Determiners and clitics pronouns in French-speaking children with SLI. *Language Acquisition* 7: 113–160. doi:10.1207/s15327817la0702-4_3

Hinzen, W. 2014. What is un-Cartesisian linguisitics? *Biolinguistics* 8: 226–257.

Hornstein, N. & Pietroski, P. 2009. Basic operations: Minimal syntax-semantics. *Catalan Journal of Linguistics* 8: 113–139.

Kayne, R. 2005. *Movement and Silence*. Oxford: OUP. doi:10.1093/acprof:oso/9780195179163.001.0001

Kayne, R. 2005. Some notes on comparative syntax, with special reference to English and French. In *The Oxford Handbook of Comparative Syntax,* G. Cinque & R. Kayne (eds), 3–69. Oxford: OUP.

Kayne, R. 1991. Romance clitics, verb movement, and PRO. *Linguistic Inquiry* 22: 647–686.

Kayne, R. 1994. *The Antisymmetry of Syntax*. Cambridge MA: The MIT Press.

Legate, Julie. 2012. Types of ergativity. *Lingua* 122: 181–191. doi:10.1016/j.lingua.2011.10.014

Mesgarani, N., Cheung, C., Johnson, K. & Chang, E.F. 2014. Phonetic feature encoding in human superior temporal gyrus. *Science* 343(6174): 1006–1010. doi:10.1126/science.1245994

Mavrogiorgos, M. 2010. *Clitics in Greek: A Minimalist Account of Proclisis and Enclisis* [Linguistik Aktuell/Linguistics Today 160]. Amsterdam: John Benjamins. doi:10.1075/la.160

Palmer, R. 2009. Animal asymmetry. *Current Biology* 19(12): 473–477. doi:10.1016/j.cub.2009.04.006

Palmer, R. 2004. Symmetry breaking and the evolution of development. *Science* 306: 828–833. doi:10.1126/science.1103707

Poeppel, D. 2012. The maps problem and the mapping problem: Two challenges for a cognitive neuroscience of speech and language. *Cognitive Neuropsychology* 29(1–2), 34–55. doi:10.1080/02643294.2012.710600

Richards, M. 2008. Two kinds of variation in a minimalist system. In *Linguistische arbeitsberichte* 87, F. Heck, G. Müller & J. Trommer (eds), 133–162. Leipzig: University of Leipzig.

Roberts, J.A., Rice, M.L. & Tager-Flusberg, H. 2004. Tense marking in Children with autism. *Applied Psycholinguistics* 25: 429–448. doi:10.1017.S0142716404001201 van Riemsdijk, Henk (ed.). 1999. *Clitics in the Languages of Europe.* Berlin: Mouton de Gruyter.

Stavrakaki, S. & Tsimpli, I.M. 2000. Diagnostic verbal IQ test for Greek preschool and school age children: Standardization, statistical analysis, psychometric properties. In *Proceedings of the 8th Symposium of the Panhellenic Association of Logopedists,* 95–106. Athens: Ellinika Grammata.

Sportiche, D. 1999. Pronominal clitic dependencies. In van Riemsdijk (ed.), 679–708.

Terzi, A., Marinis, T. Kotsopoulou, A. & Francis, K. 2014. Grammatical abilities of Greek-speaking children with autism. *Language Acquisition* 21: 4–44. doi:10.1080/10489223.2013.855216

Uriagereka, J. 1995. Aspects of the syntax of clitic placement in Western Romance. *Linguistic Inquiry* 26: 79–123.

Villanueva P., De Barbieri, Z., Palomino, H.L. &. Palomino, H. 2008. High prevalence of specific language impairment in Robinson Crusoe Island. A possible founder effect. *Revista Médica de Chile* 136: 186–192

Villanueva, P., Newbury, D., Jara, L., De Barbieri, Z., Mirza, G., Palomino, H.M., Fernández, M.A., Cazier, J.B., Monaco, A.M., & Palomino, H. 2011. Genome-wide analysis of genetic susceptibility to language impairment in an isolated Chilean population. *European Journal of Human Genetics* 19(6): 687–695. doi:10.1038/ejhg.2010.251

SECTION 1

Language Faculty

The biolinguistics program

Questions and hypotheses

Anna Maria Di Sciullo & Calixto Aguero-Bautista
Université du Québec à Montréal / Université du Québec à Trois-Rivières

The Biolinguistics Program is an emergent interdisciplinary field encompassing natural sciences, neurosciences and the humanities. Its core object of inquiry is human language. The overarching questions it raises are the following: what is language and what is the relation between language and biology. The central hypothesis it brings to the fore is that human language has a biological basis as well as unique traits that make language unique in the biological world. This paper details some of the specific questions and the hypotheses that have been formulated in this field, and it considers recent works on the intersection of language and biology. We start by stating the rationale for Biolinguistics. We then identify the questions and hypotheses raised by this field. Finally, we consider works that aim to bridge the explanatory gap between language and biology while preserving the unique properties of language.

1. The rationale for Biolinguistics

The biolinguistic approach to human language started to crystallize at the epicenter of the cognitive revolution that took place in the second half of the XX century, which, arguably, had a precedent in the great intellectual revolution of the XVII century. The approach emerged out of significant academic discussions among the members of a group of scholars carrying out interdisciplinary research in Cambridge, USA. Important figures of the biolinguistic movement in its early stage include Noam Chomsky, Morris Halle, Eric Lenneberg, and George Miller, among others (Piattelli-Palmarini 1980). This group of scholars sought to provide rational explanations to certain classical questions central to the study of language and mind that, despite beeing considered for centuries, had not been answered satisfactorily. We intend *satisfactory* in this context to mean *explanatory*. That is, we take the position already present at the time of the Port Royal Grammar, and so eloquently advocated much later in generative theories of grammar, that an answer to a linguistic question should not amount to a mere description of the

DOI 10.1075/la.235.01sci

data but should also provide rational explanations as to why the data should show the particular traits they do. In this regard, the achievement of explanatory power by theories concerned with the fundamental questions of linguistics (or any other science for that matter) becomes a kind of litmus test for measuring and evaluating the competing theories of the various phenomena under scrutiny.

The pursuit of linguistic theory with the goal of explanatory power in mind imposes upon researchers a basic research agenda concerned with the questions of the nature, origin and use of language. The fundamental aspect of these questions is perhaps demonstrated by the fact that the same set of research topics is found on a recurrent basis throughout the history of linguistic thought. In that history, however, although numerous attempts had been made to search for satisfactory answers to those fundamental questions, it was only with the emergence of the biolinguistic perspective that these questions began to be pursued with some considerable depth. It was also with the advent of Biolinguistics that the goal of achieving the power of theoretical explanations in linguistics became a realistic one. Biolinguistics seeks to provide biologically grounded explanations to the properties of language, and especially to those properties that are specific to the human species. To understand the biological basis of language is to understand the innateness of language, a topic right at the crossroads of linguistics and the natural sciences. Perhaps the limited advances of the traditional linguistic theorizing that predated the biolinguistic approach, in terms of its explanatory scope, has much to do with the fact that if one is to provide rational explanations for even the most basic facts of language, the questions in (1) become a necessary part of the linguistic research agenda.

(1) A: What is the nature and structure of the biological capacity that allows humans to acquire any natural language?
B: How did the capacity develop in phylogeny?
C: How does the capacity develop in ontogeny?

But the investigation of these questions before the advent of biolinguistics might have been a premature enterprise, given that the methodological conditions that were necessary for even formulating the questions in a sensible manner were not in place before the 1940s. The required conditions, made possible by a series of key developments in several areas of science (e.g. mathematics, the theory of computation, and biology), appear to have been in place by the 1950s. In particular, the combination of traditional Darwinian evolution with ulterior discoveries in classical and molecular genetics in the so-called *modern evolutionary synthesis* allowed the questions in the traditional research core, alluded to above, to be reinterpreted as the problem of finding explanatory answers for the questions in (1). As Chomsky (2007) puts it, the traditional linguistic concerns got reinterpreted as "the problem of discovering the genetic endowment that underlies the acquisition and use of language." It is this reinterpretation that is taken to have launched the biolinguistic agenda, a research program that has as its goal the interdisciplinary investigation of the questions in (1). As is often the case in the initial stages of scientific research, the questions in (1) are formulated at a very general level and touch upon issues clearly pertaining to different scientific domains or disciplines (e.g., biology, linguistics, mathematics).

The interdisciplinary investigation of these questions is necessary, although pursuing the same object through different avenues of research and methodology raises the question of whether the results obtained collectively in the different disciplines will ever be unified. This is what is often called the *unification problem*, Jenkins (2000). The path to unification can only come out from the interdisciplinary discussion of the results obtained in the various domains. And the requirement that the independent results of the different interacting disciplines in Biolinguistics be consistent with the fundamental facts of language can go a long way, we believe, in preventing irreducible divergence among such disciplines, see Di Sciullo et al. (2010).

Researchers in the biolinguistic framework have in fact identified a fact of language that is accepted, consensually, as an established fact across the various interacting disciplines. The fact in question is the generalization that human infants, as opposed to the infants of any other species, can acquire any human language without explicit instructions. All that is required for language acquisition to be successful in human infants is that they be exposed to the linguistic data found in the day-to-day interaction among the members of the speech community in which the child grows. By contrast, a pet chimpanzee, for instance (or any other animal for that matter), if exposed to the same linguistic data under the same conditions will not be able to acquire the natural language of the speech community in which the animal grows. A hypothesis consistent with this observation and which can be investigated independently in the domains of linguistics and biology is that there is a biological capacity that is present in humans but absent in chimpanzees, call it the Capacity of Human Biology (C_{HB}), that is responsible for channeling and making possible the acquisition of a natural language on the basis of interaction with experience. At this point we should note that the interesting questions in a biolinguistic agenda (e.g., the questions in (1)) always presuppose the existence of C_{HB}.

We noted above that the questions in (1) are of a very general character. We must say, however, that these questions have become more specific as they have been pursued at the different levels of abstractions imposed by the methods of the various disciplines informing the biolinguistic framework. Thus, the biolinguistic agenda has been extended with newer and sharper questions. For instance, the question of the nature and structure of the biological capacity C_{HB} in (1A) is often decomposed into the questions below.

(2) A. What are the properties of C_{HB}?
B. What are the necessary components of C_{HB}?
C. What are the components of C_{HB} that are uniquely human?
D. Do humans share any of these components with other biological beings?
E. Are any of these components uniquely adapted to the demands of language?

Similarly, the questions in (1B–C) have been decomposed into the more specific questions in (3).

(3) A. How did C_{HB} evolve?
B. Was C_{HB} the result of an evolutionary leap?
C. Was it shaped gradually by natural selection?
D. How is C_{HB} genetically encoded?
E. How does C_{HB} grow by interacting with epigenetic and environmental factors (i.e. experience)?

In keeping with the guiding principle in science requiring that the answers to the fundamental questions raised in a given domain be consistent with the obvious facts of the phenomenon under scrutiny, in the given domain, researchers in biolinguistics have sought to find answers and develop hypotheses that are consistent with the most mundane and basic facts of both language and biology. For instance, in answering the questions in (2A–B), biolinguists have started by adopting the hypothesis that C_{HB} is a faculty of language just like the faculty of vision or of hearing. This hypothesis is consistent with a whole array of factual truths in biology, including the fact that human offspring inherit the capacity to acquire language.

Once the consistency of the hypothesis postulating C_{HB} with such biological facts is verified, there are two other mundane facts of language that have been used as guiding points for developing tentative answers for the questions in (2A–B). The first relevant fact is that the mechanism generating linguistic expressions has the property of discrete infinity. What this means is that any sentence can be extended infinitely by adding a discrete linguistic unit to the given sentence. Systems capable of yielding the property of discrete infinity are known to be computational systems. This state of affairs has led to the hypothesis that at least one of the components of the faculty of language is a computational system.

The other relevant fact is that linguistic expressions are externalized by way of sounds or signs and are interpreted by whatever components of the mind interprets the meaning of expressions. The externalization system has been called the sensori-motor (SM) system. The interpretation system is referred to as the conceptual-intentional (CI) system. A plausible hypothesis in Biolinguistics has been that these two components, together with the computational system mentioned above, constitute the components of the faculty of language. More recently, however, a distinction has been made between the computational system, on the one hand, and the conglomerate of the three components. Hauser, Chomsky and Fitch (2002) call the computational system the faculty of language in a narrow sense (FLN). These authors refer to the combination of the computational system with the SM and CI systems as the faculty of language in a broad sense (FLB). We adopt their terminology here.

With these distinctions in place, the core content of the biolinguistic agenda becomes the set of questions in (4) which we obtain by replacing C_{HB} in (2)–(3) by either the concept FLB or that of FLN or both, depending on what is applicable.

(4)
A. What are the properties of the FLN/FLB?
B. What are the necessary components of the FLB?
C. What are the components of the FLB that are uniquely human?
D. Do humans share any of the components of the FLB with other biological beings?
E. Are any of the components of the FLB uniquely adapted to the demands of language?
F. How did the FLN/FLB evolve?
G. Was the FLN/FLB the result of an evolutionary leap?
H. Was it shaped gradually by natural selection?
I. How is the FLN/FLB genetically encoded?
J. How does the FLN/FLB grow by interacting with epigenetic and environmental factors (i.e. experience)?

The questions in (4), which span the different areas of research currently being pursued in the biolinguistic agenda, are a testimony to the necessarily multidisciplinary nature of research in Biolinguistics. As we mentioned above, the need of such an interdisciplinary research comes from the fact that many interesting linguistic questions cannot be investigated in depth unless they are reformulated within the various interacting disciplines by abstracting away from those things that are not relevant within the confines of the particular domains. It is difficult to see how a biologist can investigate the evolution of the faculty of language while being agnostic as to the properties of that faculty. This is revealed by the work that the linguist has produced albeit by use of procedures that are very different from those used in the biological domain. Thus, there must be a division of labor among the interacting domains in the field of Biolinguistics. In exploring the nature of the FLB, linguists should provide the linguistically relevant evidence, whereas geneticists, evolutionists, neurologists, etc., should produce the evidence relevant to their specific domains in ways that are consistent with the undeniable facts of language.

It is because of the interdisciplinary and complementary nature of the biolinguistic agenda, as well as the need for a division of labor among the various scientific domains constituting this multidisciplinary field, that this essay groups current contemporary research in biolinguistics into three related research areas, each dealing with important topics of biolinguistics. The first area mainly addresses the question of the evolution of language. The second area addresses the properties of the FLN and the FLB, as well as their relations from a formal linguistic perspective. Finally, research in the third area is concerned with questions of methodology in Biolinguistics and the search for potential homologues and/or analogues for the different components of the FLB among other species of organisms. This last area advocates a comparative approach to research in biolinguistics and deals, therefore, even if indirectly, with questions pertaining to the unification problem. The following sections outline the scope of these three important research areas.

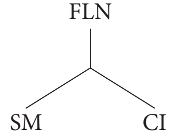
2. Evolution of language

The question of the origin of language is as much a question of linguistics as a question of biology. From the biological point of view, perhaps the most salient feature of human language is how isolated it seems to be in the biological world: the fundamental properties of human language seem to be missing in all the other species, including our evolutionarily close primate cousins. This much was recognized since the first classic works on language and has been emphasized by Descartes and Chomsky, respectively working within the cognitive revolution of the XVII century and the so-called second cognitive revolution of the 1950's. Today, given the advances in linguistics and biology, scientific discussion on the origin of language needs to be framed in an evolutionary perspective. This question is a difficult one, however, and although Darwin himself considered it to some extent, in his *Origin of Species* and *Descent of Man*, we must point out that, as noted by Chomsky on several of his lectures on Biolinguistics, Alfred Russel Wallace, the co-founder of the theory of evolution, and who considered the question of the origin of language in greater detail, already concluded that language and other cognitive traits of the human species (e.g., the capacity for mathematics) could not be accounted for by the theory of natural selection in any known possible way. Some modern scholars, however, do try to account for certain properties of language in terms of natural selection. Thus, Pinker and Bloom (1990) lay out the argument that the human capacity for language is an adaptation that has been shaped by natural selection for the purpose of communication. This position, which underlies several works on the evolution of language, came as a response to the mainstream position in linguistics, which holds the view that the relevant facts of language and biology seems to suggest that the former is probably an exaptation rather than an adaptation.

Chomsky's (1988) writes: "Evolutionary theory is informative about many things, but it has little to say, as of now, of questions of this nature [the evolution of language]… in the case of such systems as language or wings it is not easy even to imagine a course of selection that might have given rise to them" (Chomsky 1988: 167). This emergent view of the origins language is at the core of modern Biolinguistics and of the works on the biology of language deriving from the Minimalist Program (Chomsky 1995, and seq.). This research programs seeks to achieve greater explanatory adequacy by getting rid of unnecessary theoretical apparatus (operations, constraints, categories, etc.). As linguistic theory progresses, this methodological reduction is expected in light of the principle of theoretical economy (parsimony), the standard methodological constraint guiding the normal development of scientific progress. By Occam's razor, the classic rendition of this very principle, if two theories are empirically coextensive – that is, if they achieve the same empirical coverage – the theoretically simpler theory is selected by theoretical economy over the theoretically more complex one. The Minimalist Program is consistent with the emergent view of the origin of language. If language emerged recently in history, perhaps about 50–100,000 years ago, and if it remains isolated in the biological world in the face of new evidence, it will be difficult to attribute its emergence to an evolutionary adaptation.

The question then is what part of language if any have homologues among the other living organisms. Several works point to evidence showing that aspects of semantic and general reasoning systems as well as aspects of the sound system are already in place in non-human primates and other species, including songbirds. Thematic agent-patient relations, the ability to count small numbers and to perform elementary arithmetic operations have been observed in monkeys (Hauser 2000; Hauser, MacNeilage & Ware's 1996, a.o.) as well as in pigeons (Rugani et al. 2009, 2011). In contrast, the ability for discrete infinity, or the ability to compute complex vocalic or gestural expressions based on complex syntactic form, such as multiple center embedding, has not been observed elsewhere in the animal kingdom.[1] Assuming the Minimalist architecture of the Language Faculty (5), where the faculty of language in the narrow sense, narrow syntax, (FLN) feeds the semantic and the sensorimotor systems, thus forming the faculty of language in the broad sense (FLB), the origin and the evolution of language can be approached in architectural terms.

(5)



1. Quite limited instances are present in the song of Bengalese finches. See work by Michale Fee and Kazuo Okanoya in Bolhuis & Everaert (2013).

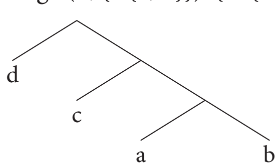
For example, Hauser, Chomsky and Fitch (2002) proposed that of the components of the FLB, only the FLN (i.e., narrow syntax) is hypothesized to be unique to the human specie. Berwick (2011), building upon the same point, points out that the uniquely human aspects of language (i.e., those features of language without apparent correlates in the biological world) present a problem for an evolutionary theory based on the assumption that the evolution of language has proceeded on the basis of a continuous, adaptive process. In biology, uniqueness of a feature signals the occurrence of a discontinuous event. Since adaptation works on a continuous evolutionary process, it is difficult to see how such a procedure could shape those aspects of language that are unique to the human specie. Berwick considers how to resolve the discontinuity problem arguing that the "micromutational adaptationist" view adopted in the modern synthesis theory of evolution needs not hold.

The strongest argument for an adaptive theory of language comes from the so-called argument from design. If natural selection is the only procedure that can shape complex derived structures, proponents of the argument would argue, then, that the complexity of language requires the works of that procedure. Borrowing an argument from Hauser, Chomsky, and Fitch, Berwick essentially argues that if the FLN, i.e., the uniquely human aspects of language, consists of a single structure building operation, i.e. the operation Merge in (6), with many cascading effects, then the argument from design disappears. From Berwick's perspective, the only thing that needs to be explained is the origin of the single operation merge, which remains as a discontinuous trait that, although not amenable to adaptive theory, could be explained by alternative deductive systems of regulatory interactions. As defined in Chomsky (2001) Merge takes two syntactic objects a and b, (a, b) and forms a set consisting of a and b, {a, b}. Merge reapplies to its own output. In (7), we provide a step-by-step derivation of the structure consisting of the objects a, b, c, and d, and in (8) we present the result of the derivation in the form a binary branching oriented graph. The formal properties of Merge do not follow from an adaptive theory of the origin of language. They do find an explanation in a constrained deductive system where syntactic objects are combined on the basis of conceptual necessity and elegance to derive the discrete infinity of language.

(6) Merge (a, b): {a, b}

(7) Merge (c, {a, b}): { c{a, b}}
Merge (d, { c{a, b}}): { d { c{a, b}}}

(8)



The operation Merge is binary and recursive. That is, it applies to two objects and derives a set formed by the two primary objects, without altering their form. By definition, a binary operation cannot apply to a number of objects n, if n is greater than two. It follows then that Merge may not apply to three objects at once, although it could apply in order to merge two of the objects first, and then apply again to merge the remaining object to the complex object derived by the application of the operation to the first two objects. The new object that is created inherits its main properties from one of the two primary objects. Binary merger can apply to its own output, thus combining previously derived structures, or part thereof, viz., roots or dependents, mother or sister nodes, to other objects. Recursive Merge derives hierarchical structures, the structural properties of which are the main ingredients of linguistic phenomena.

Defined as such, Merge finds no equivalent in biology. An example that comes to mind is the process of cell division in morphogenesis. Cell movement and division is recursive. However, the cell division operation, although recursive, cannot be equated with Merge. For one thing, Merge applies to two objects and yields one (a derived object). Cell division, on the other hand, is a unary operation that applies to one object and yields two. One may wonder if cell division could not be conceived as the homologue of a mirror image of the operation Merge, we might call it Branch, starting with a sentential node as the relevant syntactic object, and then proceeding to branch or split that node into two. Subsequent application Branch to its own output will mimic the recursive property of both Merge and cell division.[2] Like cell division, such a branching operation would be unary and would output two objects from the single one in its domain, but there would still be differences between such an operation and cell division. Daughter nodes, whether derived by Merge or by Brach, are distinct from mother nodes and are actually a part of them, but there is no clear sense in which a new cell could be considered to be a part of its mother cell and different from it. In other words, the structure created by Merge in human language is cumulative, but this is not the case in cell division, and this is probably because such notions as roots and dependents, mother and sister nodes are irrelevant in morphogenesis. This is also the case, needless to say, for more complex relations, such as sister containment, which is central in linguistic agreement and movement phenomena. Moreover,

2. Richards (2002) argues that by adopting the operation he calls *sinking*, which is identical to the operation we call Branch here, it is possible to generate syntactic structure in a top-down fashion that besides being recursive like Merge, can help syntactic theory get rid of many conflicts in its set of tests for syntactic constituencies. What is relevant for the present purpose is that *sinking* would be easier to conceive as a homologue of the cell-division operation, although important differences would remain as discussed in the text above.

Merge is a binary set that is of the same category as one of the two merged elements. This tells it even more apart from cell division.

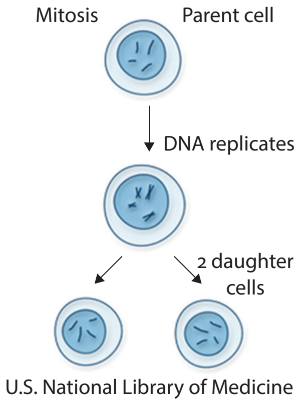
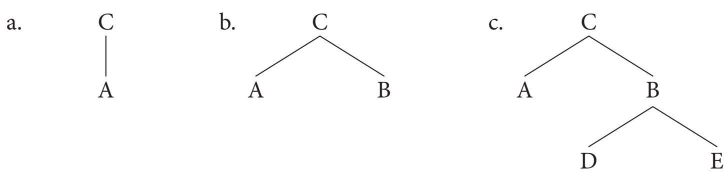


Figure 1. Cell division

As mentioned before, if the Language Faculty consists of only the operation Merge, as proposed by Hauser et al. (2002), the argument for and adaptation theory of its origin loses ground unless it can be shown that the operation Merge itself is complex, and hence derived from more primitive stages. It is, however, difficult to find evidence that Merge must have evolved from a more primitive stage, for example, from a stage where only the dominance relation would be generated, (8a), to a state where only the sisterhood relation would be generated, (8b), to a latter stage where the sister-containment, (9c), would be generated. In fact there is no evidence that Merge would have adapted as a response to selective pressures in a continuous evolutionary process.[3]

(8)



3. Hauser et al. (2014) discuss four approaches to the evolution of language: comparative animal behavior, paleontology and archeology, molecular biology and mathematical modeling. The paper considers, in each case, that the evidence brought forward is inconclusive and irrelevant. It concludes that little progress has been achieved in that field and the evolution of language is still a mystery.

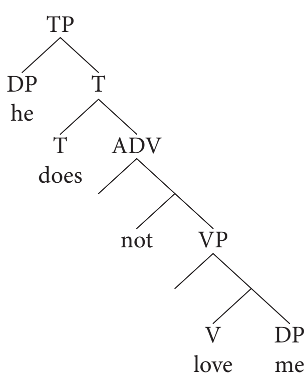
Research in the interdisciplinary field of Biolinguistics can benefit a great deal from the search of homologues of the different components of the FLB in other living organisms in the way just sketched above, and by maintaining researchers in each of the interacting disciplines abreast of the latest findings in each of the fields, with an eye for finding inspiration for the application of such novel findings to the solutions of traditional and emergent problems. As pointed out by several scholars, solutions to such persistent problems might lie within the data uncovered by collaborative research. This point has been emphasized by some of the leading researchers in the field. Thus, Berwick and Chomsky (2011), consider how research can be informed by development in evo-devo biology as well as the framework provided by the Minimalist Program, arguing that if human language is driven by a single recursive, structure-building operation, a conclusion that seems supported by the available evidence, then it is possible to explore the question of how an account of the recent and saltational emergence of the FLN profits from an examination of the ongoing revision of evolutionary explanation in light of new research on evo-devo biology, which highlights the possibility of relatively rapid shifts in an organism's biology given minor variation. Boeckx (2011) makes a similar point, drawing a parallelism between the problem of explaining how language (i.e., the FLN) originated in humans, and the problem of explaining how language growth is possible in ontogeny.

The search for illumination and inspiration from novel research in the different collaborating fields of Biolinguistics is already bearing fruits. Recent findings in biology and in linguistics reinforce the general approach of D'Arcy Thompson and Alan Turing on the principles that constrain the diversity of organisms in the natural world in parallel ways. Language and living organisms are systems that can similarly be studied at different levels of abstraction. On the one hand, both languages and living organisms can be studied individually (at the level of the species) or collectively (at the level of the phylum), and much can be learned from exchanging information gathered while researching these two analogous domains in such a manner. Perhaps the best example of this comes from consideration of a central question of both linguistics and biology and how the particular question has been approached in both domains. The relevant question is how to best capture the relation between the universal properties of the organisms (languages or living beings) and the apparently great variation found among them. Research within the evo-devo revolution showed around the beginning of the '80s that variations could be restricted greatly and in predictable ways with the work of very small mechanisms that guided the attested variation depending on a very small number of states that such devices could assume. Adoption of such a position in linguistics around the same time resulted in the Principles and Parameters model (henceforth P&P) (Chomsky 1981, 1986), where variation is the effect of choices or parameters left open in the instantiation of principles of Universal grammar during language growth (Chomsky 1995, et seq.), much in the same way that regulatory mechanisms direct the superficial variations in biology in predictable ways. Although all languages share some universal properties, by virtue of being the results of the same set of universal principles, the P&P approach builds variation in word order in possible differences in the states of parameters associated with the feature system of the different languages, which differ with respect to the choice of the unvalued syntactic features associated with functional categories. Thus, according to the Minimalist Program, language variation is a consequence of feature valuation, which is a consequence of Merge. A minimal difference in the valued or unvalued states of a feature may give rise to language diversity at the micro-parametric level. We can illustrate this, for example, with a concrete example concerning the different position of negation in English and French. Sentential negation precedes the verb in English, while it follows it in French, as shown below.

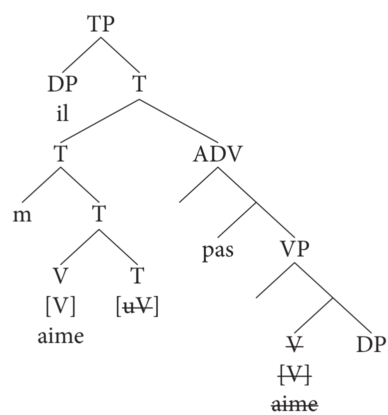
(9) a. He doesn't love me.
b. Il m' aime pas. (Fr)
He me loves not
'He does not love me.'

This variation follows from a minimal difference in the value of the V feature of T. In French, the unvalued V feature of T, [uV], attracts to a higher position than negation, (10b). In contrast, in Modern English, V is valued, and thus it does not attract the verb to a higher position than T, (10a). This parametric feature was however available in Old English, as attested in Shakespearean English, (11).

(10) a.



b.



(11) Some heavy business hath my lord in hand, And I must know it, else he loves me not. (Lady Percy, Act II, Scene III of King Henry IV)

Word order variation, for example the position of the verb with respect to a negative adverb, as well as the position of a nominal complement (DP) with respect to its prepositional (P) head thus follows from a minimal difference in the abstract feature specifications of functional categories, such as T and P. This abstract approach to variation is elegant and does not require an adaptive theory of language variation. Minimalism has been designed to account for such variations, while being entirely consistent with a saltational view of the emergence of language. Moreover, as Di Sciullo (2011, 2012) suggests, there is a homology between the phylogenetic variation observed in language and that observed in the form of bi-partite organisms in evo-devo (Lewontin 2004; Palmer 1996, 2004, 2009), whereby a stage of fluctuating symmetry, where one or the other side of the organism may be prominent, shifts to a stage where only one is. The variation in the position of the verb with respect to negation in Old and in Modern English, as well as the variation of the position of the nominal complement with respect to its prepositional head in the evolution of Indo-European language, and the existence of intermediate fluctuating stages can be seen as being subject to the same symmetry breaking natural law (see also Li & Bowerman (2010) for the role of symmetry and symmetry breaking in biology). Thus, what emerges is a set of principles that constrain the diversity of language and other biological organisms.

The saltational emergence of the FLN contrasts with the gradualist, adaptationist approach to the evolution of syntax. In the adaptationist approach, assumed for example in Bickerton (1990), the evolution of language follows a linear path: the pre-syntactic (one-word) stage precedes the proto-syntax (two-word) stage and this, in turn, precedes the stage called modern syntax. The proto-language, in this conception of the evolution of syntax in ontogeny, is an intermediate step in language development, possibly associated with the two-word phase. However, the notion of "proto-language" is unclear, and different views are available in the literature. According to Jackendoff (2011) "A protolanguage has phonology, but it has little or no constituent structure, no recursion, no subordination, and no functional categories. […] Progovac (2006, 2007) explores this position further, arguing that proto-grammar survives inside and underneath full modern grammars." (ibid, pg. 614–615). Progovac (2015) pursues an internal reconstruction of the stages of grammar based on 'living fossils', such as exocentric VN compounds drawn from English, e.g. *dare-devil*. She argues that these fossil structures do not just coexist alongside more modern structures, but are in fact built into more complex structures, and are suggestive of a gradualist evolutionary scenario. From a Minimalist perspective however, the hypothesis that there would be a proto-language preceding Language, a proto-Merge preceding Merge, is not a viable one, given the principle of theoretical economy referred to above. In the case at hand, the hypothesis that language emerged as a result of an evolutionary event and that the Language Faculty consists of the unique operation Merge, is simpler than the one positing the existence of proto-Merge, together with Merge. This second theory uses an extra theoretical device; hence the first theory is preferable in light of theoretical economy. Besides this theoretical argument, there is no convincing empirical evidence in favor of proto-Merge, as the analysis of apparently simple structures, such as VN exocentric compounds in English and in other language already have a complex internal structure, hence such a structure is presumably derived, as shown by Di Sciullo (2013), and further discussed in Nobrega and Miyagawa (2015). Di Sciullo (2013) provided evidence that the internal structure of VN exocentric compounds is asymmetrical. The verb bares inflectional features that are validated in a phrasal domain (CP). The internal structure of these compound is that of a relative clause, where the V is structurally prominent (asymmetrically c-commands) with respect to N nominal complement, in cases such as *dare devil*, and the subject is structurally prominent with respect to the verb in cases such as *cry-baby*. Further evidence from similar structures in the Romance languages, such as *crève-faim* and *crève-la-faim* (Fr), *morto-di-fame* (It) (dead of hunger, 'down-and-out') show overt phrasal constituents (DP), other exocentric compounds include ADVP, AP and PP adjuncts. These facts bring support in favor of a hierarchical structure and against a flat structure for exocentric compounds. Furthermore, they show that no notion of 'living fossil' of proto-language can be based on VN exocentric compounds. Nobrega and Miyagawa (2015) endorse this phrasal analysis and argue further for the precedence of syntax in the emergence of human language.

Phylogenetic evidence indicates that contrary to what is implicitly assumed in the works on evolution of language, including Bickerton (1990), Jackendoff (2011), as well as Hurford (2014), language does not necessarily evolve from more simple stages to more complex ones. This can be seen, for example, by focusing on the phylogeny of a syntactic constituent such as the prepositional phrase (PP). Di Sciullo et al. (2013) provide extensive evidence from the phylogeny of several Indo European languages, showing that while complexity may arise in the structure of PPs, for example by the emergence of postpositions, adpositions or circumpositions, in addition to prepositions, such complexity is normally reduced in the evolution of a language. This is also true of the type of linguistic complexity introduced by language acquisition and languages in contact. We illustrate this below for Italian, similar facts are observed in English and other languages. Thus, while Latin is strongly prepositional, the comitative preposition (cum, con, co) generally precedes its complement, but may also follow it. In Old Italian (13th and 14th centuries) a reduplicated form of the comitative P may also be found in the prepositional phrase. Modern Italian however, is prepositional:

Old Italian (13th, 14th c)

(12) a. …. e per li compagnoni che **teco** fuggiro, per li dei… (Brunetto, Rettorica)
'and for the friends who escaped **with you**, for the gods…'

b. E altre donne, che si fuoro accorte di me per quella che **meco** piangia, fecer lei partir via… (Dante, Vita Nuova)
'And her beauty is so virtuous that there is no envy from the others, she made them go **with her**, with [lit. dressed of] kindness, love and faith.'

c. neiente de lo mondo ; **con te** le tue, parole voria **conte** avere… (Rinuccino, Sonetti)
'And close by came a cavalier against her, very large, deformed and terrible to the sight, well armed with black weapons, on a very large horse; and he had **with him** so many people who were covering the entire field.'

d. Ballata, i' voi che tu ritrovi Amore, e **con lui** vade a madonna davante, sì che la scusa mia, la qual tu cante, ragioni poi **con lei** lo mio segnore. (Dante, Vita Nuova)
'Ballata, I want you to find love again, and **with him** go to see the madonna in front, so that my excuse, which you sing, you reason **with her** my lord'

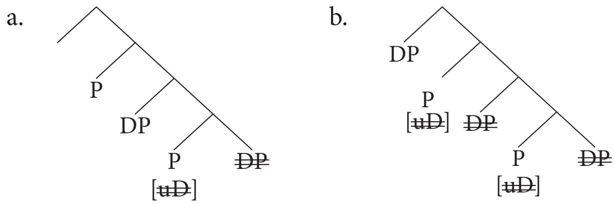
e. Gli altri tenea in pregione, e costui di fuori, **con seco**, e vestialo nobilemente (Anonimo, Novellino)
'He was keeping the others in prison and this one outside **with him** dressed like a noble man.'

f. … Amor non venga sempre ragionando **con meco**, et io **collui**. (Petrach)
love not comes always talk with me=with and I with him.
'love doesn't always come talk with me, and I with him'

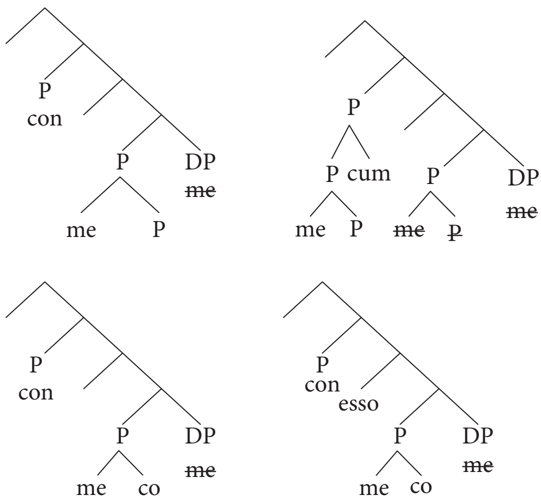
g. Non ti dar malinconia, figliuola, no, ché egli si fa bene anche qua; Neerbale ne servirà bene **con esso teco** Domenedio (Boccaccio, Decamerone)
'Don't be sad daughter, no, because he will do well here as well; Neerbale will do well **with you** [lit. with FOCALIZER you] Domenedio.'

In Latin as well as in Old Italian *con me* and *meco* are derived, given the displacements for feature valuation of the [uD] feature of P. The P-shell includes two P heads, one of which is not spelled out, (13a,b). However, both heads can be spelled out at a given point of the historical development, giving rise to *con meco* and *con* *esso meco*.[4] Through the diachronic changes the only derivation that survived is the one requiring the fewer steps. Only one possibility remains in Modern Italian: *con me*, (14a).[5]

(13)



(14)



Di Sciullo et al. (2013) provides cross-linguistic evidence based on English and Estonian that the oscillation of a complement with respect to its prepositional head

4. Modern Spanish have similar forms like *conmigo* 'with me', *contigo* 'with you' and *consigo* 'with him/herself', with two copies of the same preposition spelled out at both side of the pronominal element, and voicing of the initial velar stop on the rightmost copy of the preposition. This is also the case in Brazilian Portuguese, as well as in other languages. The Directional Asymmetry Principle (Di Sciullo 2011) predicts that complexity followed by its reduction will take place in language diachrony. This developmental principle, does not predict exactly when this reduction will take place.

5. Notice that if Kayne (1994, 2011) is correct in assuming that there is no head-parameter, a position consistent with the current minimalist assumption that parameters are restricted to certain inflectional properties of lexical items, then it follows that of the three types of prepositional order given above; that is, prepositions, postpositions, and circumposition, the modern Italian head initial *con me* is simpler than the other variants discussed above. This is because, assuming with Kayne that phrases are universally head initial, *con me* can be put

is Case dependent. The facts indicate that cross-linguistically the grammatical principles have precedence over principles external to the Language Faculty, as argued independently in Di Sciullo and Aguero (2008) on the basis of the difference between Binding and Coreference to account for the so called 'delay of Condition B effect' in first language development, see below pp. 19–20.

In a diachronic perspective, once internal factors allowing for a certain structure vanish, external forces to the Language Faculty will drive diachronic development. The fluctuation between the pre and post-position of the complement with respect to its prepositional head is reminiscent of the stage of fluctuating asymmetry that has been observed in evolutionary development (evo-devo) of bipartite organisms (Palmer 2004, Levin and Palmer 2007, Lewontin 2000). The fluctuating asymmetry stage is followed by a stage of directional asymmetry, where one side of a bipartite organism is prominent. Di Sciullo (2011) shows that the Directional Asymmetry Principle (DAP), according to which language development is symmetry breaking, will reduce the complexity brought about in an instable grammatical system, where two valued of a same feature are available, as represented in (15) for the valued, [D], and the unvalued D, [uD], feature of P. All things being equal, it follows that P – DP will become the only available option under the DAP for Modern Italian or Modern English.

(15) P
[P] [P]
[D] [uD]

Since the early days of generative grammar, language variation, including diachronic variation, has been linked to language acquisition (Chomsky 1981; Lightfoot, 1979, 1982, 1991; Robert & Roussou 2003, Roberts 2007, 2011). An interesting question from this perspective is whether there is a pattern along the line of the DAP that is observed in language acquisition. We will leave this question for further research.

Since the very inception of generative grammar, a guiding heuristic has been to view language development, in its essential properties, as a process resembling more the growth of organs in living organisms than the process of inductive

together by External Merge. The other variants, however, would require both External Merge and Internal Merge, being therefore more complex. Languages show however fluctuation with respect to the pre- and postpositional structures, as it is the case for Russian, Chinese, and Pashto. Moreover, most languages tend to eliminate the fluctuation in favor of the simplest derivation, as discussed in Di Sciullo (2011), Di Sciullo & Somesfalean (2013, 2015) and Di Sciullo et al. (2013).

learning on the basis of experience. This view has required the hypothesis that the essential principles of language development (growth) are given to the human species as part of our genetic endowment. Organ growth, generally, requires the interplay of two factors: the genetic program or set of specifications directing the way in which development of the relevant organ is to proceed, and environmental factors, determining the unfolding of the program. This much has been recognized since the beginning of the biolinguistic framework (Chomsky 1968, 2005, 2011, Lenneberg 1967).

Three facts provide a strong argument for the genetic specification of human language. The first fact is that it is specific to the human species, and if the infants of humans and other intelligent creatures (e.g., pets) are exposed to the same linguistic experience, only the human infant will ultimately develop human language, despite the fact that the experience factor is kept constant. The second fact is the rapidity with which human language develops. This fact actually allows us to construct a mathematical argument for the genetic basis of language growth. Our capacity for understanding the sentences of our native language is mathematically astronomical and children seem to have this capacity in place by age three, as frequently pointed out when lecturing on the subject. What this means is that given the mathematical size of the set of linguistic expressions, we simply have no time for learning the things about such expressions that we know at a very early age. Pinker (1994) illustrates the issue by pointing out that any human capable of dealing with a twenty-word sentence, is capable of dealing with 10^{20} variations of such sentences. This number is huge (a one followed by twenty zeros or a hundred million trillions) and Pinker correctly points out that if one learns such sentences at a rate of five seconds per sentence, one would need to have an infancy of a hundred trillion years in order to know what we know about such variations. The third fact that argues for the genetic specification of human language is the fact that we know of certain linguistic properties that are not present in the linguistic input. This is known in the linguistic literature as the poverty of the stimulus argument, Chomsky (1986), Piattelli-Palmarini & Berwick (2013), we refer the reader to the extensive literature on the topic for detailed discussion on the relevant issues.

Reexamination of the previous facts as to whether they provide an argument for the biological and/or genetic foundation of language has essentially reaffirmed the generative position. For instance, the species-specific property of human language has been acknowledged by Gallistel (1990) who noted that nonhuman mammals with good statistical learning and computational capacities nevertheless do not develop language.

The mathematical argument discussed above in support of a genetic specification of human language is at times ignored on the basis that language acquisition, although admittedly a rapid process, does not seem to be instantaneous.

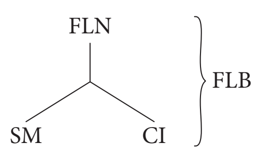
The conclusion that language acquisition is not instantaneous, however, is not warranted. It might be the case that there are maturational principles of the kind discussed by Ken Wexler and his collaborators obscuring knowledge of language in childhood. One such principle might be Wexler's *Unique Checking Constraint* (UCC) (Wexler 1998). According to this principle, the linguistic genetic system developing in childhood has the property that more than one checking are not allowed at young ages in the same linguistic environment. In the clausal domain, AGReement and Tense cannot be both checked, because of the UCC, and thus only one is eliminated giving rise to the Optional Infinitive stage. The child's expressions in the relevant domain will become adult-like once the constraint in question becomes irrelevant with maturation.

While language evolution is still a mystery, the biolinguistic program provides a search space for the formulation of questions and hypothesis leading to a further understanding of human language, its emergence and its constrained variation through time and space.

3. The structure and properties of the FLN/FLB

The question of the evolution of language depends to a great extent on the question of the structure of the linguistic capacity. Minimalist linguistics (e.g. Chomsky 1993, 1995, 2001) recognizes at least three different components of what has been called the faculty of language in a broad sense (FLB): the computational system responsible for recursively combining linguistic expressions, what Hauser et al. (2002) call the FLN; the sensorimotor system (SM), responsible for the externalization of linguistic expressions; and the conceptual intentional system (CI), responsible, among other things, for the interpretation of linguistic expressions. Biolinguistics seeks to investigate the exact properties of these cognitive systems as well as the exact relation among them, and many scholars today are exploring the issues surrounding such question. For example, Larson (2011) explores the question of the relation between the FLN and the FLB. What is the exact relation between these two systems? A working hypothesis has been that the FLN is a component of the FLB together with the SM and CI systems as schematized in (16).

(16)



FLN has been taken to be the sole human-specific dimension of the FLB (e.g, Hauser et al. (2002)). Merge is hypothesized to be the core operation of the FLN.

As mentioned above, Merge is a binary and recursive structure-building operation. Two types of Merge have been proposed: External Merge, and Internal Merge, the latter being responsible for carrying out the displacement of syntactic constituents. The computational system or FLN includes an operation Select that makes a onetime selection of a set of items from the lexicon, called a numeration (N). The operation Select can also apply to N, in order to extract an array of lexical items from it and place it in the workspace. Elements in N are parts of the workspace and await further computation. The FLN also contains the operation Agree. Agree drives the checking/valuing of features and generally leads to displacement. The items from the numeration are associated with formal, semantic and phonetic features. Formal feature can be valued or unvalued. Unvalued features must be valued in the syntactic derivation before the expressions they are part of reach the interfaces. Thus, the output of Agree complies with the demands of the Principle of Full Interpretation. According to this principle, only expressions including valued features can be interpreted by the external systems, semantic and sensorimotor. The operations referred to above can informally be defined as follows:[6]

(17) a. Merge (Chomsky 1995)
Target two syntactic objects α and β, form a new object Γ{α, β}, the label LB of Γ(LB(Γ)) = LB(α) or LB(β).

b. Merge (α, β): {α, β} Chomsky 2001
External Merge applies to two separate syntactic objects;
Internal Merge applies if either of them is part of the other.

(18) a. Numeration: the set of lexical items extracted from the lexicon by Select with their original features.

b. SELECT: an operation that selects items from the lexicon (i.e. the numeration) and from the numeration (i.e. the lexical arrays) and inserts them into the workspace.

c. Workspace: the space where the derivation unfolds and which will eventually contain the output of the recursive application of Merge.

d. TRANSFER: operation that ships linguistic expressions at different moments during the derivation to the SM and CI interfaces.

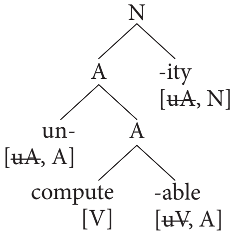
According to Di Sciullo (2005, 2014), morphological Merge applies to a pair of elements in the Numeration whose sets of features are in a proper inclusion

6. See Chomsky (2013, 2015) for the latest development in Minimalism, including the labeling algorithm, which simplifies the definition of Merge as well as it unifies other principles, including the Extended Projection Principle (EPP) and the ECP Empty Category Principle (ECP) in terms of labeling.

relation, (19). This is also the case for syntactic Merge, according to Di Sciullo and Isac (2008), (20).

(19) Numeration: {compute: [V], -able: [A, uV], un-: [A, uA], -ity: [N, uA]}

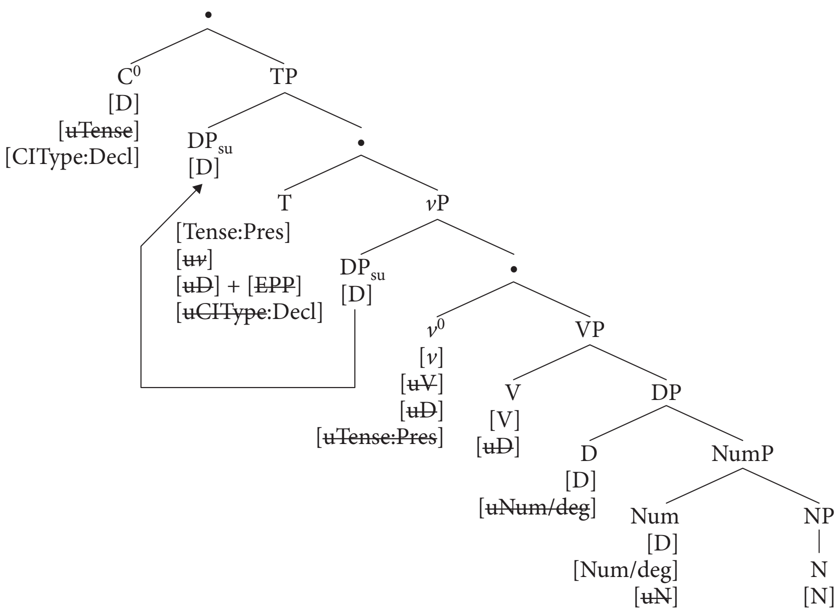
(20)



According to Di Sciullo and Isac (2008), syntactic Merge is an operation that applies to a pair of elements in the Numeration whose sets of features are in a proper inclusion relation.

(21) Numeration: {C, T, {D, Num, N, *v*, V, D, Num, N}}

(22)



In both cases, the criterion for deciding the order in which items in the Numeration must be Merged is the proper inclusion relation: the set of features of the merged item must stand in a proper inclusion relation with the set of features of the object derived in the workspace. Asymmetry is deeply-rooted in syntactic composition.

Within the foundational assumptions of the Minimalist Program, the hypothesis that the FLN is an optimal solution to legibility conditions, imposed by the SM and CI systems, has been a productive one. From a methodological point of view, the search for interface conditions imposing demands on the FLN is a programmatic objective and guiding heuristic of the Minimalist Program and such a search has in fact intensified recently. Larson (2011) suggests that a promising place to search for such conditions is provided by the phenomenon of intentionality as it is represented in syntax. More precisely, Larson argues that the semantic property of intentionality is strongly correlated with the syntactic environment of clausal complementation, a fact that can be concealed by the surface properties of linguistic expressions. Larson further argues that mastery of intentionality appears to correlate with mastery of clausal complementation, in language acquisition, and with the development of a child's theory of mind. Larson suggests that it is plausible that the correlation between intentionality and clausal complementation reflects an interface constraint requiring that the CI system inputs the propositional units sent by the FNL only when these are presented in an appropriate format. Larson observes that the results of his research suggests a view of the notion of a phase, that is a unit of computation and interpretation, see below p. 26, that is different from the one assumed in the Minimalist Program in that it "adverts" to notions like memory and processing load. As he puts it, "[it] can be seen as the point where the Language Faculty computes propositions for the psychological faculty."

Besides the search for conditions imposed by the external systems on the structure of the FLN, contemporary minimalist research also seeks to independently investigate the very nature of such a cognitive system. Lasnik (2011), for instance, reconsiders the question of the generative power of the syntactic system associated with the FLN. To generate such common linguistic expressions as those involving agreement among certain syntactic constituents, at least the power of context free procedures is needed over the less powerful finite state Markov model (an argument made by Chomsky 1957). This is because context free grammars introduce abstract structure that is not visible on the surface or linearized linguistic expressions but play a role in syntactic computations. Since some grammatical operations like the phenomenon of agreement operate on such abstract structures, it follows that such grammatical operations cannot be generated by Markovian models. Lasnik, however, points out that there are areas of syntax that appear to involve a flattened structure. Such structures were used as motivation for the move into transformational grammar, but Lasnik expresses uncertainty as to whether transformations can solve the problem of coordination. He wonders if we need to retain the lower power of Markov procedures for such cases. Arguing that Markovian vs. non-Markovian properties have also been discussed with respect to transformational derivations, Lasnik notices that there have been early and recent arguments for globality in derivations and discusses the implications of some such cases.

In addition to the search for conditions and/or architectural constraints determining the relation between the FLN and the SM interface, on the one hand, and that between FLN and CI interface, on the other, Biolinguistics also assumes the existence of language independent principles that apply to natural phenomena generally, including language. These are the principles that Chomsky (2005) calls the third factor principles. General principles of economy and efficient computation fall within this category. The assumption that the FLN only consists of the sole operation Merge, leaves researchers in Biolinguistics with a heavy task: to show that the role of the many principles attributed to UG in the previous stages of the P&P approach can be accounted for without the given principles. Within the Minimalist Program, some researchers have started to carry out such a task by reanalyzing phenomena previously treated in terms of principles of UG, and their applicability or inapplicability, as phenomena resulting from restrictions imposed by third factor principles. As an example of this practice, consider the so-called Delay of Principle B Effect discussed by us in earlier work (Disciullo & Agüero-Bautista 2008). A number of studies show that children from various languages around age 5 seem to violate Principle B, when the antecedent of the pronoun is a name, but not when the antecedent is a quantifier (Chien & Wexler 1990; Grodzinsky & Reinhart 1993, for English; Koster 1993; Philip & Coopmans 1996, for Dutch; Avrutin & Wexler 1992 for Russian). These findings are at first sight unexpected if Principle B, (23), where governing category refers to the minimal propositional or nominal category including the pronoun, is one of the principles of UG, something that seems to be the case given the universality of this principle in adult speech, (24).

(23) Principle B: A pronoun must be free in its governing category.
(Chomsky, 1981)

(24) a. John_1 likes $\text{him}_{*1/2}$
b. John_1 said that Peter likes $\text{him}_{1/2}$

According to the Standard Analysis (Grodzinsky & Reinhart (1993), there are two strategies of anaphora resolution: Binding and Coreference (see (25)). Principle B is about binding, not about Coreference. There's an interface principle (Rule I) that ensures that binding takes precedence over coreference (see (26)).

(25) Two Strategies of Anaphora Resolution for a sentence like (1).
a. Binding
λx (x touches x) (Mama Bear)
b. Coreference
Mama Bear_1 touches her_2 (where 1 = 2)

(26) **Rule I**
NP A cannot corefer with NP B if replacing A with C, C a variable A-bound by B, yields an indistinguishable interpretation
(Grodzinsky & Reinhart 1993).

One of the intriguing features of the phenomenon is that it is not universal in all environments, as it is notably missing in languages with clitic pronouns in simple clauses (McKee 1992; Baauw et al. 1997, 1999), as in (27), but found to some extent in ECM-type contexts (Baauw et al. 1997, 1999), as in (28). The right theory of the acquisition of Principle B should therefore account for the cross-linguistic presence and absence of the DPBE.

(27) Gianni lo asciuga (It)
Gianni him-dries off
'Gianni dries him off.' (McKee 1992).

(29) La madre la ve ballar (Sp)
The mom her-sees dance
'The mom sees her dance.' (Baauw et al. 1997)

The DPBE is a complex phenomenon that seems to be determined by non-linguistic and linguistic factors. The non-linguistic factors include the ability to handle the additional computational complexity implied in the process of comparing alternative structures in order to choose the optimal one, what Collins (1997) calls global economy.

Di Sciullo and Aguero (2008) argue that the DPBE is not due to a lack of knowledge of Principle B, or any other aspect of the binding theory, but rather to the fact that certain Interface principles induce comparison of structures for truth-conditional equivalence, such as Fox's (2000) Scope Economy principle, (29).

(29) **Scope economy**
The output of a scope-shifting operation must be semantically different from its input.

Both adults and children know Scope Economy in addition to Principle B, but kids in languages with clitics get lost, just like their Germanic counterparts, when having to compare two structures for equivalence. In such cases, kids in languages with clitics also take a guess in the process of interpreting an antecedent-pronoun/variable dependency, with the result that they also perform at chance level.

4. A comparative methodology and unification of results

The biolinguistic program is the study of language as a biological object. This section is concerned with questions of methodology in Biolinguistics. A comparative approach that searches for potential homologues or analogues of the components of the Language Faculty in other organisms is needed. Understanding the multidisciplinary nature that such a comparative approach presupposes also lead to important issues that are central to the goal of obtaining convergent (unified) results. A number of researchers have in fact emphasized this point. Thus, Piattelli-Palmarini and Uriagereka (2011) highlight the importance of searching for convergent results in one important area of both language and biology: the genetics of language. They essentially argue that, to be plausible, results in the genetics of language should be compatible with sound evidence in the domains of both linguistics and genetics. To illustrate the problem they discuss the case of the FOXP2 gene, which has recently been found to play a role in a very specific language deficit in a population of subjects they refer to as the AKEFIs. Subjects in the affected population have problems producing and understanding linguistics expressions involving tense, number, and gender agreement. This has at times been referred to "feature blindness," (e.g., Gopnik 1990). The mastery of these different areas of grammatical agreement is fundamental for the normal development of a language in the individual. The genetic nature of the condition is suggested by the fact that the syndrome is caused by a mutation in one of the copies of the FOXP2 gene. But explaining how exactly the FOXP2 gene is responsible for the language deficit has proven to be a thorny issue. Piattelli-Palmarini and Uriagereka point out that some of the analyses proposed to explain the connection between FOXP2 and the language deficit with AKEFIs assume an implausible conception of language, which essentially equates language to the sensorimotor system. As we saw above, the SM system is just one of the components of the FLB. The FOXP2 gene is known to regulate many other genes that in turn play a role in the development of brain tissues in different brains loci. The authors warn, however, against an analysis that purports to find a neat mapping between genes and brain loci on the basis that no area of language seems to be plausibly circumscribed to one single brain locus. In looking for an alternative explanation that is more consistent with the linguistic evidence, Piattelli-Palmarini and Uriagereka point out to the fact that the FOXP2 gene has a counterpart in birds, the Foxp2 gene. Drawing from conclusions in the role of this gene in the acquisition of bird songs found in the relevant literature, these authors suggest that the language deficit in AKEFIs might result from damage to an area of the brain implementing the human language parser caused by the specific mutation in the FOXP2 gene.

In a similar vein, Jenkins (2011) argues for a comparative method under the assumption that homologues to natural language could be found in other organisms and domains. For Jenkins, the study of the biology of language, i.e. *Biolinguistics*, encompasses the study of knowledge of language, its development in the child and its evolution in the species. Each of these areas can be studied while abstracting away from underlying physical, neural and genetic mechanisms. For example, one can study the Language Faculty by studying properties of language such as word order and distribution of pronouns and anaphors. The development of language can be investigated by looking for both universal principles and language-specific variation across many languages. Language evolution, its use, and development, can be studied by mathematical models simulating language change in time. Jenkins emphasizes that the biolinguistic program hopes to relate the properties of the Language Faculty discovered in linguistics (and in particular to the research areas outlined above) to physical mechanisms at the level of language micro-circuits of the brain and of language genetics. In recent years, there have been a large number of studies of specific genes which have been associated with language. The case of the FOXP2 gene mentioned above is one example, but there are other similar comparative studies where the subjects compared are humans, non-human primates, mice and birds.

In addition to the comparison of research across species, much can be learned from comparing different brain or cognitive areas in the same or different species. For instance, the development of language is often compared with the development of vision, and the existence of critical periods has been investigated in both domains. Although the molecular basis for the "critical period" for language learning has not been found, genes involved in the critical period for vision have been identified. From the perspective of a comparative approach, there is hope that further understanding of the development of vision can be used to illuminate language development and vice versa. In general, the comparison of brain areas within and across species can only reward us with the wealth of new data and evidence needed for understanding the very nature of such complex problems.

The search for possible homologues to the different components of the FLB, among the other species, has led to a burgeoning area of comparative animal work. Fitch and Hauser (2004), for instance report that cotton-top tamarins are able to learn an artificial language, through a long process of training. The type of artificial language they have in mind can be generated by a finite state machine. Cotton-top tamarins, however, cannot learn a language whose grammar has the generative capacities of phrase structure grammar. This does not entail that the human capacity for language originates in finite state grammars. That humans outperform cotton-top tamarins (and all other creatures for that matter) in our command of such generative devices like phrase structure grammar is not a mystery. This is expected in light of experimental results like the one reported in Musso et al. (2003), suggesting that Broca's region is "[…] specialized for the acquisition and processing of hierarchical (rather than linear) structures, which represent the common character of every known grammar." (ibid, pg. 778). See also Bahlmann et al., 2008.

Similarly, Berwick et al. (2012) suggest that the structure of bird song could be derived by concatenation, and here again there is a gap between bird song and human language, as only in the case of human language does hierarchical syntax ensure the association of form with meaning. Berwick et al. point out that the capability for auditory–vocal learning is not shared with our closest relatives, the apes, but is present in such remotely related groups as songbirds and marine mammals. While there are convergent evolutions of the capacity for auditory–vocal learning, and possibly for structuring of external vocalizations, there are significant limitations arising in the ability to compose smaller forms such as words into phrasal constituents. One sticking aspect of comparing the syntax or bird songs to that of human language is the pervasive role of asymmetric relations in the latter (see Kayne 1994; Moro 2000; Di Sciullo 2005). Such relations are not found in bird songs. For example, in English, verbs form syntactic units with their complements, but not with their subjects. This suggests that syntactic units are put together in a highly cyclic fashion, requiring that certain syntactic objects be built first in the workspace, before others constituents can be added to the growing syntactic constituent (Chomsky 1995, 2001; Hornstein & Uriagereka 2002; Di Sciullo & Isac 2008). Neither such asymmetries nor the cyclic fashion in which syntactic objects are constructed has been found in bird songs. A similar point can be made with the fact that complements can be displaced in embedded context contrary to adjuncts (Huang 1982; Rizzi 1990; Chomsky 1995, a.o.). This points toward the existence of natural language asymmetries arising as a consequence of the inner workings of Internal Merge and the interaction of this operation with the different syntactic cycles. Again, such properties of form have not been observed in bird songs, or the vocalizations of marine mammals and apes. More generally, the structure dependent character of syntactic phenomena (e.g. wh-extraction phenomena in questions and exclamation formation), determining the exact context in which syntactic operations apply or fail to do so, although they have been acknowledged as a common property of language since the very beginning of Generative Grammar (Chomsky 1965, 2013), does not seem to have analogues in the biological world.

The research strategy of searching for possible homologues of the different components of FLB is expected to change our original views of such components, as new evidence is considered. This is already happening, for instance, with respect to our conception of the operation Merge. Although Hauser et al. (2002) takes the position that only Merge seems to be specific to the human species, evidence reviewed in several works seems to indicate that Merge is not human specific. Thus, Byne and Russon (1998) arrives at that conclusion studying the process of food preparation with mountain Gorillas, while McGonigle et al. (2003), Seyfarth et al. (2005) and Schino et al. (2006) do so while respectively studying the capuchin monkeys' ordering of objects, baboons knowledge of their companions, and Japanese macaques knowledge of their companions. But even if homologues of Merge can be argued to exist in other domains among the various species of the primates, one can still argue that the way this operation is used by the FLN is uniquely human. As discussed above, natural language expressions can be put together either by External Merge or by Internal Merge. It is the combination of these two types of Merge that is responsible for the unbounded character of linguistic expressions, but nothing like Internal Merge has ever been reported in the literature on primatology or ethology, which rules out the possibility of homologues of the way Merge is used in humans among the living organisms of those species. Internal Merge yields Operator-variable structures, Opx (…x…), and such structures are likely to be human-specific. Quantificational operator-variable structures are necessary in theoretical languages and determine the expressive power of linguistic expressions, making possible the generation of terms of a very symbolic (non-referential) nature. The reasons why Internal Merge seems unavailable to other species have already been considered. Thus, Uriagereka (2008) argues that, as a context-sensitive operation, Internal Merge places greater demands on working memory than does External Merge alone. The probe-goal search, required by Internal Merge, involves scanning the derivational record to find the object to be merged. External Merge does not require a scan of the derivational history. So, less developed working memory in the other primitive species might suffice to explain their using Merge, but not Internal Merge (Coolidge & Wynn 2005).[7] Accounting for the biological isolation of Internal Merge will hopefully lead to an account of the uniquely human systems of open-ended expressions (e.g., linguistic expressions, number systems). A system based on merging lexical items one at a time, and where the operation Merge can apply to its own output, is a system of discrete infinity. Number systems are also systems of discrete infinity. One could possibly argue that the operations responsible for the discrete infinity property of number systems are derivable from Merge, hence our understanding of Internal Merge, besides illuminating the open-endedness and symbolic character of linguistic expressions, may also be expected to shed some light on our understanding of such similar systems as music and mathematics, while generally explaining the similar isolation of these systems in the biological domain. Symbolic reasoning, the ability to think beyond the here and now, is a by-product of our uniquely human, not evolved piecemeal and gradually as an adaptation, cognitive capacity, a capacity best put in display in our handling of unbounded expressions. The

7. Research in this area is just beginning, so the issues are far from being settled. Important questions arise at each turn. In the present case, an interesting question is the relation between memory and working memory. Some animals, e.g. elephants, are known to have a big memory. Can we find evidence of items placed in large working memories when a computational task is being carried out among the other species? If so then we can proceed to investigate the question of whether or why such species have not developed Internal Merge, and whether possession of such an operation is independent of the size of the working memory.

ability for the human mind to compute complex linguistic expressions might, therefore, be a consequence of the great leap from our ability to deal with finite and continuous systems, such as the gesture system, to our capacity for handling systems of discrete infinity, such as language, mathematics and music.

The closest homologue to language is found among the insects, despite the fact that many of the brain components that interact with the faculty of language are widely shared among the species (Fitch 2011). Recognizing this fact, as well as the uniquely human origin of some of the capacities separating Homo sapiens from other living beings, Fitch (2011) points out that some of the novel capacities may depend on different underlying mechanisms that have a separate evolutionary history. Addressing how the mechanisms in question evolved, Fitch argues, requires a comparative approach that goes beyond the study of non-human primates to include virtually any living organism. "If we want to understand which aspects of a trait like bipedalism or vocal learning are incidental, versus either phylogenetically or developmentally necessary, our best source of empirical data will be from multiple species that have evolved that trait independently of one another … Deep homology exists when the developmental mechanisms responsible for generating a trait are shared by common descent, even though the phenotypic trait itself was not present in the common ancestor (Shubin, Tabin & Carroll 1997; Hall 2003). For example, the wings of flies and those of birds are not homologous in any traditional sense (the common ancestor of birds and flies did not have wings). Nonetheless, the genes and developmental processes that generate wings turn out to be shared between these species. Thus, in cases of deep homology, the developmental mechanisms generating a trait are homologous, but the trait itself is not." (Fitch 2011: 136).

The possibility of gaining insights from the search for homologues of the different components of the FLB, among other living organisms, is by now an accepted wisdom, but we hope to extend the search beyond living organisms to encompass the broader natural world. Considerations of this kind have led to a search for language independent principles active in nature, principles that might be deeply grounded in physical law, to paraphrase the way Chomsky (2005) frames the issue, and that might apply to all sort of natural phenomena, including language. An example that comes to mind are the principles of computational efficiency that appear to have a broad range of application in the natural world, from determining the way light travels to regulating insects' navigation. Lewis (2013), for instance, reports the result of a study about the path that fire ants choose on the way to a food source. She points out that "just as light does, ants travelling through different materials follow the fastest path…" The article in question concludes that "Fermat's principle of least time" applies to both light's travel and the path taken by fire ants on their route to a food source. The role of such principles of computational efficiency has been recognized in generative grammar since the beginning of the Minimalist Program (Chomsky 1995). The question has at time taken the form of investigating what determines the path taken by the displacement operation or fronting of elements (now called Internal Merge) attested in many languages. In English, for instance, the first verbal element of an affirmative sentence, as given by a left to right scan of the linear string of elements, is the one fronted in order to derive a question. Thus, the left-most verbal element in both (30a,b) is respectively fronted to yield (31a,b).

(30) a. The child **is** sleeping.
b. The child **has** been sleeping

(31) a. Is the child __ sleeping?
b. Has the child__been sleeping?

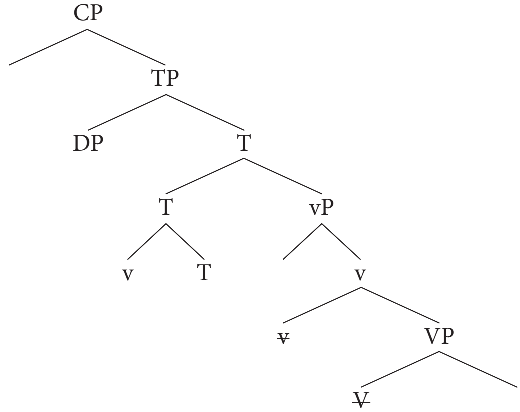
In a complex example like that in (32a) below; however, fronting the left-most verbal element (i.e the first *is*) results in an ungrammatical example, as shown in (32b). The right result is obtained if the right-most verbal element (i.e., the second *is* from left to right) is fronted.

(32) a. The child who is sleeping is happy.
b. *Is the child who __ sleeping is happy?
c. Is the child who is sleeping __ happy?

One interesting question that arises in connection with the data in (30)–(32) is how children learn to front the proper verbal element in these types of examples. This question has been investigated through psycholinguistic experiments, designed in order to determine whether children learn to front the proper element in examples like (32) by analogy with simpler examples like those in (31). The results of such experiments show that children do not seem to learn about the proper path of fronting, but rather that such a path is determined by general principles constraining language. If one takes into account the structure of the examples above, one finds that the second *is* in (32a) is structurally closer to the landing site of the fronting operation, so that in fronting this element a child is actually choosing the fastest path to turn the relevant example into a question. From the perspective of the broad comparative method, assumed in the biolinguistic program, the analogy with Fermat's principle of the least time could not be greater: just as it happens with light travel and the choice by ants of a path to a food source, the path taken by the Internal Merge operation in the FLN seems to be the fastest, most efficient one.

Comparative methodology between language and the genetic code may lead to further substantiate the unification of language and biology. The genetic code is nearly universal in the sense that it is nearly used by all known organism, animals, plants, fungi, archaea, bacteria, and viruses. The genetic laws of preservation ensuring the efficient transmission of the pedigree, the genetic heritage, may find their homologue in language Inclusiveness Condition and the No Tampering condition. According to Chomsky's (1995:225) Inclusiveness Condition, the output of a system does not contain anything beyond its input. This condition implies that the interface levels contain nothing more than arrangements of lexical items. Consequently no traces of displacement or other material introduced in the derivation such as indices may be part of the interfaces. The No Tampering Condition (Chomsky 2008a) also falls into the set of principles of efficient computation. According to this condition, the merger of two syntactic objects, for example [Q] and C in question formation, leaves the two syntactic objects unchanged. Cell division and DNA replication are subject to laws of preservation. Usually, cells divide in identical copies and DNA replication generate identical DNA strands. The comparative methodology may also lead to identify deep homologies between these biological processes and language computation. Current mainstream syntactic theorizing relies on the notion of "phase", as units of derivation and interpretation, and assumes that efficient derivations proceed by phases. *Derivation by phases* limits the search space and the computational load of syntactic computation, (Uriakereka 1998, 1999, 2002; Richards 2006; Chomsky 1995, 2001, 2008a, b, 2013, a.o.). A phase is a unit of derivation and interpretation. It minimally includes a functional head and its complement. It is subject to the Principle of impenetrability, according to which the head and the edge of a phase are the only positions available for the displacement of a constituent outside of a phase. A phase is also a separable semantic and sensorimotor constituent at the interfaces. According to Chomsky (2001, 2008a), phases are propositional. CP and v*P are unanimously recognized as phases, while DP and PP are still under discussion. Morphological constituents have also been argued to be phases (Di Sciullo 2004, 2005; Marantz 2008; Embick 2010, a.o.) Thus, vP is a phase, and the verbal head for vP as well as the phrasal constituent at the edge of the vP are the only constituents that may be displaced to the next phase up. We illustrate this in (33), where the identical copies of the displaced constituents are displayed in strikethrough.

(33)



Since phase-based procedures in language are enforced by general principles of efficient computation and economy, and given that such principles can have a broad range of application in nature, it is conceivable that there might be biological processes proceeding in a phase-by-phase fashion.

A comparative approach that searches for potential homologues or analogues of the components of the Language Faculty in other organisms is part and parcel of the biolinguistic research. Several works indicate that the comparative approach also covers the effect of economy principles, including locality, preservation and symmetry breaking principles on the growth and development of biological organisms. These principles rely on the formal properties of the objects and phenomena under scrutiny and contribute to the unification of language and biology.

5. Summary

The biolinguistic program is a research space dedicated to the study of human language as a biological object. Biolinguistic research relies on current knowledge in linguistics, as well as in biology and neurosciences. As knowledge in these fields evolves, further questions and hypotheses will arise, pushing further explanatory accounts of the biological basis of the human Language Faculty, its emergence, the articulation of FLN and FLB, language phylogeny, language acquisition and variation, as well as principles of efficient computation.

References

Avrutin, S. & Wexler, K. 1992. Development of principle B in Russian: Coindexation at LF and coreference. *Language Acquisition* 2: 259–306. doi:10.1207/s15327817la0204_2

Baauw, S. 1999. The role of the clitic-full pronoun distinction in the acquisition of pronominal coreference. In *Proceedings of the 23rd Annual Boston University Conference on Language Development*, A. Greenhill, H. Littlefield & C. Tano (eds), 32–43. Somerville MA: Cascadilla Press.

Baauw S., Escobar, M. & Philip, W. 1997. A delay of principle B effect in Spanish speaking children: The role of lexical feature acquisition. In *Proceedings of the GALA 97 Conference on Language Acquisition,* A. Sorace, C. Heycock & R. Shillcock (eds), 16–21. Edinburgh: University of Edinburgh.

Bahlmann J., Schubotz R.I. & Friederici, A.D. 2008. Hierarchical artificial grammar processing engages Broca's area. *NeuroImage* 42(2): 525–34. doi:10.1016/j.neuroimage.2008.04.249

Berwick, C.R. 2011. All you need is Merge. All you need is Merge: Biology, computation, and language from the bottom up. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 461–491. Oxford: OUP.

Berwick, R.C., Beckers, G.J., Okanoya, K. & Bolhuis, J.J. 2012. A bird's eye view of human language evolution. *Front. Evol. Neurosci.* 4(5). doi:10.3389/fnevo.2012.00005

Berwick C.R. & Chomsky, N. 2011. The Biolinguistic Program. The current state of its development. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 13–45. Oxford: OUP.

Bickerton, D. 1990. *Language and Species*. Chicago IL: University of Chicago Press.

Boeckx, C. 2011. The emergence of the language faculty, from a biolinguistic point of view. In *The Oxford Handbook of Language Evolution*, M. Tallerman & K. Gibson (eds), 492–201. Oxford: OUP.

Bolhuis, J.J. & Everaert, M. (eds). 2013. *Birdsong, Speech, and Language: Exploring the Evolution of Mind and Brain*. Cambridge MA: The MIT Press.

Byrne, R.W. & Russon, A.E. 1998. Learning by imitation: A hierarchical approach. *Brain and Behavioral Sciences* 21: 667–721.

Chien, Y.C. & Wexler, K. 1990. Children's knowledge of locality conditions in bindings as evidence for the modularity of syntax and pragmatics. *Language Acquisition* 1: 225–295. doi:10.1207/s15327817la0103_2

Chomsky, N. 2015. Problems of projections: Extensions. In *Structures, strategies and beyond: Studies in honour of Adriana Belletti*, E. Di Domenico, C. Hamann & S. Matteini (eds), 1–16. Amsterdam: John Benjamins. doi:10.1075/la.223.01cho

Chomsky, N. 2013. Problems of projections. *Lingua* 130: 33–49. doi:10.1016/j.lingua.2012.12.003

Chomsky, N. 2011. Poverty of the stimulus unfinished business. Ms, MIT.

Chomsky, N. 2008b.The Biolinguistic Program: Where does it stand today? Ms, MIT.

Chomsky, N. 2008a. On phases. In *Foundational Issues in Linguistic Theory. Essays in Honor of Jean-Roger Vergnaud*, R. Freiden, C.P. Otero & M.L. Zubizarreta (eds), 133–166. Cambridge MA: The MIT Press.

Chomsky, N. 2007. Of mind and language. *Biolinguistics* 1: 9–27.

Chomsky, N. 2005. Three factors in language design. *Linguistic Inquiry* 36: 1–22. doi:10.1162/0024389052993655

Chomsky, N. 2001. Derivation by phase. In *Ken Hale: A Life in Language*, M. Kenstowicz (ed.), 1–52. Cambridge MA: The MIT Press.

Chomsky, N. 1995. *The Minimalist Program*. Cambridge MA: The MIT Press.

Chomsky, N. 1988. *Language and Problems of Knowledge*. Cambridge MA: The MIT Press.

Chomsky, N. 1986. *Knowledge of Language: Its Nature, Origins and Use*. New York NY: Praeger.

Chomsky, N. 1981. *Lectures on Government and Binding: The Pisa lectures*. Berlin: Mouton de Gruyter.

Chomsky, N. 1968. *Language and Mind*. New York NY: Harcourt, Brace & World. doi:10.1037/e400082009-004

Chomsky, N. 1965. *Aspects of the Theory of Syntax*. Cambridge MA: The MIT Press. Vol. II, R.D. Luce, R. Bush & E. Galanter (eds), 269–321. New York NY: Wiley & Sons.

Chomsky, N. 1957. Three models for the description of language. *IRE Trans. Inf. Theory* 2: 113–124. doi:10.1109/TIT.1956.1056813

Collins, C. 1997. *Local Economy*. Cambridge MA: The MIT Press.

Coolidge, F.L. & Wynn, T. 2005. Working memory, its executive functions, and the emergence of modern thinking. *Cambridge Archaeological Journal* 15(1): 5–26. doi:10.1017/S0959774305000016

Darwin, C. 1871. *The Descent of Man, and Selection in Relation to Sex*. London: John Murray. doi:10.1037/12293–000

Di Sciullo, A.M. 2014. Minimalism and I-morphology. In *Minimalism and Beyond: Radicalizing the Interfaces* [Linguistic Faculty and Beyond 11], P. Kosta, S. Franks & T. Radeva-Bork (eds), 267–286. Amsterdam: John Benjamins. doi:10.1075/lfab.11.10sci

Di Sciullo, A.M. 2013. Exocentric compounds, language and proto-language. *Language Information Society* 20: 1–26.

Di Sciullo, A.M. 2012. Biolinguistics, minimalist grammars and the emergence of complex numerals. Presented at Theoretical Linguistics/Biolinguistics Workshop (EVOLANG 9), 13 March, Kyoto.

Di Sciullo, A.M. 2011. A biolinguistic approach to variation. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*. A.M. Di Sciullo & C. Boeckx (eds), 305–328. Oxford: OUP.

Di Sciullo, A.M. 2005. *Asymmetry in Morphology*. Cambridge MA: The MIT Press.

Di Sciullo, A.M. 2004. Morphological phases. In *The 4th GLOW in Asia 2003. Generative Grammar in a Broader Perspective*, J.-Y. Yoon (ed.), 113–137. The Korean Generative Grammar Circle and Cognitive Science, Seoul National University.

Di Sciullo, A.M. & Somesfalean, S. 2015. Object pronouns in the evolution of Romanian: a biolinguistic perspective. In Formal approaches to DPs in Old Romanian, V. Hill (ed.), 269–290. Leiden/Boston: Brill.

Di Sciullo, A.M., Nicolis, M. & Somesfalean, S. 2013. Evo-devo language universals. Paper presented at the International Linguists Conference 19, University of Geneva.

Di Sciullo, A.M & Somesfalean, S. 2013. Variation in the Position of the Definite Determiner in Romanian: a Biolinguistic Perspective. Romance Linguistics in the Pacific: Variations in Time and Space. Special Issue of the *Australian Journal of Linguistics 33*(2):121–139. Taylor&Francis.

Di Sciullo, A.M. et al. 2010. The Biological Nature of Human Language. *Biolinguistics* 4: 4–34.

Di Sciullo, A.M. & Isac, D. 2008. The asymmetry of Merge. *Biolinguistics* 2: 260–290.

Di Sciullo, A.M. & Aguero-Bautista, C. 2008. The delay of principle B effect (DPBE) and its absence in some languages. *Language and Speech* 51:77–100. doi:10.1177/00238309080510010601

Embick, D. 2010. *Localism versus Globalism in Morphology and Phonology.* Cambridge MA: The MIT Press. doi:10.7551/mitpress/9780262014229.001.0001

Fitch, W.T. 2011. "Deep homology" in the biology and evolution of language. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 135–166. Oxford: OUP.

Fitch, W.T. & Hauser, M.D. 2004. Computational constraints on syntactic processing in a nonhuman primate. *Science* 303: 377–380. doi:10.1126/science.1089401

Fox, D. 2000. *Scope and Semantic Interpretation*. Cambridge MA: The MIT Press.

Gallistel, C.R. 1990. *The Organization of Learning*. Cambridge MA: Bradford Books/The MIT Press.

Gopnik, M. 1990. Feature blindness: A case study. *Language Acquisition* 1(2): 139–164. doi:10.1207/s15327817la0102_1

Grodzinsky, J. & Reinhart, T.1993. The innateness of binding and coreference. *Linguistic Inquiry* 24: 69–102.

Hall, B.K. Descent with modification: The unity underlying homology and homoplasy as seen through an analysis of development and evolution. *Biological Reviews* 78: 409–433. doi:10.1017/S1464793102006097

Hauser, M.D., Chomsky, N. & Fitch, T. 2002. The faculty of language: What is it, who has it, and how did it evolve. *Science* 198: 1569–79. doi:10.1126/science.298.5598.1569

Hauser, M.D. 2000. What do animals think about numbers? *American Scientist* 88(2): 144–15. doi:10.1511/2000.19.863

Hauser, M.D., MacNeilage, P. & Ware, M. 1996. Numerical representations in primates. *Proceedings of the National Academy of Sciences of the United States of America* 93(4): 1514–1517. doi:10.1073/pnas.93.4.1514

Hauser, M.D., Yang, C., Berwick, R.C., Tattersall, I., Ryan, M.J., Watumull, J., Chomsky, N. & Lewontin, R.C. 2014. The mystery of language acquisition. *Frontiers in Psychology* 5. doi:10.3389/fpsyg.2014.00401

Hornstein, N. & Uriagereka, J. 2002. Reprojections. In *Derivation and explanation in the Minimalist Program*, S. Epstein & T. Seely (eds), 106–132. Malden MA: Blackwell. doi:10.1002/9780470755662.ch6

Huang, J. 1998[1982]. *Logical Relations in Chinese and the Theory of Grammar.* New York NY: Garland.

Hurford, J.R. 2014. *Origins of Langage. A Slim Guide*. Oxford: OUP.

Jackendoff, J.R. 2011. What is the human language faculty: Two views? *Language* 87(3): 586–624. doi:10.1353/lan.2011.0063

Jenkins, L. 2011. Biolinguistic investigations: Genetics and dynamics. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 126–134. Oxford: OUP.

Jenkins, L. 2000. *Biolinguistics: Exploring the Biology of Language*. Cambridge: CUP. doi:10.1017/CBO9780511605765

Kayne, R. 2011. Why are there no directionality parameters? In *Proceedings of the 28th West Coast Conference on Formal Linguistics*, M. Byram Washburn, K. McKinneyBock, E. Varis, A. Sawyer & B. Tomaszewicz (eds), 1–23. Somerville MA: Cascadilla Press.

Kayne, R. 1994. *The Antisymmetry of Syntax*. Cambridge MA: The MIT Press.

Koster, C. 1993. Errors in Anaphora Acquisition. Ph.D. dissertation, Utrecht University.

Larson, R. 2011. Clauses, propositions and phases. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 366–391. Oxford: OUP. 366–391.

Lasnik, H. 2011. What kind of computing device is the human language faculty. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 354–365. Oxford: OUP.

Lenneberg, E.H. 1967. *Biological Foundations of Language*. New York NY: Wiley & Sons.

Lewontin R.C. 2000. *The Triple Helix: Gene, Organism and Environment*. Cambridge MA: Harvard University Press.

Levin, M. & A.R. Palmer. 2007. Left-right patterning from the inside out: Widespread evidence for intracellular control. *BioEssays* 29: 271–287.

Lewis. T. 2013. Ants 'use math' to find fastest route. *Livescience*. ⟨http://www.livescience.com/28795-ants-find-fastest-route-using-math.html⟩

Lewontin R. 2004. Response to 'Selection for Asymmetry". *Science* 306: 812. doi:10.1126/science.306.5697.812

Li, R. & Bowerman, B. 2010. Symmetry breaking in biology. *Cold Spring Harbor Perspectives in Biology* 2(3): A003475. doi:10.1101/cshperspect.a003475

Lightfoot, D. 1991. *How to Set Parameters. Arguments from Language Change*. Cambridge MA: The MIT Press.

Lightfoot, D. 1982. *The Language Lottery*. *Toward a Biology of Grammars.* Cambridge MA: The MIT Press.

Lightfoot, D. 1979. *Principles of Diachronic Syntax*. Cambridge: CUP.

McKee, C. 1992, A comparison of pronouns and anaphors in Italian and English acquisition. *Language Acquisition* 2: 21–54. doi:10.1207/s15327817la0201_2

Marantz, A. 2008. Phases and words. In *Phases in the Theory of Grammar*, S.-H. Choe (ed.), 191–222. Seoul: Dong In.

McGonigle, B., Chalmers M. & Dickinson, A. 2003. Concurrent disjoint and reciprocal classification by Cebus Apella in seriation tasks: Evidence for hierarchical organization. *Animal Cognition* 6:185–197. doi:10.1007/s10071-003-0174-y

Nobrega, V.A. & Miyagawa, S. 2015. The precedence of syntax in the rapid emergence of human language in evolution as defined by the Integration Hypothesis. *Frontiers Psychology* 6: 271.

Moro, A. 2000. *Dynamic Antisymmetry*. Cambridge MA: The MIT Press.

Musso, M., Moro, A., Glauche, V., Rijntjes, M., Reichenbach, J., Büchel, C. & Weiller, C. 2003. Broca's area and the language instinct. *Nature Neuroscience* 6(7): 774-781. doi:10.1038/nn1077

Palmer, R. 2009. Animal asymmetry. *Current Biology* 19(12): 473–477. doi:10.1016/j.cub.2009.04.006

Palmer, A.R. 2004. Symmetry breaking and the evolution of development. *Science* 306: 828–833. doi:10.1126/science.1103707

Palmer, A.R. 1996. From symmetry to asymmetry: Phylogenetic patterns of asymmetry variation in animals and their evolutionary significance. *Proceedings of the National Academy of Sciences* (USA) 93: 14279–14286.

Philip, W. & Coopmans, P. 1996. The role of lexical feature acquisition in the development of pronominal anaphora. In *Amsterdam Series on Child Language Development* 5, W. Philip & F. Wijnen (eds). Amsterdam: University of Amsterdam.

Piattelli-Palmarini, M. (ed.). 1980. *Language and Learning: The Debate between Jean Piaget and Noam Chomsky*. Cambridge MA: Harvard University Press.

Piattelli Palmarini, M. & Uriagereka, J. 2011. A geneticist's dream, a linguist's nightmare: The case of FOXP2. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty*, A.M. Di Sciullo & C. Boeckx (eds), 100–125. Oxford: OUP.

Piattelli-Palmarini, M. & Berwick, R.C. (eds). 2013. *Rich Languages from Poor Inputs*. Oxford: OUP.

Pinker, S. 1994. *The Language Instinct: How the Mind Creates Language.* New York NY: HarperCollins.

Pinker, S. & Bloom, P. 1990. Natural language and natural selection. *Behavioral and Brain Sciences* 13(4): 707–78. doi:10.1017/S0140525X00081061

Poeppel, D. & Embick, D. 2005. Defining the relation between linguistics and neuroscience. In *Twenty-First Century Psycholinguistics: Four Cornerstones,* A. Cutler (ed.), 103–118. Mahwah NJ: Lawrence Erlbaum Associates.

Progovac, L. 2015. *Evolutionary Syntax*. Oxford: OUP. doi:10.1093/acprof:oso/9780198736547.001.0001

Progovac, L. 2007. Grammars within without recursion: Implications for evolutionary studies. Paper presented to Illinois State University Conference on Recursion in Human Languages, Normal IL.

Progovac, L. 2006. The syntax of nonsententials: Small clauses and phrases at the root. In *The Syntax of Nonsententials* [Linguistik Aktuell/Linguistics Today 93], L. Progovac, K. Paesani, E. Casielles & E. Barton (eds), 33–71. Amsterdam: John Benjamins. doi:10.1075/la.93.04pro

Richards, N. 2002. Very local A' movement in a root-first derivation. In *Derivation and Explanation in the Minimalist Program,* S.D. Epstein & T.D. Seely, 227–245. Oxford: Blackwell. doi:10.1002/9780470755662.ch10

Richards, N. 2006. Deriving the edge: What's in a phase? Ms, University of Cambridge.

Rizzi, L. 1990. *Relativized Minimality*. Cambridge MA: The MIT Press.

Roberts, I. 2011. Parametric hierarchies: Some observations. Presented at the workshop on linguistic variation and the minimalist program, Universidad Autonoma de Madrid.

Roberts, I. 2007. *Diachronic Syntax*. Oxford: OUP.

Roberts, I. & Roussou, A. 2003. *Syntactic Change: A Minimalist Approach to Grammaticalization*. Cambridge: CUP. doi:10.1017/CBO9780511486326

Rugani, R., Vallortigara, G., Vallini, B. & Regolin, L. 2011. Asymmetrical number-space mapping in the avian brain. *Neurobiology of Learning and Memory* 95: 231–238. doi:10.1016/j.nlm.2010.11.012

Rugani, R., Fontanari, L., Simoni, E., Regolin, L. & Vallortigara, G. 2009. Arithmetic in newborn chicks. *Proceedings of the Royal Society of London B, Biological Sciences* 276: 2451–2460. doi:10.1098/rspb.2009.0044

Schino, G., Tiddi, B. & di Sorrento, P. 2006. Simultaneous classification by rank and kinship in Japanese macaques. *Animal Behaviour* 71: 1069–1074. doi:10.1016/j.anbehav.2005.07.019

Seyfarth, R.M., Cheney, D.L. & Bergman, T.J. 2005. Primate social cognition and the origins of language. *Trends in Cognitive Sciences* 9(6): 264–266. doi:10.1016/j.tics.2005.04.001

Shubin, N., Tabin, C. & Carroll, S. 1997. Fossils, genes and the evolution of animal limbs. *Nature* 388: 639–648. doi:10.1038/41710

Uriagereka, J. 2008. *Syntactic Anchors. On Semantic Structuring*. Cambridge: CUP. doi:10.1017/CBO9780511481482

Uriagereka, J. 2002. *Derivations*. London: Routledge.

Uriagereka, J. 1999. Multiple spell-out. In *Working Minimalism*, S.D. Epstein & N. Hornstein (eds), 251–282. Cambridge MA: The MIT Press.

Uriagereka, J. 1998. *Rime and Reason*. Cambridge MA: The MIT Press.

Wexler, K. 1998. Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage. *Lingua* 106: 23–79. doi:10.1016/S0024-3841(98)00029-1

Symbol taxonomy in biophonology*

Camila Matamoros & Charles Reiss
Concordia University, Montréal

We present phonological parallels to Gallistel & King's (2009) discussion of symbols, variables and function in animal cognition in order to take up Poeppel's (2012) challenge to cognitive scientists to formulate their models in general computational terms that can potentially be translated into the kind of representational and computational behaviors that we might plausibly find in a nervous system.

1. Introduction

Generative phonological theory is formulated as part of the Computational-Representational Understanding of Mind (see Thagard (2005) for accessible discussion). In order to unify such a theory with neurobiology it is necessary to map the representations and computations posited by phonologists to the entities that populate neuroscience. As David Poeppel points out, this has not proven to be a simple task for phonology (or any other branch of linguistics, or any other cognitive science) and no straightforward mappings, like '*This* neuron corresponds to *that* syllable' seem even remotely plausible. Unlike some of his neuroscience colleagues, Poeppel's reaction to this "mapping problem" is not to reject phonological theory, but rather to exhort phonologists, and cognitive scientists in general, to try to formulate their models in general computational terms where possible, in terms that can potentially be translated into the kind of representational and computational behaviors that we might plausibly find in a nervous system. In a nutshell, Poeppel favors having the phonologists (and other cognitive scientists) tell the neuroscientists what to look for.

Poeppel knows the linguistics literature, but as an example of the kind of low-level characterization he is looking for he refers to Gallistel & King

* The authors would like to thank an anonymous reviewer, as well as participants at the conference *Biolinguistic Investigations on the Language Faculty* held in January 2015 in Pavia, for helpful comments.

DOI 10.1075/la.235.02mat

(2009, henceforth G&K) whose primary examples of cognitive behavior come from insect navigation. The spirit of G&K, as reflected in their Preface (p. ix), is along these lines: There is no reason to think that our understanding of the computational capacity of biological systems is nearly as explicit as our understanding of the basic math and logic of a process like, say, navigation by dead-reckoning, so let's characterize the operations and representations that we know are needed in insect navigation from the perspective of theories of computation, and provide this analysis to neuroscientists so that they can figure out how to get this representational and computational behavior out of biological nervous systems. This perspective of G&K leads them to discuss fundamental notions such as variables and functions from a computational perspective and to talk about the prospects for understanding these notions under various approaches to brain science. A large part of G&K is devoted to arguing that connectionist neural network models and other dominant models of brain function based, for example, on patterns of electrical activity in the brain, have been utter failures in their attempts to model cognition, exactly because they have not and, G&K argue, cannot model variables and functions in the open-ended productive manner required for animal cognition, even at the level of insect navigation.

One reason Poeppel discusses G&K's insect studies despite his own familiarity with linguistics is that similarly explicit work concerning computational fundamentals in linguistics is hard to find. In this paper, we hope to demonstrate that phonological theory, in a fairly standard form represented by Bale and Reiss (Forthcoming) is quite consistent with the spirit of work like G&K, although linguists tend not to be as explicit about the issues as G&K are. In other words, we can think of generative phonology as high-level theoretical neuroscience – we are just making explicit some of Poeppel's suggestions.

2. Overview of Gallistel and King (2009)

When Poeppel asks how the primitive units of analysis of the cognitive sciences map onto the primitive units of analysis of the neurosciences, he stipulates that good answers come from "theoretically well-motivated, computationally explicit, and biologically realistic characterizations of [brain] function." He exhorts linguists and other cognitive scientists to formulate theories in computational terms in order to guide neurobiologists in their search for more explanatory, not just correlative, data. G&K's book length treatment helps us to understand some of the ideas that cognitive scientists should use in their discussions, ideas that are not specific to particular cognitive domains.

The main conclusions from G&K's work are quite simple: the evidence from cognition shows there must be an addressable read/write memory mechanism in brains that

- encodes information received into symbols (writes)
- locates the information when needed (addresses)
- and transports it to computational machinery that makes productive use of the information (reads)

As G&K point out, "[s]uch a memory mechanism is indispensable in powerful engineered computing devices, and the behavioral data imply that brains are powerful organs of computation", as well. This read/write memory instantiates a system of symbols, variables and functions that are somehow implemented in neural tissue. In this paper, we explore how the symbols and variables, and the functions operating over them can be expressed in "our" phonological theory in a way that potentially contributes to explanatory neuroscience research.

2.1 Symbol taxonomy

G&K explain that for the brain to compute stimuli from experience, it must be able to generate representations of the world. This concept of representations depends on a concept of functions. Functions are operations that take variables as input; these variables get their values from symbols and the function outputs a symbol that is determined by the value of the symbol that gave the input variable its value. Therefore, a discussion of symbols is required to build up the picture of how computation works.

For G&K, symbols in computation must be physically realized entities that are manipulated by the programming and architecture of a computational system. Because the brain is physically limited in power and space, and because scientific reasoning leads us to propose the simplest possible hypothesis, a desirable model is one with a small number of primitive symbols and basic processes for combining them. By combining primitive symbols, more complex symbols can be created when new stimuli require new representations.

G&K (p.79) themselves use a linguistic example to illustrate the idea of a basic symbol inventory in both engineered systems and natural systems:

> No language in the world has a word for the message, "After the circus, I'm going to the store to get a quart of skim milk."
>
> … Minimizing the number of atomic data is desirable in any symbol system as it reduces the complexity of the machinery required to distinguish these data. This is why computers use just two atomic data and likely why nucleotide sequences use only four.

The atomic data enter into combinations that lead to more complex symbols, according to the followng taxonomy:

(1) Gallistel & King's symbol taxonomy (p. 79)
  - atomic data
  - data strings
  - nominal symbols
  - encoding symbols
  - data structures

For example, atomic data can be ordered in strings, and strings can be arranged into complex structures like trees with precedence and containment relations among strings. Our modest goal in this paper is to show that standard phonological theory provides a similar model of representations. In this discussion we will focus on the combinatoric and structural aspects of phonological feature systems, although there may be interesting comparisons to be made with G&K's discussions of nominal symbols and encoding symbols.[1]

2.2 Combinatoric explosion

The effect of having a hierarchical taxonomy of symbols is that a relatively small number of lower level symbols can be combined into a very large number of higher level symbols. As we will discuss below, the combinatorial space of a simple system can lead to combinatoric explosion of the space of complex symbols. However, G&K explain that this is in fact a *desirable* trait since it removes the necessity of a look-up table for complex symbols. This idea is applicable not only to the symbols of mental representation, but to systems like the genetic code which generates the diversity of life from sequences of just four basic elements, the nucleotide 'letters' T,G,C and A. We will see that phonological symbols also give us a massive power of descriptive variety, exactly what we want in a theory of Universal Grammar.

In their chapter on symbols, G&K also address the issue of storage space. They explain that the number of possible data strings and nominal or encoding symbols is so great as to be considered infinite, for all practical purposes, but the resources required for realizing and storing these are clearly limited.

A biologically realistic computational system must therefore start with a small number of simple symbols and be able to combine them and store relevant

1. In brief, symbols are 'nominal' if there is an arbitrary mapping between their form and their referent, a property that clearly holds of the mapping between phonological mental representations and their phonetic (articulatory and acoustic) correlates (see below). It is not immediately clear to us whether phonological representation has any parallel to the notion of encoding symbols that G&K introduce.

combined symbols in response to received stimuli – the system does not store all the possibilities, only those that are actually encountered.[2] The example (p.82) of the "picture space" of a digital camera illustrates this point:

> The camera constructs a symbol for an image during the interval when the shutter is open. If it is a six-megapixel camera, the symbol consists of 6 million 24-bit binary numbers. The number of different symbols of this kind (the number of different pictures that may be taken with a 6-megapixel camera) is [for practical purposes – cm and cr][3] infinite, just as is the number of possible images. But, of course, the number of different pictures that even the most avid photographer will take is finite (…) The camera can represent an infinite range of possibilities with finite resources, because it constructs its symbols on demand. The possibilities are infinite, but the actualities are finite. (82)

We'll see how phonological systems mirror this idea of combinatoric capacity built on a simple system.

2.3 Variables and functions

Symbols and data structures that encode information about the world are key components of a computational system, but algorithms that calculate over their values must also have some way of finding the relevant data. The process of locating a symbol is called *addressing*. An address for a symbol, or set of possible symbols in a category is called a *variable*. In concrete terms the implementation of a variable is a location at which a symbol can be found – the symbol found at that address is the current value of the variable. The variable and its value are different pieces of information. The variable is the address, the value is the symbol found at that address. A category variable is the address that points to the addresses of possible values within that category. G&K give many examples of how insects must use variables. In navigation, since the position of the sun in calculating direction relative to the North-South axis is not a stable value, computation for navigation must include a variable for the sun's position. Other animal examples show the need for variables for a wide variety of dimensions including the sweetness of available nectar or the rotting rate of a cached food supply. In the following sections, we present parallels to G&K's examples of symbol taxonomy, combinatoric explosion and the role of variables from the domain of phonology.

---

2. The system has to parse, using working memory, whatever is encountered, but only store in long-term memory what cannot be (re)generated by the computational system. For example, encountered phonological representations like the segment string [dɔg] *dog* must be stored, but the syntactic structure of a sentence like *The cat bit the dog* does not have to be stored in long-term memory once it is parsed.

3. It is actually $2^{24^{6,000,000}}$

3. Symbol taxonomy in phonology

According to Distinctive Feature Theory (e.g. Jakobson et al. (1967)) the atomic symbols of phonology are not segments or phonemes like /p/, /t/, /a/, *etc.*, but rather the members of a set of *features* and the members of a set of *values*. The features correspond to a phonetic dimension with complex acoustic and articulatory correlates. For example, the feature High correlates somewhat, via complex transduction processes, with location of the first formant in a vowel spectrogram and the relative height of the tongue in the mouth. The set of values in the model we adopt has just two members, + and −. Members of the set of values and the set of features co-occur in phonological representations as complex symbols like +High or −High. A persistent ambiguity in terminology in the field is the use of the simple term *feature* to refer to such *valued features*, but we'll try to distinguish the two concepts consistently here. Note that a valued feature is just an ordered pair whose first member is a value and whose second member is a feature. The valued feature is thus the first step up in the phonological symbol taxonomy from the primitive values and features. The next level of organization will be to combine valued features into sets that correspond to phonological segments.

Let's look at the kind of phenomena that lead phonologists to posit discrete features that can combine with only two discrete values. We use a textbook example of Turkish from Isac and Reiss (2013, 128ff) to explore a phenomenon called vowel harmony. First examine the forms in (2) that show the eight vowels of Turkish in a list of words.

(2) The eight Turkish Vowels
   a. ip 'rope'
   b. kıl 'hair'
   c. sap 'stalk'
   d. uç 'tip'
   e. son 'end'
   f. öç 'revenge"
   g. gül 'rose'
   h. ek 'joint'

The eight different vowels in these words can be described along 3 axes as in (3): Backness, Height, and Rounding. Backness refers to how far back the tongue is placed in the mouth when the vowel is produced, therefore the sounds 'i', 'ü', 'e', and 'ö' are –Back whereas 'ı', 'u', 'a', and 'o' are +Back. Height refers to the height of the tongue relative to the roof of the mouth, so in the chart, those on the same line as 'i' are +High while those in line with 'e' are –High. Finally, the feature Round refers to lip rounding.

(3) Feature analysis of Turkish vowels

	-Back		+Back	
	-Round	+Round	-Round	+Round
+High	i	ü	ı	u
-High	e	ö	a	o

Vowels and consonants are segments. That is, they are the level of organization of language that we represent with phonetic alphabet symbols. However, each segment symbol is actually an abbreviation for a set of valued features. These sets are consistent, that is, abstracting away from so-called *contour segments*, they cannot contain incompatible values; for a given feature F, a segment cannot contain both –F and + F. The sets corresponding to the vowels /i/ and /u/ are given in (4), which is just another way of representing some of the information in (3).

(4) Specification of sets of valued features corresponding to the vowels /i/ and /u/

$$/\mathrm{i}/ = \begin{bmatrix} -\text{BACK} \\ -\text{ROUND} \\ +\text{HIGH} \end{bmatrix} \quad /\mathrm{u}/ = \begin{bmatrix} +\text{BACK} \\ +\text{ROUND} \\ +\text{HIGH} \end{bmatrix}$$

There are other features relevant to vowels across languages but the three features shown in (4) are sufficient for our discussion of Turkish.

To understand the usefulness of the featural analysis of segments and to understand why we think of features and values as basic symbols, as building blocks for segments, let's see how they allow us to understand vowel harmony, which we present with some simplifications for expository purposes.

In the following table, notice that the vowel of the suffix *-ler/-lar* is identical to the preceding vowel, suggesting that the vowel in the suffix copies the set of features from the vowel immediately before it.

(5) Some Turkish singular/plural noun pairs

singular	plural	meaning
dev	devler	giant
kek	kekler	cake
ters	tersler	contrary
can	canlar	soul
tarz	tarzlar	type
kap	kaplar	recipient

With more data, we see that even when the root vowel is not /e/ or /a/, the suffix vowel is still one of those two – there are only two forms for the suffix.

(6) More Turkish data

SINGULAR	PLURAL	MEANING
ip	ipler	rope
öç	öçler	vengeance
gül	güller	rose
ek	ekler	junction
kıl	kıllar	body hair
sap	sapar	stalk
uç	uçlar	edge
son	sonlar	end

If you look at the feature chart in (3) you see that the suffix vowel is not copying or agreeing with the whole set of features from the preceding vowel, but only the information relative to the backness feature.

Phonologists say that the vowels i, e, ü, ö are –Back to mean that these symbols stand for sets that have the ordered pair –Back as a member. Similarly, we say that the vowels u, o, ı, a are +Back to mean that these symbols stand for sets that have the ordered pair +Back as a member.

(7) Front and back vowels differ with respect to the value of the feature Back
– i, e, ü, ö are –Back
– u, o, ı, a are +Back

The suffix vowel is always –Round and always –High. But the suffix vowel is either /a/ or /e/ and the choice is determined by agreement with the preceding vowel's value for Back.

This simple example already illustrates the idea of a symbol hierarchy that parallels the discussion of G&K. Features and values combine into ordered pairs of valued features; valued features combine as members of sets to constitute segments; segments can be ordered in strings as the phonological part of roots and suffixes like /ip/; and, of course, these morphemes can combine into words like /ipler/ which ultimately are strung into complex symbols referred to as sentences. The vowel harmony process shows that the generalization about which vowels occur in the plural can be expressed as a function of the preceding vowel, understood as a set of valued features. An alternative that just listed the plural form for each singular in a look-up table would fail to capture the generalization of featural agreement, and also fail to explain the fact that Turkish speakers can generate plurals that they have never encountered in accordance with the same generalization we have shown. G&K (p. 51ff) go to great lengths to demonstrate the implausibility of approaches to cognition that rely heavily on look-up tables, in part because of the problem of combinatorial explosion that we touch on in the next section.

Linguistic data structures thus are not restricted to information from a single module of grammar. Features and values and segment strings are phonological, but a morpheme is a data structure that contains several kinds of information, as in Figure 1. The morpheme is a structure comprised of linked phonological, syntactic, and semantic representations. The lexicon of a language consists of a list of morphemes (or 'vocabulary items' in some work) perhaps with some structure among the members.

We have thus laid out a taxonomy of symbols from the atomic features and values up to the level of a lexicon. Other branches of linguistics in various frameworks provide the kind of explicit models for the syntactic (e.g. Adger, 2003; Bresnan et al., 2015) and semantic features (e.g. Jackendoff, 1990) of complex symbols that we have presented for phonology.

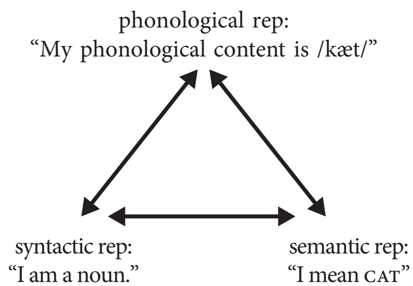


Figure 1. The morpheme of *cat*

We have suggested in this section that features are part of what Poeppel calls "the infrastructure of linguistics … [that] provides a body of concepts that permit linguists and psychologists to make a wide range of precise generalizations about knowledge of language." (35) Features are among the crucial theoretical tools that linguists use to do the work that Poeppel hopes neurobiologists can come to understand. In addition to their established theoretical utility, there is new evidence that features are neurobiologically plausible. Mesgarani et al. (2014) sought to identify the resolution at which speech sounds are received, deciphered, and encoded by the brain. They found that individual and small groups of neurons are sensitive to phonetic features in speech, supporting our hypothesis that features are indeed the atomic symbols that G&K tell us to look for.

Table 1. A hierarchical taxonomy in language

Level	Notation	Name
Atomic	{+, – } {HIGH, BACK, ROUND, *etc.* }	coefficients and features
Ordered pairs	⟨+ROUND⟩	(valued) features
Sets of ordered pairs	{ ⟨+ROUND⟩, ⟨–HIGH⟩, ⟨+BACK⟩} abbreviated [k], [i], [θ], [p] *etc.*	segments
Strings of sets of ordered pairs	[KæT]	strings (phonology of morphemes)
Tripartite structures	[KæT] and the rest of Fig.1	morphemes
Lists of morphemes	(a complex structured list)	mental lexicons

Once we adopted a feature model, we showed how features and values are organized into progressively more complex structures, providing a symbol taxonomy much like that discussed by G&K. In the next section, we examine how a small number of coefficients and features can combine to give us the great diversity of speech sounds that constitute human languages.

4. Combinatoric explosion in phonology

Once we have a system in which basic symbols, like features and values, combine into sets that constitute segments, we have a system with the potential for combinatoric explosion. As shown by Turkish, a set of three features with two possible values for each allows for $2^3 = 8$ different vowels. For each additional feature, the number of different segments doubles, so that with, say four features, we get $2^4 = 16$ segments and with a system of just ten features, we get $2^{10} = 1024$ different segments.

For reasons discussed in Reiss (2012), many phonologists have come to believe that, although a set of valued features constituting a segment must be consistent, with no conflicting values for a given feature, it need not be *complete*. That is, a segment may be represented by a set of valued features that lacks a specification for some feature. For example, the form of the plural suffix in Turkish stored in long-term memory may contain a vowel that is neither /e/ nor /a/, but rather the intersection of these two sets, namely {–HIGH, –ROUND}. The phonology of the language fills in a value for the feature BACK depending on the context of occurrence (the feature of the preceding vowel), and the 'incomplete' vowel ends up being identical to either /e/ or /a/. This idea, that segments may be incomplete, is called underspecification. For our purposes, the crucial point is that the system combining features and values becomes even more explosively combinatoric, since there are now *three* possible states for each feature in a segment: combined with "+", combined with "–", and *absent*.

This possibility of having underspecified segments has a tremendous effect on the space of possible phonological systems because we move from powers of 2 to powers of 3. Now, allowing underspecification, three features gives us $3^3 = 27$ segments instead of $2^3 = 8$; four features gives $3^4 = 81$ segments instead of 16; and ten features gives $3^{10} = 59{,}049$ segments instead of a mere 1024.

Phonologists typically assume that there are about twenty to thirty phonological features provided by the language faculty (but see Hale et al. (2007) for arguments that there may be a much greater number of innate features). For our discussion of combinatorics, let's assume a language faculty that provides just four features, a very modest number. As we have seen, a set of four features allows us to define $3^4 = 81$ segments. Given this universal inventory of possible segments, we can define a set of possible segment inventories. A given inventory is defined by determining whether each of the 81 possible segments is a member of that inventory. In other words, each inventory can be characterized by a unique sequence of 81 Yes/No answers depending on the presence of each segment in the given inventory. There are 2^{81} such sequences, and so, with just four features we can define $2^{81} \sim 2.4 \times 10^{24}$ possible inventories, which Wolfram Alpha estimates to be up to 10,000 times the number of grains of sand on earth. That many from just four features! Gallistel and King tell us that this is exactly what we need:

> What is needed is an architecture that combats combinatoric explosions with combinatorics. The key to that architecture is a read/write memory. It must be possible to store sequences that actually occur in a memory capable of storing a great many […] sequences, drawn from the essentially infinite number of possible such sequences, and to compare those stored sequences to whatever sequences may prove to be relevant. This architecture uses memory and combinatorics to cope with the finitude of the actual. (136)

The wrong way to look at our trivial combinatoric result is to ask "How can a child search the space of possible segment inventories to find that of the target language?" Coming back to the digital camera analogy given by G&K, learners don't have to store every possible inventory/image – they just have to be able to represent a particular one. In order to find this inventory, they only need to parse input into segments in terms of the four features and three states (+, –, *absent*) that we have endowed them with.

5. Variables and functions in phonology

The discussion by G&K of the necessity for variables and functions as primitives of cognition also finds support in phonology. G&K discuss a fundamental fact of mathematics concerning functions: functions of two or more variables cannot be built by composing functions of a single variable. They conclude, based on the kinds of functions that must be computed in insect navigation and other tasks, that basic cognition must allow for one argument and two argument functions as basic properties – nervous systems need to compute such functions. (With those, it is possible to build up functions of three or more arguments.) In this section, we will briefly illustrate how the notions of variables and functions appear to be needed for phonological cognition, too.

5.1 Functions of one variable: Reduplication

The phenomenon of reduplication allows us to illustrate that phonology makes use of functions of one variable. Consider the following singular/plural pairs from the Australian language Warlpiri discussed in detail by Isac and Reiss (2013).

SINGULAR	PLURAL	GLOSS
kurdu	kurdukurdu	*child/children*
kamina	kaminakamina	*girl/girls*
mardukuja	mardukujamardukuja	*woman/women*

It is relatively straightforward to say that 'child' is pronounced /kurdu/ in Warlpiri, but it doesn't really make sense to ask how the plural morpheme is pronounced. Clearly there is no one pronunciation, rather the plural corresponds to a variable, x, such that x has the same form as the noun with which it concatenates. We can think of the process that spells out the phonology of the Warlpiri plural as a function of a single variable, PLURAL(x), with x having as its domain the set of Warlpiri nouns. The output of this function is the concatenation of two copies of the (phonological component) of the input: PLURAL(x) = $x\frown x$. G&K define a variable as an address in memory. The content of that address at a particular time is the current value of that variable. Given a singular noun, Warlpiri speakers can generate the corresponding plural even if they have never encountered it before, so, it appears that the phonological content of the singular can be assigned as the current value for the variable x; that is, a phonological string symbol can be copied and written into memory at address x, and the function PLURAL can be applied to x to compute an output $x\frown x$.

Another simple example of a function of one variable is a phonological rule that nasalizes a vowel before a nasal consonant. Semi-formally, we can say that such a rule corresponds to a function NASAL(x) that maps a vowel to its nasalized counterpart. For details on how we implement such a rule, both feature-filling and feature-changing variants, see Bale et al. (2014).

5.2 Functions of two variables: Computing Identity

G&K (49) point out that the “ability to realize functions of at least two arguments is a necessary condition for realizing functions of a non-trivial nature” since, generally, “[f]unctions of one argument cannot combine to do the work of functions with two”. We can now illustrate a two argument function needed for phonological computation. Reiss (2003) argues that certain phonological processes require an evaluation of whether two segments are or are not identical. There are processes that only apply if two segments are identical and there also exist processes that only apply if two segments are *not* identical. In order to determine whether the segments in two different positions (say, the two consonants flanking a vowel) are identical, we need a function with two arguments IDENTICAL(x, y), where each variable corresponds to one of the segments to be compared. See Reiss (2003) for further discussion of the internal workings of such a function – in brief, the function has to quantify over the features in the segment sets and check for each feature F whether the value associated with F is the same in the two segments. This computation requires further variables corresponding to features and values below the segment level, but we can see that even abstracting to the segment level, we need functions of at least two variables in phonology, just as G&K propose we need “functions of a non-trivial nature” to explain well-understood processes in animal cognition.

6. Conclusions

In this paper, have presented some of the “infrastructure of linguistics” and we have shown that G&K’s animal-inspired taxonomy of symbols and the functions of a read/write addressable memory are compatible with the formal model we apply to describing and investigating phonological processes.

Hopefully this attempt to define a ‘biophonology’ will be of some use and motivation to linguists and neurobiologists alike in continuing the emerging dialogue and movement toward an explanatory neurobiology.

References

Adger, D. 2003. *Core Syntax*. Oxford: OUP.

Bale, A., Papillon, M. & Reiss, C. 2014. Targeting underspecified segments: A formal analysis of feature changing and feature filling rules. *Lingua* 148: 240–253. doi:10.1016/j.lingua.2014.05.015

Bale, A. & Reiss, C. Forthcoming. *Phonology: A Formal Introduction*. Cambridge MA: The MIT Press.

Bresnan, J., Asudeh, A., Toivonen, I. & Wechsler, S. 2015. *Lexical-functional Syntax,* 2nd edn. Chichester: Wiley-Blackwell. doi:10.1002/9781119105664

Gallistel, C.R. & King, A.P. 2009. *Memory and the Computational Brain: Why Cognitive Science Will Transform Neuroscience*. Chichester: Wiley-Blackwell.

Hale, M., Kissock, M. & Reiss, C. 2007. Microvariation, variation and the features of Universal Grammar. *Lingua* 117: 645–665. doi:10.1016/j.lingua.2006.03.009

Isac, D. & Reiss, C. 2013. *I-language: An Introduction to Linguistics as Cognitive Science*, 2nd edn. Oxford: OUP.

Jackendoff, R. 1990. *Semantic Structures* [Current Studies in Linguistics 18]. Cambridge MA: The MIT Press.

Jakobson, R., Fant, G. & Halle, M. 1967. *Preliminaries to Speech Analysis*. Cambridge MA: The MIT Press.

Mesgarani, N., Cheung, C., Johnson, K. & Chang, E.F. 2014. Phonetic feature encoding in human superior temporal gyrus. *Science* 343: 1006–1010. doi:10.1126/science.1245994

Reiss, C. 2003. Quantification in structural descriptions: Attested and unattested patterns. *The Linguistic Review* 20: 305–338. doi:10.1515/tlir.2003.012

Reiss, C. 2012. Towards a bottom-up approach to phonological typology. In *Towards a Biolinguistic Understanding of Grammar: Essays on Interfaces* [Linguistik Aktuell/Linguistics Today 194], A.M. Di Sciullo (ed.), 169–191. Amsterdam: John Benjamins. doi:10.1075/la.194.08rei

Thagard, P. 2005. *Mind: Introduction to Cognitive Science*, 2nd edn. Cambridge MA: The MIT Press.

The centrality of speech for human thought

Joana Rosselló Ximenes
General Linguistics department, University of Barcelona

Speech is not language. But without speech/sign there would be neither language nor mostly human thought. A divide between an internal wordless system and an external instrumental one for speech/sign is conceptually and empirically problematic; and evolutionarily costly. Such a divide is however assumed by otherwise opposite trends (represented, say, by Tomasello and Chomsky). An alternative view where speech and rational thought are linguistic seems better supported by facts on words, modalities (spoken and signed) and brain correlates. Evolutionarily, this view leads to place a vocal learning capacity, which is exceptional among primates, as central in language evolution. Such a capacity, run by a powerful computational system, provided Sapiens with a platform for the invention of words.

1. Introduction

In December 2014, in a workshop on the biology of language that took place in Amsterdam,[1] Chomsky argued in this way:

> […] language evolved for thought and interpretation: it is fundamentally a system of meaning. Aristotle's classic dictum that language is sound with meaning should be reversed. Language is meaning with sound (or some other externalization, or none); and the concept *with* is richly significant. (Chomsky 2014ms: 9)

At some other point in the same talk, he vindicated the perspective of the Indo-Europeanist William Dwight Whitney according to which language is "audible thinking, the spoken instrumentality of thought". Expanding on it, Chomsky referred to language as a system of "audible signs of thought" but he uttered these last words with the prosodic phrasing [[audible signs] for thought] which is not the same as [audible [signs for thought]]. The latter was the intended meaning.

1. Talk at the Royal Dutch Academy of Sciences, Colloquium on 'The Biology of Language', Amsterdam, December 19th, 2014.

doi 10.1075/la.235.03ros

This paper aims to show that the uttered version, [[audible signs] for thought], is the correct one, or equivalently that the Aristotelian dictum is right and must not be reversed. For Chomsky, that view seems to go with the belief that language has "evolved from animal communication". On the contrary, to my understanding, one can maintain at the same time that language is sound with meaning and that "the origin of the language faculty does not generally seem to be informed by considerations of the *evolution of communication* [my emphasis]" (Bolhuis et al. 2014). It is also true that language has no specialized function in contrast with alarm calls, seduction songs, deceptive displays, etc., seen in other animals. Language also differs from all these animal behaviors in the sense that it is not stimulus-driven. Still, the conclusion that is usually drawn from a Chomskyan perspective, namely that language cannot be counted among animal communication systems, falls short. In line with Balari and Lorenzo (2013), and in opposition to what from the title itself, *The Evolution of Communication,* is endorsed by Hauser (1996), one might go further by arguing that adaptive behaviors that embrace from shouting and singing to releasing volatile substances or transmitting light do not constitute a natural class that we can call communication. And since communication is not a natural class, it cannot have evolved. Those approaches contending that language is an evolved animal communication system (Tomasello 2008, and Pinker & Jackendoff 2005 among many others) would be then flawed, as argued from the Chomskian side, but for reasons that are orthogonal to the issue of whether language evolved for thought or communication. And the last claim makes sense because the argument against communication as an evolved trait does not preclude us from using communication in any other sense we need.

The view presented here is able to overcome these professedly irreconcilable views on whether language evolved for thought or communication by putting words, which by their very nature, seamlessly unit thought and communication in a system known as language, in the center of the human trajectory. Moreover, since words did not evolve by means of natural selection, no evolution of an animal communication system is implied. Words were an invention able to be learned by the offspring of Sapiens, a species biologically endowed with a typical vocal learning capacity – however unheard of among primates – run by a strictly biological computational capacity. Conceiving of words in these terms amounts to recognizing both Wallace and Darwin at the same time. As for the former, the acknowledgment is for his awareness of the non accountability, in terms of natural selection, of the gap between us and the rest of species and for the latter, for entertaining a Plan B, as Bickerton (2014) has dubbed it because of not being truly selectionist. This is what Plan B says:

> If it be maintained that certain powers, such as abstraction, self-consciousness etc., are peculiar to man, it may well be that these are the incidental results of other highly-advanced intellectual faculties; and these again are mainly the result of the continued use of a highly-developed language. (Darwin 1871: 103)

As Bickerton (2014) and Rosselló (2014) discuss, Plan B, evolutionary considerations now aside, is at odds with a widely held belief:

> This notion [plan B], if seriously advanced, is bound to meet with consumer resistance. For many people, language is merely "a means of communication." Like the Morse code or semaphore flags, it is not in itself constitutive of meaning but merely transmits meanings that have come from somewhere else. First you must "have a thought," which you then dress up in words, though exactly what a thought is and where it comes from is far less clear than what words are and where they come from. For such persons, Darwin had it backward. First human intelligence must have developed, and only after long development could anything like language have emerged. Bickerton (2014: 6)

I contend that it is not only consumer's resistance but also scholar's that Plan B faces. Furthermore, resistance to it is common whether among the proponents that "language is for communication" or among those that maintain that "language is for thought". For both, as in the quotation above, first you must "have a thought" and then you "dress it up in words". The present proposal, by adhering to the so-called Un-Cartesian program (Hinzen & Sheehan 2013) according to which language and human thought are to a great extent the same, coheres with Plan B and is intended as a contribution to it.

After a critical overview of some central points in the Chomskian stance in the first part, an alternative proposal in line with Plan B will be advanced in the second part. Apart from overcoming some problematic dichotomies, the alternative view consists of (i) a more parsimonious and bottom-up new proposal for language evolution in which vocal learning plays a greater role than what is generally thought since it supplies the computational system with a clean and apt (because of meaningless) platform for the invention of words; and is further supported by (ii) considerations on language modalities (speech and sign) and neural correlates that are in conflict with the view of language as a sheer tool for the externalization of a preexistent thought. From both (i) and (ii) the idea that speech and thought are two sides of the same coin, which is language, comes out reinforced.

2. The view from the Chomskian side: The primacy of the internal component. Problems

In Chomsky's view, the concept of language that makes sense for a scientific understanding is that of a combinatorial computational system (CCS) "implemented neurally in the brain" (Bolhuis et al. 201). The CCS consists of a combinatorial mechanism (recursive merge) applied to the so-called "conceptual atoms of the lexicon or lexical items (LI)". The CCS together with the LI constitute the faculty of language interfacing with a Conceptual-Intentional (CI) system internally and with a Sensory-Motor (SM) system externally. The SM system is also called "externalization" in contrast to the CCS+LI components and the CI, which are internal by definition. This internal system would make an independent Language of Thought (LoT) (Fodor 1975, 1983) dispensable. Whether externalization is exactly what the term suggests or something else is a question to which I will turn briefly after examining how words are problematic for this view.

2.1 Natural language, LoT and words

While assumed as perfectly sound by practitioners of theoretical linguistics in the Chomskian enterprise, this "basic design" (Berwick et al. 2013) or "phenotype" (Hauser et al. 2014) of language which demotes the SM system faces important issues. As for its internal consistency, the problem mainly revolves on the nature and role of LIs. If LIs are equated to words (or lexical roots), as it seems it is for the most part of linguists and appears in scientific papers like those just mentioned (Berwick et al. 2013; Hauser et al. 2014), the internal character of the system, if the SM component is subtracted, does not sustain itself since words, insofar as they have an inherent phonological side, are linked to externalization. Moreover, in a striking contrast with the CCS, now from a learning perspective, words happen to be learned and cannot be then inherently internal to the brain. With LIs understood as words, and therefore with phonology and learning on stage, the idea of a central internal system made up of the CCS along with LI breaks down.

At this point, one might insist on the primacy of the internal nature of language taking words and, with them, phonology and learning considerations out of the picture. LIs would not then be words but some other thing which, devoid of any sound-related property, ought at least to be usable by the CCS. This view, with LIs provided with an 'edge feature' to say it more formally, is that of Boeckx (2009, 2015) and leads to legitimately equate language in this narrow sense to the LoT – see also Burton-Roberts (2011) in this connection. Yet, without words, the association of sound and meaning that natural language is, vanishes. Presumably aware of this, Chomsky prefers to keep natural language in the picture and ends then with a tensioned if not inconsistent view. Thus, while openly skeptical about the existence of a Fodorian LoT independent of natural language – see Burton-Roberts (2011) and the controversy after Hauser et al. 2002 with Jackendoff and Pinker (Pinker & Jackendoff 2005)–, he nevertheless denies that a mental representation of sound plays any role in the LoT maintaining at the same time that natural language pairs sound and meaning. In sum, the primacy of the internal component in language cannot be coherently sustained: LoT can only amount to natural language if the sound (or sign) part in the equation natural language = meaning + sound is maintained. Otherwise, what is left is an undefined LoT.

2.2 Externalization is not secondary; and even less is internalization

Terminological choices can be revealing and should be scrutinized. 'Externalization' goes with the implicit assumption that there is something internal to be executed, produced. Against what the term suggests, however, externalization is not exclusively associated with speech production but with speech perception too, which is internalization, the opposite to externalization. It is true, on the other hand, that the equation externalization = SM, where SM stands for Sensory and Motor, is well established so that the terminological choice might seem irrelevant. For the sake of the argument, one might then say that it should be the same to choose the sensory dimension to fix the umbrella term and refer to SM as 'internalization'. Would this hypothetical terminological choice have worked? I suspect it would not. It seems clear that the detachability of the internal system would have become more dubious than with the current term of 'externalization': thinking of something internal which must be associated with an internalization component seems to make it impossible for the former to be isolated from the latter. What would the internalization component feed if not the internal system itself? Once the terminological choice has unveiled its import, one may go further to uncover that for the viability of the internal system itself it is precisely perception/internalization rather than production/externalization that counts.

Cases like that of the Irish writer Christopher Nolan (see Hickok 2014: 149), who was quadriplegic from birth, strongly suggest that speech perception on its own is perfectly able to make possible a full-fledged internal language and therefore that perception can work regardless of motor behavior, inexistent in this case. This, unsurprisingly, it is not the case the other way around. An intact motor system, when not paired with a minimally working sensory system, cannot feed cognition. Children born profoundly Deaf illustrate that. As is uncontroversially accepted nowadays, Deaf children in order to reach a fully developed cognition need to be exposed to the gestural-visual modality. If only exposed to the oral-auditory one, for which they show a non-motor, uniquely perceptual primary impairment, they risk ending up with a handicapped cognition (Meristo et al. 2012), apart from facing extraordinary difficulties to produce the linguistic sounds despite their intact motor apparatus. The primacy of perception over production has gone strikingly unnoticed, as the uninformed label "deaf-mute" reveals. In short, the term 'externalization' does not seem to fit well with ample evidence for the primacy of perception in language. This primacy is, on the other hand, easy to understand when language is seen as built upon a vocal learning system which is a kind of learning that crucially depends on sensory feedback. How language was evolutionary built on a vocal learning system is the focus of the second part of this article.

Not everyone failed to notice the significance of linguistic feedback for cognition in humans or, in a roughly equivalent way, of speech for thought. Hockett

(1960: 6) for instance wrote that "feedback is important since it makes possible the so-called internalization of communicative behavior that constitutes at least a major portion of "thinking". It is worth to note that in Hockett's words, internalization is again taking the lead, which brings to an integrated view of communication and thought.

2.3 Words in language are everywhere, not only in the conceptual-intentional system

The "internalization of communicative behavior" goes with words, which have to be uttered by some interlocutor, of necessity. Words are therefore present in speech perception and production, in internalization and externalization. They are also active in our minds/brains when we are silently thinking. It is in this regard that words turn out to be completely different from non-human animal communication signals that are instructions for specific actions and mind-independent, to use the Chomskian notion. The detachment of action that words instead afford us must be linked to their mind-dependent character and, to my understanding, might well be related to the Saussurean arbitrariness – in a way that should be specified. It makes sense that the hallmark of human intelligence, namely its proneness to spread over multiple domains, is mostly ascribed to words and their detachment form behavior. By contrast in non-human animals, it seems that a focused, specialized intelligence has to be necessarily related to specific behaviors (navigation, nest/dam/mound building, grooming, survival from predators, etc.).

The conclusion to be drawn from the previous thoughts is not that of Hauser et al. (2002:1576) however, namely that "this component of FLB (conceptual-intentional) is also uniquely human", where "this component" refers to "many of the elementary properties of words" and FLB to Faculty of Language in the Broad sense. Such a conclusion is wrong insofar it locates the unique-to humans attribute of having words with all the properties they have in the CI system alone. Whereas this move clearly reminds us of the position presented in the above section on LoT, here – in Hauser et al. (2002)–, it is more striking because immediately preceded by explicit mention of *words* (instead of the more elusive *lexical items*), their "mode of acquisition", the absence of "vocal imitation in nonhuman primates" and "the rate at which children build their lexicon" among others. Expressed in a different way, from Hauser et al. (2002) premises, the right conclusion would be that words are candidates to be part of FLN (Faculty of Language in the Narrow sense), the uniquely human subset of FLB, because their properties show up across the board through the different components of language involving both sensory and motor aspects necessarily part of the acquisition of lexicon in normalcy. The fact that in opposition to Hauser et al. (2002), Hauser (2009: 93) himself takes words as "externalized symbols" whose construction and management the author considers one of the ingredients of "humaniqueness" stresses how elusive words are in the dichotomous Chomskian stance.

2.4 Towards an integrative view: From Chomskian dichotomies to codependences

In the wake of the strict divide between what is CI (internal) and SM (external), other dichotomies arise in the Chomskian view. They are mainly the following ones: competence vs. performance; individual vs. social; innate vs. learned; thought vs. communication; and, ultimately, biology vs. culture. That they partially overlap is manifest so that to some extent the criticism exerted on the first one would revolve around the others. With regard to the last and biggest one, biology vs. culture, it is interesting that in theoretical biology notions like "developmental hybrid" (Griesemer 2014) have been advanced to face cases where biology and culture, nature and nurture, integrate in a fluid and interactive view (see Balari & Lorenzo 2015a, 2015b). It seems then that what Darwin suggested in his Plan B according to which our "highly-advanced intellectual faculties" would rely on language, which is not given entirely by nature, is not anymore a chimera.

There is a further strategic justification to shift gears and try to build a view of language more integrative and in that with more cognitive import. For reasons that it would take us to far afield to consider, to the conceptual hurdles in part seen through the above, there has to be added a progressive reduction of linguistic specificity that has taken place in the framework of the Minimalist Program, the late development of generative grammar. Internal-Language (I-Language) has shrunk so much as to contribute the generative procedure itself (the CCS) alone, at least in many minimalist instantiations. Without denying the fundamental role of the CCS for the workings of the entire system, it is nevertheless clear that such combinatorial engine *per se* does contribute to the structure but not to the content of the CI interface. It follows then that regarding *content*, the specific mode of human thought is not informed by syntax and even less by speech, in this view.

The distant support of theoretical biology and some urge driven by the current stage in linguistic theory (syntax), both introduced above, constitute sort of a background for an alternative view of language and its evolution whose merits will have to be assessed independently of this background.

3. A view of language with speech and vocal learning as foundational

According to the alternative approach to be presented here, human thought relies on language to a greater extent than usually assumed, much in the spirit of Darwin's Plan B. That would be a consequence of how the species might have got language, namely on the basis of an evolved vocal learning capacity run by a powerful CCS. By vocal learning is meant an ability to learn structurally organized sounds from a tutor and to modifiy them on the basis of auditory feedback (Jarvis 2007). This capacity would have afforded the invention of words and their combination by grammar – whose obscure emergence and crucial contribution is left aside here. A silent duplicate of this equipment, which goes along with what vocal learning and words are, would have provided the individual so endowed with the cognitive profile that sets our species apart from the rest. The view which ensues from this account is that of language as sort of a bivalve shell constituted by speech and thought.

In what follows I present an evolutionary scenario that coheres with the above together with some evidence based on neural correlates and atypical cognitive profiles both suggesting that speech and thought are intimately linked rather than in a hierarchical arrangement where speech would be the distal expressive component, a fortunate accident inconsequential for thought. How sign fits in with this view is also addressed.

3.1 Words and vocal learning: Words came with syntax

A non-controversial claim regarding language evolution is that for language, words and a CCS (or 'syntax' in this context) are necessary. Their order of appearance has been extensively debated instead. As foreseen, the 'externalization as secondary' or 'words after syntax' aligns with Chomsky's side. There is a problem, however, affecting this view that has been persistently noted by Bickerton (2005, 2014; see Rosselló 2006) and that echoes some discussion in the first part of this article. And the problem is that Chomsky contends that syntax can only apply to mind-dependent entities that find no equivalent in the domain of animal signals which are mind-independent, think of vervet calls for instance, i.e. endowed with an inherent, direct reference to some aspect in the world. This being so, the shortcoming in Chomsky's account is made evident by the following question: what was merged by the CCS if there were no words yet? Words would have qualified since they do not directly refer, they are mind-dependent in Chomskian terms. But, as said, words were not still there. And the question stands out. At that point one might feel tempted, in the wake of Bickerton (1990, 2014), to invert the terms and put "words before syntax". It is dubious however that this might be a good move. The key role that words play, as Bickerton (2014) has explained, does not require that they preceded syntax in language evolution. In line with Tattersall (2008, 2014), the fact that words are the hallmark of symbolism together with the lack of unequivocal evidence for it before the *great leap forward* seems to constitute the strongest argument for a recent origin of words, a culturally triggered invention sparking a new era in which the most consequential change ever known among the species took place. At that point it happened that

> Inside their heads they [humans, start to] break down the outside world into a mass of mental symbols, then recombine those symbols to recreate that world. What they subsequently react to is often the mental construct, rather than the primary experiences themselves. (Tattersall 2008: 101)

Symbols and recombination, which amounts to words and syntax together. These ingredients along with the grammar partially distilled from words is what constitutes the core of language. No demotion then of the primary character of words argued for in Bickerton 2014, but no necessity either that "the invention of words long preceded anything one could call language" (Bickerton 2014, ms.); precursors for presyntactic words, lacking therefore their edge property, present an unnecessary difficulty if only to focus on the most important one. To get rid of the opponents disputing the primacy of words in his account, Bickerton refers to the musical protolanguage and discards it along with its "holophrastic version" (Wray 2000). Here I disagree, and yet I concur with Bickerton (2007) in the criticism of the "holophrastic protolanguage". Where I differ is in considering such holistic protolanguage as a version of the "musical protolanguage" argued for by Darwin (1871) and many others afterwards –without the equivocal term 'protolanguage' in the case of Darwin.

On the contrary, I contend that any vocal behavior yielded by a system of vocal learning might have qualified as the main precursor necessary for the scenario depicted. Dubbing it musical protolanguage is rather peripheral for my purposes here. What is substantial in the proposal is that a vocal learning capacity of the kind shown in songbirds (Arriaga & Jarvis 2013) provides a fit platform for the invention of words and also an inherent CCS. Regarding how words could have been invented, the availability of a syllabic protolanguage in the strong sense, namely with precursors for current vowels and consonants, should not count as far-fetched as many other just-so stories in view of what geladas' vocalizations show.[2] And with respect to the CCS, it has been proposed (see Balari & Lorenzo 2015b) that birdsongs and language are homologs, the result of the same biological

2. Geladas are an old-world monkey species that live in the highlands of Ethiopia (and in zoos). They are very gregarious and present with different kind of vocalizations. The so-called wobbles simultaneously combine lip-smacking and phonation, which is exceptional outside of human language thus far. See Richman 1976 and Ghazanfar 2013.

organ, a CCS – in our terms – that shows up in 'different specific character states'. In this connection, it has to be pointed out that the hierarchy that birdsongs lack (see Bolhuis 2014) might well be derived from properties of the objects to which *merge* applies, that is from properties of words themselves. As said before, we are, however, still at a loss on how grammar with its universal hierarchy of functional categories arose – but see Miyagawa et al. 2013.

3.2 What vocal learning gives us for free

Sapiens are vocal learners, probably the unique species endowed with this capacity among terrestrial mammals and one of a kind among primates. This is a fact. The extent to what vocal learning contributes to language has nevertheless been underestimated. According to the previous claims, a vocal learning system would play a much more relevant role in language phylogeny than usually thought both because of providing the vehicle for words and because of incorporating a CCS of its own. With words, the system became speech, a biologically deviant but nevertheless viable vocal learning system, implementable in the human brain. Let us briefly mention other potential gains provided by the vocal learning capacity underlying language.

Structurally, a vocal learning system underlying language supplies us with the basis for phonology with its characteristic lack of constraint in the combinations of sounds that can be generated, in a striking contrast with the vocalizations of other primates. Functionally, it goes along with a capacity for imitation which is a requirement for language acquisition and guarantees a tight social interaction among conspecifics.

A vocal learning system, which forcefully at some point was installed in our ancestors, had to enormously enhance the social profile that we see in other primates. A primate endowed with a vocal learning capacity built on, or combined with, the intentionality characteristic of great apes was a creature that was on the verge of language, of spoken language in particular. Probably we will never know what the spark was that in a group of hominids with vocal learning and the ensuing behavior lighted the genius for words and symbolism. Yet, a strikingly overlooked combination of vocal learning and primate intentionality, both being matter of fact rather than just-so stories, allows us to considerably naturalize the otherwise miraculous character of language.

As said, vocal learning entails a capacity for fine-grained imitation which is crucial for language acquisition and for word learning in particular. No need, then, of mirror neurons for which, on the other hand, there is no evidence in humans, contrary to the general belief. Mirror neurons have indeed been observed in monkeys but the excitement with the finding has lessened because of being only a conjecture in humans. Besides and more importantly, there has been a gross failure in the predictions of mirror neuron theory, which are the only thing that, given the impossibility of a direct research on humans, will count as supporting evidence (see Hickok 2014). Because of relying on this theory, the most elaborate proposal for a gestural origin of language, that of Arbib (2012), has also lost some credentials. The idea was that since macaques' mirror neurons do not become activated by vocalizations but by goal-directed hand movements, and mirror neurons in macaques are located in an area in the brain, F5, that is considered by some researchers as a homolog to Broca's area in humans, it made sense to assume a manual/gestural origin for language. However, as just said, the conjectured mirror neurons have not resisted scientific scrutiny. The prediction that damage in Broca's area must disrupt speech or sign perception failed (see Emmorey 2013 and Hickok 2014 for some more puzzling facts for the theory).

3.3 Speech and sign: Why speech is default

Irrespective of the apparent failure of the mirror neurons theory, the present account yields an answer to the related puzzling questions of why speech and not sign is phylogenetically default (Goldin-Meadow 2008) and which of both was first. Let us see how.

Consider that (a) sign languages are languages in the full sense of the word; (b) ontogenetically there is no bias in favor of spoken language: a hearing infant can acquire language in both modalities and (c) a gestural protolanguage has been proposed (Arbib 2012, Corballis 2002, etc.). Given (a), (b) and (c), the reason why the oral modality has been selected as the default remains elusive. In fact, for approaches like that of Arbib (2012), the transition to speech and its consolidation as the default modality constitute a major challenge.

By contrast, in the light of the proposal put forward here, the solution to the puzzle (a)–(c) imposes itself: there would have not been a gestural protolanguage ever. And the rationale is that a vocal learning system requires an auditory-vocal integration, which goes with a copying ability and is implied in birdsong and speech. In contrast, a "visuo-gestural" integration of the copying kind obtains forcefully in the signed modality systematically (and in other human occasional mimicry practices) but is non-existent outside sign languages themselves. There is no non-human natural "gestural learning system" so to speak. This is in striking contrast with vocal learning that was in nature much before our species evolved, which seems to constitute a strong argument in favor of the evolutionary priority of the spoken modality and a good explanation for its default character. The overlapping neural network for both modalities is also consistent with the idea that sign languages might have been modeled after spoken languages.

An important qualification is in order. The divide between sign and speech does not amount to a monomodal view of spoken language (Gillespie-Lynch et al.

2014). There is more in the so-called co-speech gestures that an accompanying ingredient. And besides the co-speech gestures, which are holistic, deictic gestures should be considered as shared across sing and speech. As Hinzen & Sheehan (2013) argue, pointing should be taken as the first instantiation of grammar in ontogeny – see Tomasello et al. (2007) for a different view.

3.4 Sensorimotor integration with copying is at the basis of language and human cognition

Against what Chomsky (2014: 9ms) contends when saying that "Language is meaning with sound (or some other externalization, or none)", what the availability of two natural modalities for language shows is not their secondary or inconsequential nature but the compulsory presence of a sensorimotor system on top of which language can develop. Furthermore, thinking of language with "some externalization or none" seems to be actually wrong in the "none": without a SM/ externalization system is not possible to develop language and human cognition normally, which is in line with the Darwinian Plan B in which the use of language is a requirement for high cognition.

The recruitment of the non-default visuo-gestural sensorimotor integration system is, instead, safe for both a linguistic and consequential cognitive normal growth. A deaf child is not precluded from fully developing linguistically and cognitively if provided with the equivalent amount of linguistic input that a hearing child receives (Humphries 2014). In a complementary way, we find instead that irrespective of a spared ear, the disruption of the sensorimotor integration for speech, can be devastating. This is what autism shows. Around a 25% of the autistic population is not verbal and speech problems are not rare in the rest. Furthermore, as Lombardo (2015) notes there is a correlation between speech impairment and cognitive outcome: poor speech in autism goes hand in hand with abnormal cognition. The preference for human voice that children present with at birth (Vouloumanos et al. 2014a, b) might be absent or reduced in the spectrum (Blasi et al. 2015). Furthermore, it might well be that speech leads to pointing -which not accidentally is often absent or abnormal in autism – after guiding joint attention in the first months of human life. As if this were not enough, to our astonishment, a very recent study (Marno et al. 2015) concludes that four-month-old children have a "basic expectation about the symbolic nature of verbal labels" that other auditory stimuli do not trigger. Altough Marno et al. (2015) refer to human language as a "special auditory stimulus" – in a view that is reminiscent of Fodor (1983), who sees language as an input system alone – and are completely oblivious of the most comprehensive sensorimotor integration system that goes with audition, it might be argued that the preference for these and not other auditory stimuli derives from the fact that these and not other are the ones that are conveyed by the sensorimotor integration system necessary in the end to be able to speak.

Be that as it may, humans are tuned to speech from birth, which would not have to come as a surprise. For songbirds it is the same, they are tuned to the songs of their conspecifics that are internally rehearsed to be later produced. The crucial difference is that from very early in development there is meaning going along with sounds only for humans.

3.5 A parsimonious and integrative account of how we got language

By putting vocal learning as the platform on top of which language was built, it would seem that with respect to the "externalization as secondary" view, the whole system has been put upside down. Although such an interpretation would be to some extent right, it needs to be qualified. The current proposal, as its opposite, goes associated with a given CCS, which is seen as part of Sapiens genetic endowment and shows the properties that the theory of formal languages and theoretical linguistics have formulated. As in the opposite account, and in contrast to views as that of Jackendoff (2002), the idea is that this CCS is a single one in humans and underlies both internal (syntactic) and external (phonological) computations.

On a different tone, the proposal also assumes a substrate of primate cognition and, in particular, primates' social skills along with their intentional behavior. As for qualifications, it must finally be made explicit that vocal learning is taken as a genetically determined capacity which is a prerequisite for language acquisition. The suggestion that word learning might rely on general domain capacities (Hauser et al. 2002) does not seem right in view of facts such as the bias for speech rather than other sounds in newborns, the consequences of its absence in part of the autism spectrum (Hinzen et al. 2015) and other considerations in line with those made known by Fodor (1983) such that of speech perception as a reflex for humans. As a consequence, it can be argued that vocal learning must enter any account intended to explain how Sapiens got language. See below its advantages over primate calls.

Everything considered, the proposal brought forward here does not seem to turn to unaccountable steps to yield language. In a way, it shows that the evolution of language might have got from nature everything but words, that at some recent point in the human lineage were invented as they are now. In this regard, the account is biologically loaded since the ingredients and mechanisms for phonology and syntax (not grammar) were put by nature rather than nurture. As said before, even vocals and consonants, which are essential to build a lexicon, could have been made available by nature, as geladas' wobbles suggest. In agreement with this favored naturalistic stance, we have seen that language should have started as speech rather than sign.

In line with the previous remarks, and to round off what has been advanced in the above sections, a proposal where vocal learning sets the stage for language evolution in primates ends out being considerably parsimonious and integrative. Let us see how.

Such a proposal is more parsimonious than the "externalization as secondary" because it does not posit a distinctive human thought detached from language, which will also be distinctively human. In other words it does not need two evolutionary episodes but one, because, overtness apart, speech and human thought are essentially the same, i.e. language. Crucially, the strategy of reducing exceptions stands out for vocal learning itself and language: Sapiens is the only species with language and the only primate with vocal learning heard of up to now. A proposal that makes vocal learning as essential as letting language be built on top of it minimizes what otherwise would be sheer coincidence. Moreover, the coincidence enlightens the puzzling fact that among vocal learners only our species has language: it would be only ours since a primate cognition is necessary together with a vocal learning capacity to reach the stage where language was made possible. Interestingly, primate calls which are common across monkeys and apes do not qualify – against Miyagawa et al. (2013) and Nóbrega and Miyagawa (2015) – as precursors of language not only because they are not the expression of vocal learning and on the contrary they are innate and almost irrepressible, but because they are not articulated and can be invested with some kind of referentiality of the mind-independent type which would have hindered rather than propelled the invention of words.

An integrative strength is also consubstantial to the view on language evolution defended here. The non-selectionist, cultural origin of words, would go hand in hand with their status as inhabitants of the human brain in a clear example of their defiance to the dichotomy culture vs. biology. Also the debate on the primacy of either communication or internal computation extinguishes when vocal learning is at the basis of language in that vocal learning requires both. And the same applies to the opposition between social behavior and individual capacity.

Finally, by considering language as a cognitive development of a vocal learning system, the UG's (Universal Grammar) domains would diminish. Against what Chomsky (2014: 7) suggests, it is not because UG reigns "from the moment of birth [that] a new-born human infant instantly selects from the environment language-related data, no trivial feat, [whereas] an ape with approximately the same auditory system hears only noise." No, it is because human infants are vocal learners and apes are not.

3.6 Speech, brain and thought

Although there are many confounding and limiting factors that may distort the results obtained through the ever growing research on the brain basis for cognition by means of continuously improved techniques in brain imagery and electrical tracing, it is notwithstanding true that these techniques are contributing to our understanding of the human mind. In the inquiry of how language works in the brain in particular, a great amount of those limitations comes from sort of taking from granted academic domains (syntax, semantics, phonology, pragmatics) as if they were natural objects, which they probably are not. Another risk, this time coming rather from the neuro(psychology) side, is the standard practice of testing 'activations' for artificial tasks (priming, repetition, naming, reading aloud or silently) that might be generated in task-specific ways which depart from those working in ordinary settings like engaging in a conversation, thinking in the awake resting state, etc. In short, we are still far away from overcoming the 'granularity mismatch' (Poeppel & Embick 2005) between the domains of linguistics and the different neurodisciplines.

Yet, with all the caution that follows from the previous considerations, there are two aspects to highlight in the context of the issues raised in this paper. The first one is that little is known about how phonology, i.e. segments (vowels, consonants), syllables, sonicity, etc., works in the brain (see Berent 2013). The second one, which I will shortly discuss here, is that both the scarce distinctive neural differences related to language in strictly anatomical terms and the left hemispheric specialization for language are to be referred specifically to speech. Furthermore, up to this time, there seems to be neither speech-independent language related networks nor speech-independent distinctive structural or functional specialization. Let us see it.

Among terrestrial mammals, the so far unique distinctive anatomical structure for language is, as matter of fact, for speech. It consists of the direct projection from cortex (layer 5 neurons) to brainstem (nucleus ambiguous) which allows for a fine control of laryngeal phonation. A similar, probably homolog neural connection is the projection from the forebrain to the brainstem of songbirds for the fine control of syringeal phonation (Fitch 2010a; Fitch 2010b; Arriaga & Jarvis 2013; Arriaga et al. 2012). In what has been called the Kuypers-Jürgens (Fitch 2010a) hypothesis, vocalizations that are independent of the state of arousal and are not innate are in need of this forebrain/cortico-ambiguo connection which contrasts with the midbrain generator of innate vocalizations (laughter and sobbing in humans included).[3]

The dominant lateralization (to the left hemisphere in most humans) for language has also to be understood in reference to speech in particular – to both production and perception. Eventually it was Broca's initial insight and has been

3. Arriaga et al. 2012 have found that mice, whose songs are innate, also present this cortico-brainstem connection. It would be interesting to know whether gibbons, the only singing primate species beside humans, whose songs are also innate, present this neural connection as well. Brain correlates for gelada's wobbles should also be studied.

emphasized by others (see Boeckx et al. 2014a, b) that are also adamant to keep distinguishing in substantial ways language from its externalization, i.e from speech/sign. The problem, however, is that the attempts to demarcate speech, by locating it mainly in left cortical areas, from something more abstract but also of linguistic nature (Boeckx & Burraco 2014) are broadly equivalent to attempts to relativize the role of cortex for cognition in general (Lieberman 2013). That said, it turns out that the subcortical involvement called for in either case singles out the roughly same subcortical networks that it might well be that end up as homolog to the corresponding networks in songbirds below their forebrain, namely the basal ganglia and the thalamus – cerebellum does not seem to play a role in birdsong. If it is true that a much fine-grained detail of the contribution of subcortical structures to language and high cognition may debunk this striking coincidence, the view obtained so far is that in which the circuitry allegedly crucial for high cognition is also underlying the ability to sing in songbirds, an ability widely, and correctly, assumed to be devoid of meaning and therefore not in the realm of high cognition. This is a problem for the Chomskian stance but not for the position argued for here. On the contrary, it coheres with the view that the computational engine in human brain (Lieberman 2006; Balari & Lorenzo 2009) has its roots in a homolog sequencer to that in charge of birdsong which was later coupled with words or symbolism.

Looking at the cortical contribution, the "externalization as secondary" view confronts further inconsistencies. According to it, speech along with words and left lateralization for language would have no cognitive import.[4] There are however some facts that suggest otherwise. Left lateralization for language is a particular case of hemispheric specialization, a characteristic that is partially in place at birth in humans but mainly emerges through development in childhood. In striking contrast to the aphasias that post-puberty lesions in left perisylvian areas result in, very young children are not precluded from learning their language after a surgical removal of (part of) the left hemisphere (Deacon 2006). This contrast leads to look at child development to understand the phenomenon. And there we find that hemispheric specialization constitutes a relatively steady brain state which unfolds from birth progressing towards a "dynamic decrease in interhemispheric connectivity and increase of intrahemispheric connectivity" (Hervé et al. 2013).

4. Lesions in the perisylvian areas for language resulting in aphasias would not either affect cognition according to this view. On this important issue for the position argued for in the text, see Hinzen & Sheehan 2013: 8.3.

Hemispheric specialization, on the other hand, is not neutral in cognitive terms. On the contrary, abnormalities related to it underly both autism and schizophrenia, as has been observed repeatedly (Lombardo et al. 2015; Nielsen et al. 2014; Kujala et al. 2013, for autism; Angrilli et al. 2009; Crow et al. 2013). This alone is suggestive of a linguistic factor in the hemispheric specialization because of linguistic abnormalities being present in either. Moreover, the suggestion is strengthened by the fact that is language itself that ends up predominantly in the left hemisphere in normalcy. This happens in a complementary form with regard to visuospatial abilities that rely more on the right hemisphere in a pattern that is believed to be the default for the cognitive profile typical in humans (Hervé et al. 2013) and has extensively been shown since Sperry's experiments with split-brain subjects in the sixties (Gazzaniga 2005). Beyond the raw fact of language being acquired precisely along the development of the hemispheric specialization, which *per se* speaks of its contribution to the specialization, and hence to typical human cognition, there are additional reasons to ponder. An important one is that this 'central asymmetry', contrary to a widely spread belief, is not observed in songbirds in the same way. In contrast to humans, left lateralization in oscine birds, appears to be peripheral, at the level of the hypoglossal nerve that controls the syrinx. It does not seem to be an adult and steady trait either but rather a juvenile one (Moorman et al. 2012).[5] That being so, the steady character of language lateralization cannot be derived from vocal learning as such. The hemispheric segregation observed in humans might be somewhat related to the fact that language requires different *processing* rates running in parallel to compute all the overlapping elements with a meaning import that are conveyed in speech.

As a matter of fact, the role of brain rhythmic oscillations in human cognition and communication is now a growing field of research in neuroscience. And in this field it is widely assumed that the kind of fast processing required for segmental phonological analysis is carried out by the left auditory cortex where oscillations in the gamma-band range (30~ ms.) entrain to the segmental pace in the stimulus; prosody, instead, which runs at a lower pace synchronizes with slower oscillations in the theta-band range (150~ ms.) in the right auditory cortex (Giraud & Poeppel

5. Regarding the peripheral character of the asymmetry, Suthers 1997 says that there is "absence of hemispheric asymmetry in the morphology or activity of the song control nuclei above the hypoglossal nucleus." (Suthers 1997: 648). Moorman et al. (2012) report that in zebra finches, there is left lateralization at the NCM (caudio medial nidopallium), which is in charge of song perception, in the learning period. Either in adult or juvenile individuals, activation in the HVC (a letter based name), the central motor nucleus that is in charge of song production, was found also in sleep. This spontaneous activation is not seen in Broca's area in either adults or infants.

2012). In accordance with this division of labor is the fact that right hemisphere damage can often result in aprosodic speech.

In short, there starts being ample evidence supporting the view that it is speech processing (see also Ocklenburg 2012 and Pulvermüller et al. 2012) through language development in childhood that drives a significant left lateralization for language and a consequential by-product hemispheric specialization – visuospatial abilities to the right hemisphere – with all the cognitive significance it has in humans. In this light Balari and Lorenzo's (2015b) claim that "there is no real distinction between the development of the brain and the acquisition of language" could hardly be more appropriate.

The involvement of sound processing in thinking, another aspect that comes as a natural expectation from the proposal presented in this paper, has also been suggested by different studies nowadays. It seems to be the case that areas widely assumed to be involved in speech processing at its distal ends are not in charge at these terminal points. Flinker et al. (2015) have shown by means of direct recordings in neurosurgical patients that Broca's area "is surprisingly quiescent during articulation" and add that "contrary to classic notions of this area's role in speech, our results indicate that Broca's area does not participate in production of individual words". In a similar tone, again by means of recording the electrophysiological activity in language areas in awake neurosurgical patients, Magrassi et al. (2014) have found that "the electrocorticogram correlates with the sound envelope of the utterances, starting before any sound is produced and even in the absence of speech" and conclude that "sound representation is at the heart of language and not simply a vehicle for expressing some otherwise mysterious symbolic activity of our brain."

Finally, it is also relevant to consider the classical arguments in favor of the divide between competence and performance – or, in a roughly equivalent way, between I-Language and externalization – in the light of brain imaging of linguistic tasks comparing perception and production. According to the standard Chomskian view, the idea is that underlying production and perception there should be a separated but common knowledge system for both. However, taking into consideration what Menenti et al. (2011) have found, it seems that the areas activated for syntax, semantics and phonology mostly overlap in speaking and listening. That is a problem for the idea that there must be an I-Language detached from speech as the guarantor of the necessary coincidence of the linguistic construct both in production and perception. All in all, this leaves open the possibility that the guarantor is the sensorimotor integration system itself, that which is involved in speaking (production and perception) and runs through any vocal learning system.

To close, one would say that what we have learned from neuroscience supports the view defended here by showing that sound is, say, close to thought and that language in the brain essentially overlaps with speech in the brain.

4. Conclusion

The aristotelian dictum according to which language is sound with meaning is literally right and does not need to be reversed to "language is meaning *with* sound" as Chomsky contends. Speech is not secondary. On the contrary, speech shapes the human thought. Speech and thought make language side by side. The leading role of speech is well supported empirically in terms of modalities (speech and sign), brain correlates, ontogeny and phylogeny. A vocal learning system underlying language can explain many of its characteristics.

References

Angrilli, A., Spironelli, C., Elbert, T., Crow, T.J., Marano, G. & Stegagno, L. 2009. Schizophrenia as failure of left hemispheric dominance for the phonological component of language. *PloS One* 4(2): e4507. doi:10.1371/journal.pone.0004507

Arbib, M.A. 2012. *How the Brain Got Language*. Oxford: OUP. doi:10.1093/acprof:osobl/9780199896684.001.0001

Arriaga, G. & Jarvis, E.D. 2013. Mouse vocal communication system: Are ultrasounds learned or innate? *Brain & Language* 124: 96–116. doi:10.1016/j.bandl.2012.10.002

Arriaga, G., Zhou, E.P. & Jarvis, E.D. 2012. Mice, birds, and men: The mouse ultrasonic song system has some features similar to humans and song-learning birds. *PLOS ONE* 7(10): 1–15. doi:10.1371/journal.pone.0046610

Balari, S. & Lorenzo, G. 2009. Computational phenotypes: Where the theory of computation meets Evo–Devo. *Biolinguistics* 3(1): 002–060. ⟨http://biolinguistics.eu/index.php/biolinguistics/article/viewArticle/93⟩

Balari, S. & Lorenzo, G. 2013. *Computational Phenotypes. Towards an Evolutionary Developmental Biolinguistics*. Oxford: OUP.

Balari, S. & Lorenzo, G. 2015a. The end of development. *Biol. Theory* 10: 60–72. doi:10.1007/s13752-014-0180-0

Balari, S. & Lorenzo, G. 2015b. It is an organ, it is new, but it is not a new organ. Conceptualizing language from a homological perspective. *Frontiers in Ecology and Evolution* 3: 1–18. doi:10.3389/fevo.2015.00058

Berent, I. 2013. *The Phonological Mind.* Cambridge: CUP.

Berwick, R.C., Okanoya, K., Beckers, G.J.L. & Bolhuis, J.J. 2011. Songs to syntax: The linguistics of birdsong. *Trends in Cognitive Sciences* 15(3): 113–121. doi:10.1016/j.tics.2011.01.002

Berwick, R.C., Friederici, A.D., Chomsky, N. & Bolhuis, J.J. 2013. Evolution, brain, and the nature of language. *Trends in Cognitive Sciences* 17(2): 89–98. doi:10.1016/j.tics.2012.12.002

Bickerton, D. 1990. *Language and Species*. Chicago IL: The University of Chicago Press.

Bickerton, D. 2007. Language evolution: A brief guide for linguists. *Lingua*117(3): 510–526. doi:10.1016/j.lingua.2005.02.006

Bickerton, D. 2014. *More Than Nature Needs: Language, Mind and Evolution*. Cambridge MA: Harvard University Press. doi:10.4159/9780674728523

Blasi, A., Lloyd-Fox, S., Sethna, V., Brammer, M.J., Mercure, E., Murray, L., Simmons, A., Murphy, D.G.M. & Johnson, M.H. 2015. Atypical processing of voice sounds in infants at risk for autism spectrum disorder. *Cortex* 71: 122–133. doi:10.1016/j.cortex.2015.06.015

Boeckx, C. 2015. *Elementary Syntactic Structures. Prospects of a Feature-Free Syntax*. Cambridge: CUP.

Boeckx, C., Martinez-Alvarez, A. & Leivada, E. 2014a. The functional neuroanatomy of serial order in language. *Journal of Neurolinguistics* 32: 1–15. doi:10.1016/j.jneuroling.2014.07.001

Boeckx, C. & Benítez-Burraco, A. 2014b. The shape of the language-ready brain. *Frontiers in Psychology* 5: 282.

Bolhuis, J.J., Okanoya, K. & Scharff, C. 2010. Twitter evolution: Converging mechanisms in birdsong and human speech. *Nature Reviews Neuroscience* 11: 747–759. doi:10.1038/nrn2931

Bolhuis, J.J., Tattersall, I., Chomsky, N. & Berwick, R. 2014. How could language have evolved? *PLoS Biology* 12(8): e1001934. doi:10.1371/journal.pbio.1001934

Burton-Roberts, N. 2011. On the grounding of syntax and the role of phonology in human cognition. *Lingua* 121(14): 2089–2102. doi:10.1016/j.lingua.2011.08.001

Chomsky, N. 2007. Approaching UG from below. In *Chomsky's Minimalism and the View from Syntax-Semantics,* U. Sauerland & H.-M. Gartner (eds), 1–29. Berlin: Mouton de Gruyter.

Chomsky, N. 2013. Problems of projection. *Lingua* 130: 33–49. doi:10.1016/j.lingua.2012.12.003

Chomsky, N. 2014. The biology of language. Royal Dutch Academy of Sciences (KNAW), Trippenhuis, Amsterdam. ⟨https://www.youtube.com/watch?v=H-fRSrfr2L0⟩ (12 December 2014).

Collier, K., Bickel, B., van Schaik, C.P., Manser, M.B. & Townsend, S.W. 2014. Language evolution: Syntax before phonology? Language evolution: syntax before phonology? *Proceedings of the Royal Society B*, (June).

Corballis, M.C. 2002. *From Hand to Mouth: The Origins of Language*. Princeton & Oxford: Princeton University & OUP.

Crow, T.J., Chance, S.A, Priddle, T.H., Radua, J. & James, A.C. 2013. Laterality interacts with sex across the schizophrenia/bipolarity continuum: An interpretation of meta-analyses of structural MRI. *Psychiatry Research* 210(3): 1232–1244. doi:10.1016/j.psychres.2013.07.043

Darwin, C. 1871. *The Descent of Man, and Selection in Relation to Sex*. London: John Murray. doi:10.5962/bhl.title.110063

Deacon, T.W. 2006. The evolution of language systems in the human brain. In *Evolution of Nervous Systems,* Vol. 5: *The Evolution of Primate Nervous Systems,* John Kaas (ed.). Amsterdam: Elsevier.

Emmorey, Karen. 2013. The neurobiology of sign language and the mirror hypothesis. *Lang Cogn* 5(2–3): 205–210. doi:10.1515/langcog-2013-0014

Fitch, W.T. 2010a. *The Evolution of Language*. Cambridge: CUP. doi:10.1017/CBO9780511817779

Fitch, W.T., Huber, L. & Bugnyar, T. 2010b. Social cognition and the evolution of language: Constructing cognitive phylogenies. *Neuron* 65: 1–21. doi:10.1016/j.neuron.2010.03.011

Fitch, W.T. 2011. 'Deep homology' in the biology and evolution of language. In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Language Faculty,* C. Boeckx & A.M. Di Sciullo (eds), 135–166. Oxford: OUP.

Flinker, A., Korzeniewska, A., Shestyuk, A.Y., Franaszczuk, P.J., Dronkers, N.F., Knight, R.T. & Crone, N.E. 2015. Redefining the role of Broca's area in speech. *Proceedings of the National Academy of Sciences* 112(9): 201414491. doi:10.1073/pnas.1414491112

Fodor, J.A. 1975. *The Language of Thought*. New York NY: Crowell & Harvard University Press.

Fodor, J.A. 1983. *The Modularity of Mind. An Essay on Faculty Psychology.* Cambridge MA: The MIT Press.

Gazzaniga, M.S. 2005. Forty-five years of split-brain research and still going strong. *Nature Reviews. Neuroscience* 6(8): 653–659. doi:10.1038/nrn1723

Ghazanfar, A., Morrill, R.J. & Kayser, C. 2013. Monkeys are perceptually tuned to facial expressions that exhibit a theta-like speech rhythm. *Proceedings of the National Academy of Sciences of the United States of America* 110(5): 1959–1963. doi:10.1073/pnas.1214956110

Gillespie-Lynch, K., Greenfield, P.M., Lyn, H. & Savage-Rumbaugh, S. 2014. Gestural and symbolic development among apes and humans: Support for a multimodal theory of language evolution. *Frontiers in Psychology* 5: 1–10. doi:10.3389/fpsyg.2014.01228

Giraud, A.-L. & Poeppel, D. 2012. Cortical oscillations and speech processing: Emerging computational principles and operations. *Nature Neuroscience* 15(4) 511–517. doi:10.1038/nn.3063

Goldin-Meadow, S. 2008. Gesture, speech and language. *Proceedings of the 7th International Conference on the Evolution of Language* (Evolang 7), 427–428.

Griesemer, J.R. 2014. Reproduction and the scaffolded development of hybrids. In *Developing Scaffolds in Evolution, Culture, and Cognition*, L.R. Caporael, J.R. Griesemer & W.C. Wimsatt (eds), 23–44. Cambridge MA: The MIT Press.

Hauser, M.D. 1996 *The Evolution of Communication*. Cambridge MA: The MIT Press.

Hauser, M.D. 2009. The possibility of impossible cultures. *Nature* 460: 190–196. doi:10.1038/460190a

Hauser, M.D., Chomsky, N. & Fitch, W.T. 2002. The faculty of language. What is it, who has it, and how did it evolve? *Science* 298: 1569–1579.

Hauser, M.D., Yang, C., Berwick, R.C., Tattersall, I., Ryan, M.J, Watumull, J., Chomsky, N. & Lewontin, R.C. 2014. The mystery of language evolution. *Frontiers in Psychology* 5: 41.

Hervé, P.-Y., Zago, L., Petit, L., Mazoyer, B. & Tzourio-Mazoyer, N. 2013. Revisiting human hemispheric specialization with neuroimaging. *Trends in Cognitive Sciences* 17(2): 69–80. doi:10.1016/j.tics.2012.12.004

Hickok, G. 2014. *The Myth of Mirror Neurons. The Real Neuroscience of Communication and Cognition*. New York NY: W.W. Norton & Company.

Hinzen, W. & Sheehan, M. 2013 *The Philosophy of Universal Grammar*. Oxford: OUP. doi:10.1093/acprof:oso/9780199654833.001.0001

Hinzen, W., Rosselló, J., Mattos, O., Schroeder, K. & Vila, E. 2015. The image of mind in the language of children with autism. *Frontiers in Psychology* 6: 1–4. doi:10.3389/fpsyg.2015.00841

Hockett, C.F. 1960. The origin of speech. *Scientific American* 203: 88–111. Reprinted in Wang, W.S-Y. 1982. *Human Communication: Language and Its Psychobiological Bases,* 4–12. doi:10.1038/scientificamerican0960-88

Humphries, T., Kushalnagar, P., Mathur, G., Napoli, D.J., Padden, C. & Rathmann, C. 2014. Ensuring language acquisition for deaf children. *Language* 90: 31–52. doi:10.1353/lan.2014.0036

Jackendoff, Ray. 2002. *Foundation of Language. Brain, Meaning, Grammar, Evolution*. Oxford: OUP. doi:10.1093/acprof:oso/9780198270126.001.0001

Jackendoff, R. & Pinker, S. 2005.The nature of the language faculty and its implications for the evolution of language (Reply to Fitch, Hauser, and Chomsky). *Cognition* 97: 211–225. doi:10.1016/j.cognition.2005.04.006

Jarvis, E. D. 2007. Neural systems for vocal learning in birds and humans: A synopsis. *Journal of Ornithology,* 148(Suppl. 1). doi:10.1007/s10336-007-0243-0

Kujala, T., Lepistö, T. & Näätänen, R. 2013. The neural basis of aberrant speech and audition in autism spectrum disorders. *Neuroscience and Biobehavioral Reviews* 37(4): 697–704. doi:10.1016/j.neubiorev.2013.01.006

Lieberman, P. 2006. *Toward an Evolutionary Biology of Language*. Cambridge MA: Harvard University Press.

Lieberman, P. 2013. *The Unpredictable Species. What Makes Humans Unique*. Princeton NJ: Princeton University Press. doi:10.1515/9781400846702

Lombardo, M.V., Pierce, K., Eyler, L.T., Carter Barnes, C. Ahrens-Barbeau, C., Solso, S., Campbell, K. & Courchesne, E. 2015. Different functional neural substrates for good and poor language outcome in autism. *Neuron* 86: 1–11. doi:10.1016/j.neuron.2015.03.023

Magrassi, L., Aromataris, G., Cabrini, A., Annovazzi-lodi, V. & Moro, A. 2014. Sound representation in higher language areas during language generation. *Proc Natl Acad Sci U S A*. 112(6): 1868–1873. doi:10.1073/pnas.1418162112

Marno, H., Farroni, T., Vidal Dos Santos, Y., Ekramnia, M., Nespor, M. & Mehler, J. 2015. Can you see what I am talking about? Human speech triggers referential expectation in four-month-old infants. *Nature. Scientific Reports* 5: 13594. doi:10.1038/srep13594

Meristo, M., Morgan, G., Geraci, A., Iozzi, L., Hjelmquist, E., Surian, L., & Siegal, M. 2012. Belief attribution in deaf and hearing infants. *Developmental Science* 15(5): 633–640. doi:org/10.1111/j.1467-7687.2012.01155.x

Miyagawa, S., Berwick, R.C. & Okanoya, K. 2013. The emergence of hierarchical structure in human language. *Frontiers in Psychology* 4: 71. doi:10.3389/fpsyg.2013.00071

Moorman, S., Gobes, S. M. H., Kuijpers, M., Kerkhofs, A., Zandbergen, M. A. & Bolhuis, J. J. 2012. Human-like brain hemispheric dominance in birdsong learning. *Proceedings of the National Academy of Sciences*, 109(31), 12782–12787. doi:10.1073/pnas.1207207109

Nielsen, J.A., Zielinski, B.A., Fletcher, P.T., Alexander, A.L., Lange, N., Bigler, E.D., Lainhart, J.E. & Anderson, J.S. 2014. Abnormal lateralization of functional connectivity between language and default mode regions in autism. *Molecular Autism* 5(1): 8. doi:10.1186/2040-2392-5-8

Nóbrega, V.A. & Miyagawa, S. 2015. The precedence of syntax in the rapid emergence of human language in evolution as defined by the integration hypothesis. *Frontiers in Psychology* 6: 271. doi:10.3389/fpsyg.2015.00271

Ocklenburg, S. & Güntürkün, O. 2012. Hemispheric asymmetries: The comparative view. *Frontiers in Psychology* 3, art. 5. doi:10.3389/fpsyg.2012.00005

Poeppel, D. & Embick, D. 2005. The relation between linguistics and neuroscience. In *Twenty-first Century Psycholinguistics: Four Cornerstones,* A. Cutler (ed.),173–189. Mahwah NJ: Lawrence Erlbaum Associates.

Pulvermüller, F., Kiff, J. & Shtyrov, Y. 2012. Can language-action links explain language laterality?: An ERP study of perceptual and articulatory learning of novel pseudowords. *Cortex* 48(7): 871–881. doi:10.1016/j.cortex.2011.02.006

Richman, Bruce. 1976. Some vocal distinctive features used by gelada monkeys. *The Journal of the Acoustical Society of America* 60(3): 718–724. ⟨http://www.ncbi.nlm.nih.gov/pubmed/824335. doi:10.1121/1.381144

Rosselló, J. 2006. Duality of patterning and recursion: combinatorial properties at the roots of language. In *The Biolinguistic Turn. Issues on Language and Biology*, J. Rosselló & J. Martín (eds), 162–186. Barcelona: PPU.

Rosselló, J., Tolchinsky, L. & Junyent, M.C. 2014. Darwin sobre el llenguatge: Filogènia, ontogènia i glossogènia. In *Homenatge a Sebastià Serrano*, M.A. Martí & M. Taulé (eds), 233–259. Barcelona: University of Barcelona.

Suthers, R.A. 1997. Peripheral control and lateralization of birdsong. *Journal of Neurobiology* 33(5): 632–652. doi:10.1002/(SICI)1097-4695(19971105)33:5<632::AID-NEU10>3.0.CO;2-B

Tattersall, I. 2008. *The World from the Beginnings to 4000 BCE*. Oxford: OUP

Tattersall, I. 2014. An evolutionary context for the emergence of language. *Language Sciences* 46: 199–206. doi:10.1016/j.langsci.2014.06.011

Tomasello, M. 2008. *Origins of Human Communication*. Cambridge MA: The MIT Press.

Tomasello, M., Carpenter, M. & Liszkowski, U. 2007. A new look at infant pointing. *Child Dev.* 78: 705–722. doi:10.1111/j.1467-8624.2007.01025.x

Vouloumanos, A., Martin, A. & Onishi, K.H. 2014a. Do 6-month-olds understand that speech can communicate? *Dev. Sci*. 17: 1–8.

Vouloumanos, A. & Waxman, S.R. 2014b. Listen up! Speech is for thinking during infancy. *Trends Cogn. Sci*. 18: 642–646. doi:10.1016/j.tics.2014.10.001

Wray, A. 2000. Holistic utterance in protolanguage: The link from primates to humans. In *The Evolutionary Emergence of Language: Social Function and the Origins of Linguistic Form*, C. Knight, M. Studdert-Kennedy & J.R. Hurford (eds). Cambridge: CUP.

Electroencephalographic evidence of vowels computation and representation in human auditory cortex

Mirko Grimaldi[1], Anna Dora Manca[1],
Francesco Sigona[1] & Francesco Di Russo[2,3]
[1]Centro di Ricerca Interdisciplinare sul Linguaggio (CRIL) –
University of Salento, Lecce, Italy
[2]Department of Human Movement, Social and Health Sciences,
University of Rome "Foro Italico", Rome, Italy
[3]IRCCS Santa Lucia Foundation, Rome Italy

By exploiting the N1 component of the auditory event related potentials we aimed to measure and localize the processing involving the spectro-temporal and the abstract featural representation. We investigated the electroencephalography patterns of 11 Salento Italian speakers discriminating their native five stressed vowels [i, ɛ, a, ɔ, u]. Findings showed two distinct N1 sub-components: the N1a peaking at 125–135 ms, localized in the bilateral primary auditory cortex (BA41), and the N1b peaking at 145–155 ms, localized in the superior temporal gyrus (BA22) with a strong leftward lateralization. Crucially, while high vowels elicited higher amplitudes than non-high vowels both in the N1a and N1b, back vowels generated later responses than non-back vowels in the N1b only. Overall, these findings suggest a hierarchical processing where from the N1a to the N1b the acoustic analysis shift progressively toward the computation and representation of phonological features.

1. Introduction

1.1 Neurophysiological and linguistic grounds of speech perception

Speech perception requires specific capabilities, which consist in the processing of rapid sequential information embedded in the acoustic signal and in its decoding onto abstract units of representation. Thus, one of the central aspects for understanding the speech processing mechanisms is to discover how these phonetic and phonological operations are implemented at a neuronal level to shape the mental representations of the speech sounds.

doi 10.1075/la.235.04gri

Imaging data have provided a picture of the main areas involved in speech information processing showing the sophisticated functioning of the auditory pathway. In principle, within a complex neuronal network, the primary auditory cortices (A1) extract the acoustic features from the signal (Hickok et al. 2004; Scott & Johnsrude 2003) whereas some non-primary auditory areas as the superior temporal gyrus (STG) and the superior temporal sulcus (STS) encode the acoustic features onto phonological representations (Hickok et al. 2004; Scott & Johnsrude 2003; Rauschecker & Scott 2009). At this level of analysis, some disagreements remain in predicting the lateralization of the involved brain structures between who supports the bilateral analysis of the signal (Hickok et al. 2004, 2007; Scott & Johnsrude 2003) and who assumes the left hemispheric dominance for the phonological mapping (Scott & Johnsrude 2003; Rauschecker & Scott 2009) and the categorization processes (Obleser & Eisner 2009). However, beyond some localizationist divergences, robust evidences have widely suggested that the cortical organization of the auditory fields relies on topographic principles suitable to explain how the brain processes phonemes (Romani et al. 1982; Talavage et al. 2004; Saenz & Langers 2014). That is, the human auditory areas exhibit gradients of selective responsiveness to different acoustic parameters of the sounds so that different spatio-temporal patterns can be observed (Romani et al. 1982; Pantev et al. 1995; Kaas & Hackett 2000). Actually, it is assumed that *tonotopy* and *tonochrony* represent two of the main models of cortical organization of the auditory pathway. Tonotopy principle predicts that some pool of neurons are spatially organized in the primary and secondary auditory cortices for encoding different frequencies of sounds onto the cortical sheets (Ohl & Scheich, 1997; Romani et al. 1982). Tonochrony states the existence of discrete encoding temporal strategies for different acoustic properties of the sounds (Roberts et al. 1996, 1998) and presumably for distinct category of stimuli (Roberts et al. 2004). Accordingly, most magnetoencephalographic (MEG) studies on speech encoding have focused mainly on vowels for their stable spectro-temporal nature (Diesch et al. 1996; Diesch & Luce 1997, 2000; Eulitz et al. 2004; Roberts et al. 2004; Mäkelä et al. 2003; Obleser et al. 2003a; Shestakova et al. 2004; Scharinger et al. 2011), and rarely on consonants (e.g., Gage et al. 1998; Obleser et al. 2003b, 2004b, 2006).

Vowels are described by the first three peaks of their spectral envelopes, i.e., the formant frequencies F1, F2, and F3 that strongly correlate with specific articulatory configurations (Stevens 2002). For example, F1 inversely correlates with the tongue height movements along a potential vertical plane in the month, F2 correlates with the tongue place of articulation in a virtual horizontal dimension, and F3, together with F2, describe vowels produced with the lip rounding. Following the *analysis by synthesis* framework, we assume that the mapping principles exploited by the human brain to construct a sound percept are determined by bottom-up acoustic properties that are affected by top-down features based on abstract featural information relating to articulator positions (Stevens 2002). Such features, called *distinctive features*, would represent the primitives for phonological computation and representation (Halle 2002). Accordingly, vowels and consonants may be specified by a set (or bundle) of binary *distinctive features* that constitute primitives for the phonological computations and representations (Halle 2002; Stevens 2002; Poeppel et al. 2009); thus, distinctive features represent the abstract linking between articulatory plans and acoustic outputs (Halle 2002). The major features for vowels are the features specifying the position of the tongue body and lip rounding – [±high], [±low], [±back] and [±round] – and their computation and representation may be related with phonemotopic and tonochronic properties of the auditory cortex.

1.2 The auditory responses investigated in speech perception

In the last decades, the MEG research has attempted to describe the spatiotemporal models of the auditory activities engaged in vowel processing as reflected in the most prominent early magnetic auditory response, i.e., the N1m component, the magnetic counterpart of the electric N1 auditory evoked potential (AEP) (Näätänen & Picton 1987). The N1m/N1 wave is one of the most prominent signal elicited from human auditory cortex by any discrete auditory stimulus. It usually appears as a negative deflection peaking between 50 and 170 ms after the onset of an auditory stimulus over the central site of the scalp (Näätänen & Picton 1987; Woods 1995) and represents the initial readout of information from the sensorial system (Näätänen 1990). A peculiarity of the N1m/N1 wave is its sensibility to the stimuli rise/fall times. Indeed, it has been shown that increases in stimulus rise-time generate long N1 latencies and small N1 amplitudes in humans and animals (Kodera et al., 1979; Biermann & Heil 2000) for pure tones or tone bursts. On the contrary, it seems that the ramp of fall-time does not influence the N1m behaviour as it is only sensitive to temporal changes in the first ~40 ms of the signal (Gage et al. 2006). As for the N1 generators, pioneering N1m investigations on tones, clicks, and bursts encoding suggested that the N1m cortical origins were located in primary auditory areas, as the lower bank of the lateral sulcus (Diesch et al. 1996; Pantev et al. 1995). Recently, it has been shown that the N1m might have source generators in the supra temporal gyrus (STG) and in the planum temporale (Inui et al. 2006) suggesting a crucial role for the final (May & Tiitinen 2010) rather than for the initial stages (Näätänen & Picton 1987) of the sensorial data processing.

MEG data showed that the effects of the vowel spectral shape on the auditory activity reflected in the N1m amplitude and latency modulations (Diesch et al. 1996; Diesch & Luce 1997, 2000; Eulitz et al. 2004; Roberts et al. 2004; Mäkelä et al. 2003; Obleser et al. 2003a, 2004a; Shestakova et al. 2004; Scharinger et al. 2011). As for amplitude, it is found a reduction in the amount of neural activity for the vowels marked by low formant frequencies; thus, vowels like [a] with close formant (F1-F2) peaks, exerted weaker N1m/N1 responses than [i] or [u] (Obleser et al. 2003a;

Mäkelä et al. 2003; Manca et al. in press). Scharinger et al. (2011) distinguished vowel phonological oppositions of the Turkish system revealing that high vowels (e.g., [u]) elicited larger N1m amplitudes than non-high vowels (e.g., [ɑ]) as well as rounded back vowels (e.g., [u]) were larger than rounded front vowels (e.g., [y]). As for latency, a common finding is that the N1m latency depends on the acoustic correlates of speech segments such as first formant's frequency: that is, low vowels as [a] peaked earlier than high vowels as [i] or [u] (Poeppel et al. 1997; Roberts et al. 2000; Obleser et al. 2003a). Moreover, subsequent MEG studies speculated that the specific phonemotopic maps could be explained by referring to distinctive features rather than mere acoustic properties. For example, Obleser et al. (2004a, 2004b), studying the natural German vowels [a], [e], [i], [o], [u] [ø] and [y] found that back vowels [o] and [u] peaked later than front vowels [e], [i] and that high front vowel [i] peaked later than non-high front vowel [e]. Thus, the authors concluded that first formant frequencies alone not account for interaction of vowels when binary opposition of phonological features play a crucial role in contrasting phonemes within a linguistic system (in this case front-back, unrounded-rounded, and high-non-high vowels). On the contrary, Scharinger et al. (2011) showed that back vowels (e.g., [u]) were earlier than front vowels (e.g., [y]), and high vowels (e.g., [i]) peaked on average 4 ms later than non-high vowels (e.g., [ɑ]). Moreover, the authors found that Round affected timing neuronal strategies in that unrounded vowels (e.g., [ɯ]) elicited faster responses than rounded counterpart (e.g., [u]). In short, available MEG studies provide clues of specific vowel maps although the data may appear contradictory and the tonotopic and tonochronic organization of the auditory fields sometimes elusive (Poeppel et al. 1997; Mäkelä et al. 2003; Eulitz et al. 2004) and not systematic (Robert et al. 2000; Eulitz et al. 2004; Mäkelä et al. 2003; Shestakova et al. 2004).

In the present work, we studied the amplitudes, the latencies and the cortical generators of the AEP N1 response during vowel perception through electroencephalography (EEG) and compared our results with previous N1m MEG data. To date, the interface of tonochrony with the processes of vowel perception has poorly explored through the EEG system in favor of the MEG measurements, which are thought to be the best in localizing the neuronal activities (Roberts & Poeppel 2000). However, recent experiments on the MEG and EEG measurement sensitivity (Eulitz et al. 1997; Malmivuo et al. 1997; Virtanen et al. 1998) have shown that not all of the potential generators of an observed activity at the scalp are detectable by the magnetic technique. MEG is sensitive to radial currents only, whereas EEG is sensitive to both radial and tangential sources. This suggests that, using MEG for monitoring the higher information processing stages in which the currents flow in both radial and tangential directions can be a restrictive factor leading to describe only a partial aspect of the behavior of the neural activity under observation (Eulitz et al. 1997; Roberts et al. 2000). Moreover, in the case of N1m and its N1 electric counterpart, the pioneering studies on the processing of simple stimuli provided evidence that the N1 event arises from multiple neuronal activities, whose generators are represented by distinct sub-components at the scalp, some of them hardly detectable by MEG (Woods 1995; Näätänen & Picton 1987).

1.3 The aims of the present work

We scrutinized the auditory activity engaged in the processing of the Salento Italian (SI) vowel inventory, i.e., the Italian variety spoken in Southern Apulia, which consists of five-stressed vowel system: i.e., [i, ɛ, a, ɔ, u] (Grimaldi 2003; 2009). This simple phonological system is suitable for our objective since the acoustic-articulatory contrasts characterizing the five vowels are the most common in the systems of the world's languages (Maddieson & Precoda 1990). A five-stressed vowel system as SI is marked by three contrasts for Height ([+high], [−high, −low] and [+low]) and two parallel contrasts for Place ([±back] and Round ([±round]) as showed in Figure 1 (Calabrese 2011).

We assume that if the spectral properties and the phonological feature oppositions differentiating SI vowels affect the mapping processes in the auditory cortices, we expect to find relative modulations in timing and amplitude of the N1 component due to the features that are linguistically relevant to represent specific classes of speech sounds. Furthermore, we used natural stimuli without controlling the ramp for rise- and fall-times in order to verify (i) whether the sensibility of N1 for rise-time holds also for vowels as showed for pure tones or tone bursts and (ii) whether stimuli fall-times do not affect the N1 amplitude and latency patterns as previously shown for N1m. We assume that speech sound computation and representation are both grounded on an abstract rather than on a sensorial processing. Thus, for speech sounds that have a phonemic role within linguistic systems, the physical parameters may have a secondary role in the auditory process in favor of phonological primitives for phoneme representation.

2. Materials and methods

2.1 Stimuli

The stimuli consisted of the five stressed SI vowels (see Figure 1). A native Italian male speaker (age 32) realized ten repetitions of each vowel at a normal rate. The speech signal was recorded in a soundproof room with CSL 4500 and a Shure SM58-LCE microphone with a sampling rate of 44.1 Kiloherz (kHz) and an amplitude resolution of 16 bits. The stimuli were edited and analyzed by using the speech analysis software Praat 5.2 (Boersma & Weenink 2011). All stimuli were normalized for duration (200 milliseconds (ms), and intensity (70 decibel/ sound pressure level, dB/SPL). The best five exemplars of each vowel type were presented in the experimental protocol and the ramp for rise/fall times was not controlled (see Table 1). The F0 values of each vowel were normalized according to the values reported in previous studies where a representative sample of Italian vowels was acoustically analyzed (Ferrero et al. 1978). The F1, F2 and F3 formant values were measured in the vowel steady tract (50 ms) centered at the midpoint (see the representation on a Cartesian plane in Figure 1). A pure tone of 1000 Herz (Hz) and duration of 200 ms was created by Praat software. Before the EEG recordings, subjects familiarized with the stimuli and all of them were able to identify each of the vowels with an accuracy of 100%.

Table 1. Means of the formants and Rise and Fall Time

Vowels	F0	F1	F2	F3	F2-F1	Rise	Fall
[i]	145	294 (±11)	2325 (±50)	2764 (±28)	2031 (±47)	21	28
[ɛ]	145	549 (±32)	1880 (±46)	2489 (±60)	1330 (±71)	40	32
[a]	140	794 (±30)	1231 (±24)	2528 (±95)	418 (±46)	33	27
[ɔ]	140	550 (±14)	856 (±13)	2551 (±54)	306 (±21)	29	22
[u]	130	310 (±12)	660 (±33)	2437 (±49)	349 (±25)	22	23

*Pitch (F0), Formant Frequency (F1, F2, F3 in Hz) mean values and rise and fall times (ms) of the vowels used as stimuli (standard deviation is given in parenthesis). The parameter F2-F1 is also given.

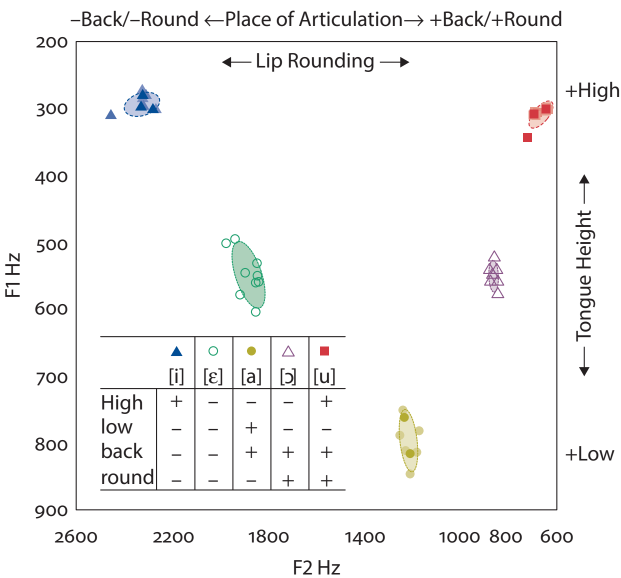


Figure 1. F1-F2 Hz scatterplot of Salento Italian vowels

*68.27% confidence ellipse corresponding to ±1 standard deviation from the bivariate mean. The F1 is inversely correlated with articulatory tongue height, while the F2 reflects the place of articulation in the horizontal (non-back/back and unrounded-rounded) dimension.

2.2 Participants and procedure

Sixteen volunteer students of the University of Salento (8 females; mean age 23 (±3sd) years) participated in the experiment after providing written informed consent. All subjects were consistently right-handed according to Handedness Edinburgh Questionnaire and none of them had any known neurological disorders or other significant health problems. The local Ethics Committee approved the experimental procedure. The data were acquired in the "Centro di Ricerca Interdisciplinare sul Linguaggio (CRIL)". Continuous EEG was recorded by using a 64-channel ActiCapTM (Brain Products GmbH, Germany) and Brain Vision Recorder 1.20 (Brain Products GmbH, Germany) at a sampling rate of 250 Hz, a band pass filter of 0.16–80 Hz and a notch filter of 50 Hz. Vertical eye movements were monitored using Fp2 and an additional electrode attached below the right eye. FT9 and FT10 were used for horizontal movements. The online reference was at FCz, the ground was AFz and the impedance was kept under 5 KΩ.

During the experiment, the participants sat in front of a computer monitor in a shielded room, and they were asked to listen to the vowels and to push a button with their left index whenever heard a pure tone of 1000 Hz used as a "distractor" stimulus (Figure 2). Stimuli were binaurally transmitted to the subjects through two loudspeakers (Creative SBS 2.1 350) at a comfortable loudness (about 70 dB/SPL) by using the Presentation software 2.0. Two sequences of 1000 vowel stimuli were presented in two blocks. Each block consisted of 200 tokens per vowel category, 70 distractor stimuli and 70 post-distractor stimuli (14 for vowel category). Stimuli were randomly presented with a variable interstimulus interval ranged from 1000 to 1400 ms and the distractor stimulus was interspersed with a probability between 6% and 7% in the train of the vowel sounds. In order to reduce excessive eye movements, during the performance subjects looked at a white cross at the center of the monitor. The experiment lasted approximately 1hour.

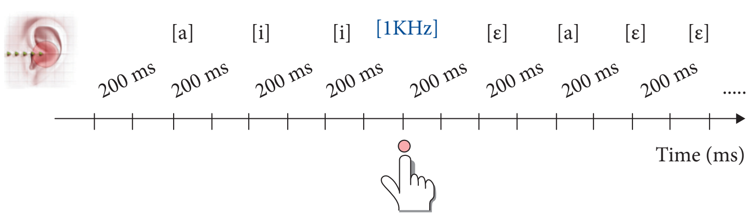


Figure 2. Exemplification of the experimental procedure

*Participants had to press a response button when they heard a pure tone (occurring with a probability between 6% and 7%), represented as [1Khz].

2.3 Data analysis

Off-line signal processing was carried out with the software package Brain Vision Analyzer 2.0.1 (Brain Products GmbH, Germany). The EEG was segmented in relation to the onset of the five vowels: Thus, the distractor and post-distractor stimuli were left out of analyses; 1200 ms epochs (including 200 ms pre-stimulus baseline) were extracted, digitally filtered by a 1–30 Hz band pass filter (48 dB) and re-referenced to the left and right mastoids (M1/2). Ocular artifacts were removed by applying the independent component analysis (ICA) algorithm and, additionally, rejection criteria for trials were set to 120 microvolt (μV) maximum absolute difference. Artifact-free segments were averaged for each vowel and a baseline correction was applied. Finally, grand averages were computed across all subjects and for each vowel type. Only participants with a reliable N1 response were included in the further analyses. Hence, five participants were excluded on the base of this criterion reducing the sample to 11 subjects (3 females; mean age 24(±3sd) years)

By looking at the scalp distribution of the early activity after stimulus onset, we observed that two N1 distinct peaks emerged specifically, from 80 to 160 ms, here termed N1a and N1b for convenience. The earliest N1a peak was identified as the most prominent between 125 and 135 ms after the stimulus onset on central medial electrodes and the latest N1b peak as the most prominent between 145 and 155 ms over left central, fronto-central and centro-parietal electrodes.

2.4 Source analysis

Tridimensional topographical maps and an estimation of the N1a and N1b intracranial sources were conducted using BESA 2000. We used the spatiotemporal source analysis of BESA that estimates location, orientation and time course of the equivalent dipolar sources by calculating the scalp distribution obtained for a given model (forward solution). This distribution was then compared to that of the actual AEPs. Interactive changes in source location and orientation lead to the minimization of residual variance between the model and the observed spatiotemporal AEP distribution. The three-dimensional coordinates of each dipole in the BESA model were determined with respect to the Talairach axes. BESA assumed a realistic approximation of the head (based on the magnetic resonance imaging or MRI of 24 participants). The possibility of interacting dipoles was reduced by selecting solutions with relatively low dipole moments with the aid of an "energy" constraint (weighted 20% in the compound cost function, as opposed to 80% for the residual variance). The optimal set of parameters was found in an iterative manner by searching for a minimum in the compound cost function. Latency ranges (N1a: 100–125 ms; N1b: 125–155 ms) for fitting were chosen to minimize the overlap between the two topographically distinctive components and consequently based on the N1 topography observation, which was clearly medial from 100 to 125 ms and then shifted to the left side from 125 to 155 ms. The global field power of the AEP confirmed this bimodal distribution with two peaks at 130 and 150 ms. In addition, after the initial fitting in those ranges, we fit again all source simultaneously in the 100–155 ms interval to fortify the model. A first model was made on the grand-average AEP to obtain a reliable and stable model of the N1a and N1b for all vowels using two bilateral mirror symmetric pairs of dipoles on the basis of the topographical maps obtained here and in previous studies (McDonald et al. 2003; Teder–Sälejärvi et al. 2003, 2005) showing bilateral localization on the auditory N1 component. Then, the model was used as starting point to model the AEP of each subject, fitting the source locations and orientation on the individual data. The accuracy of the source model was evaluated by measuring its residual variance as a percentage of the signal variance, as described by the model, and by applying residual orthogonality tests (ROT) (e.g., Böcker et al. 1994). The resulting individual time series for the dipole moments (the source waves) were subjected to an orthogonality test, referred to as a source wave orthogonality-test (SOT) (e.g., Böcker et al. 1994). All t-statistics were evaluated for significance at the 5% level.

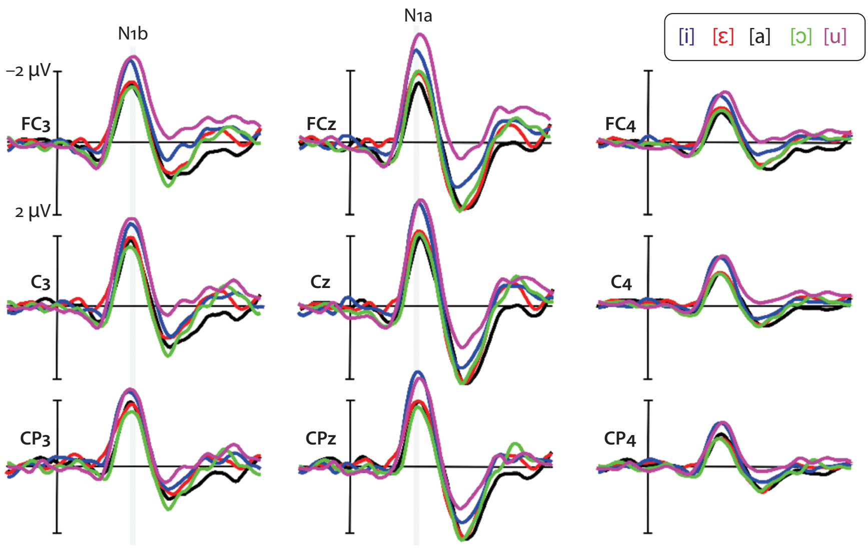
2.5 Statistical analyses

Statistical analyses were carried out with the Statistica 8.0 software package. The N1 peak amplitudes and latencies were measured at Cz or CPz for N1a and at C5 or CP5 electrodes for N1b. To test whether the two components represent different brain activity the N1a and N1b peak amplitude and latency were compared using a 2X5 analysis of variance, ANOVA (2 components X 5 vowels). Our main analysis consisted in the comparison of latencies and amplitudes performing two separate repeated measure ANOVAs on each component with vowel type as a within-factor. Moreover, a 2X5 ANOVA design was used to test hemispheric asymmetries on N1b amplitudes using hemisphere (2) and vowel type (5) as within-factors. For this analysis, four strongest electrodes in each hemisphere have been averaged: C3-FC5-F3-FC1 for the left and C4-FC6-F4-FC2 for the right hemisphere. All statistical results were corrected with the Greenhouse–Geisser method and the Bonferroni post-hoc method was applied to adjust the univariate output of repeated measurements of variances for violations of the compound symmetry assumption.

Moreover, to test the assumption of the distinctive features as primitives for the phoneme encoding, a series of paired-samples has been conducted to compare the mean responses to the vowels specified in terms of the phonological features Height, Place and Round. Finally, different Pearson correlation coefficient analyses (bivariate correlation) were computed to assess the relationship between stimuli mean rise values and the N1s mean latencies, and between the stimuli mean fall times and the N1s mean amplitudes.

3. Results

In the N1 range, two distinct components were found: i.e., the N1a peaking at 125-135ms on medial electrodes around the vertex bilaterally and the N1b peaking at 145-155ms bilaterally with a clear leftward asymmetry. Figure 3 shows the AEP waveforms of representative electrodes were the activity was prominent and Figure 4 shows the topographical mapping of the two components elicited for each vowel from a top-view. N1a was prominent on medial parietal scalp areas and was posterior for the low vowel [a] and the non-high back vowel [ɔ] relative to the other vowels. N1b was prominent on parieto-temporal scalp and was more lateral and posterior for the low vowel [a] and the non-high front [ɛ] and back [ɔ] vowels than the other vowels.



Figures 3. Grand averaged AEP waveforms of the most representative electrode sites

*The five vowels are superimposed using different colors. The peaks of the two N1 subcomponents are marked by a vertical gray line.

3.1 Latencies

Differences between the N1 components were statistically confirmed since the N1a latency (130ms) was significantly earlier ($F(1,10) = 121.16$, $p < 0.0001$) than the N1b latency (149ms). This effect was present in all vowels as the component by vowel interaction was not significant ($F < 1$). Because their diversity, the two components were analyzed separately as function of the vowel type.

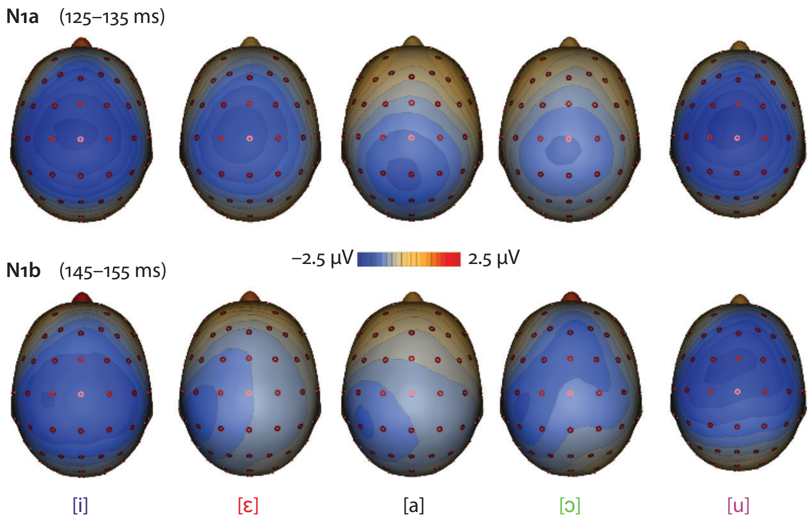


Figure 4. N1a and N1b topographical maps displayed from a top view

*The N1a activities peak early over the central medial electrodes whereas the N1b activities show the most prominent potential later, over the left central, fronto-central and centro-parietal electrodes.

The N1a latency was affected by the vowel type ($F(4,40) = 4.27$, $p = 0.0056$). Post hoc revealed a later processing for low vowel [a] than high front [i], non-high front [ɛ], and back [ɔ] ($p < 0.05$). Moreover, [a] was close to high back [u] (see Table 2). Again, the N1b latencies differed between vowels ($F(4,40) = 3.36$, $p = 0.0184$): but, interestingly, here the latency of [a] was close to [ɔ] and [u] and peaked later than [i] and [ɛ] ($p<0.05$).

The paired-sample t-tests on the mean values of the N1s to vowels grouped for distinctive features revealed that the vowels specified for the feature [+back], i.e., [a, ɔ, u], peaked on average 5 ms later than vowels specified for the feature [–back], i.e., [i, ɛ]: (N1a: $t(10) = -2.611$, $p = 0.026$; N1b $t(10) = -3.083$, $p = 0.012$). Conversely, the latency values of both components did not differ between these vowel categories ($p > 0.05$) (see Figure 5(a–b)).

Finally, Peterson correlation revealed that the N1a responses did not correlate with the rise ramps of the stimuli ($r = -0.575$, $n = 5$, $p = 0.310$), whereas there was a negative correlation between the N1b values and the rise times of the vowels ($r = -0.887$, $n = 5$, $p = 0.045$).

3.2 Amplitudes

N1a and N1b components did not statistically differ ($F(1,10) = 3.42$, $p = 0.094$). Both were significantly affected by vowel type along the F1 dimension ($F(4,40) = 6.22$,

$p = 0.0005$) in line with previous MEG studies (Obleser et al., 2003a; Scharinger et al., 2011). Post hoc revealed that the N1s amplitude increases with decreasing of the F1 values, that is, high vowels [i] and [u] showed greater amplitudes than non-high [ɛ], [ɔ] and low [a] vowels ($p < 0.05$). The interaction Component *per* vowel type was not significant ($F < 1$).

The t-test results suggested that for both components, the mean amplitude of high vowels [i] and [u] were greater than non-high [ɛ] and [ɔ], and low vowel [a], ((N1a: $t(10) = -.2.416$ $p = 0.036$; N1b: $t(10) = -3.108$, $p=0.010$)) (see Figure 5 (a–b)). Peterson correlation revealed that the N1a and N1b responses did not correlate with the fall ramps of the stimuli (N1a: $r = -0.203$, $n = 5$, $p = 0.743$), N1b: $r = -0.234$, $n = 5$, $p = 0.705$).

Table 2. N1s amplitude and latency values to Salento Italian vowels

Vowel	N1a		N1b	
	Latency	**Amplitude**	**Latency**	**Amplitude**
[i]	128 (±7.6)	–3.20 (±1.5)	145 (±6.7)	–2.56 (±0.8)
[ɛ]	127 (±7.7)	–2.19 (±0.6)	146 (±6.7)	–2.31 (±0.9)
[a]	134 (±11.6)	–2.45 (±1.6)	151 (±9.3)	–2.07 (±0.9)
[ɔ]	130 (±9.3)	–2.45 (±1.1)	148 (±8.5)	–1.98 (±0.8)
[u]	131 (±8.6)	–3.17 (±1.6)	152 (±7.3)	–2.69 (±1.1)

*Amplitude (μV), latency (ms), and standard deviation (±) values of the five SI vowels for the N1a and N1b for N=11.

3.3 Hemispheric processing

ANOVA on the N1a amplitude laterality revealed no significant difference for the main effect hemisphere ($F(1,10) < 1$). Means values: Left=-1.369 μV, Right = –1.349 μV. The vowel type effect was statistically relevant, ($F(4,40) = 6.62$, $p < 0.05$), showing the same results found in the analyses made at the midline electrodes. Hemisphere per vowel type interaction was not significant ($F(4,40)= 1.74$, $p = 0.167$). In contrast, the N1b amplitudes were affected by hemisphere showing a leftward asymmetry ($F(1,10) = 115.78$, $p < 0.0001$). On average, N1b amplitudes were –2.319 ± 0.5 μV for the left and 1.115 ±0.3 μV for the right. The main effect of vowel type was not significant ($F(4,40) = 1.87$, $p = 0.134$), whereas the hemisphere interaction by vowel type was statistically significant ($F(4,40) = 6.09$, $p < 0.0006$), showing that only in the left hemisphere high vowels [i], [u] were stronger than low [a], and [u] was stronger than non-high vowels [ɛ] and [ɔ]. See Figure 5(c).

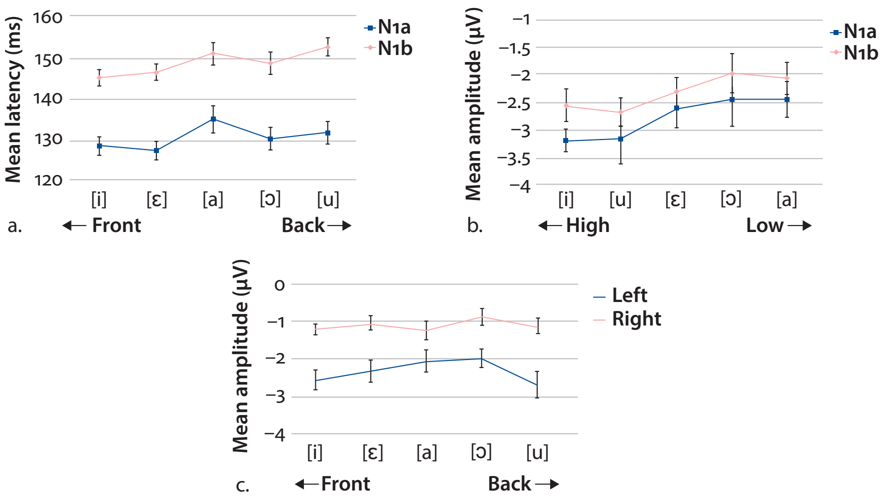


Figure 5. Representation of the effects of the distinctive features on the N1 modulations

*(a) Mean latency of the two N1 subcomponents for back, i.e. [a], [ɔ], [u], and front, i.e. [i], [ɛ], vowels. (b) Mean amplitude of the two N1 subcomponents for high, i.e. [i], [u], low, i.e. [ɛ], [ɔ] and low, i.e. [a], vowels. (c) Mean amplitude of the N1 subcomponents according to their hemispheric distribution: The N1b shows the greatest amplitude in left hemisphere.

3.4 Source locations

The intracranial localization of the N1 sources is shown in Figure 6. The waves represent the time course of those sources in both hemispheres averaged across vowels. All vowels produced a N1a response that was bilaterally localized within primary auditory cortex in the A1, Brodmann area (BA) 41. The N1a time-course showed that this component initiated at 80 ms and peaked at 130 ms with equal intensity in the two hemispheres. The N1b was localized more ventrally and anteriorly within the superior temporal cortex in the STG, BA22. The N1b time-course revealed that this component initiated at 110 ms and peaked at 150 ms and that was much larger in the left hemisphere ($t(10)=23.42$ $p<0.0001$). The source model was quite reliable having a residual variance of 2.5% in the 100–155 ms range. Table 3 shows the source coordinates for the five vowels and the two components.

4. Discussion

To date, the most exploited technique to describe the layout of the auditory cortices has been MEG. To the best of our knowledge, this is the first study that investigated an entire vowel system by the EEG technique (but see Vihla & Eulitz 2003). We studied N1 amplitude and latency modulations, and the N1 cortical generators

Table 3. Talairach coordinates (X, Y and Z) expressed in millimeter (mm) (and standard deviation) of the bilateral source locations of the five vowels (and relative mean) for the N1a and N1b components

Vowel	N1a			N1b		
	X	Y	Z	X	Y	Z
[i]	±46 (4)	−24 (2)	13 (3)	±52 (5)	−4 (2)	1 (2)
[ɛ]	±48 (4)	−26 (4)	12 (2)	±49 (4)	−8 (2)	−2 (2)
[a]	±54 (7)	−30 (2)	15 (3)	±60 (9)	−25 (2)	−2 (2)
[ɔ]	±51 (7)	−22 (5)	9 (2)	±56 (6)	−17 (3)	−7 (2)
[u]	±50 (8)	−17 (3)	10 (2)	±46 (4)	−11 (2)	−10 (4)
Mean	**±50 (6)**	**−24 (3)**	**12 (2)**	**±53 (6)**	**−13 (2)**	**−4 (2)**

*The ± symbols before the X value indicate that sources were constrained to be bilateral mirror symmetric in both hemispheres.

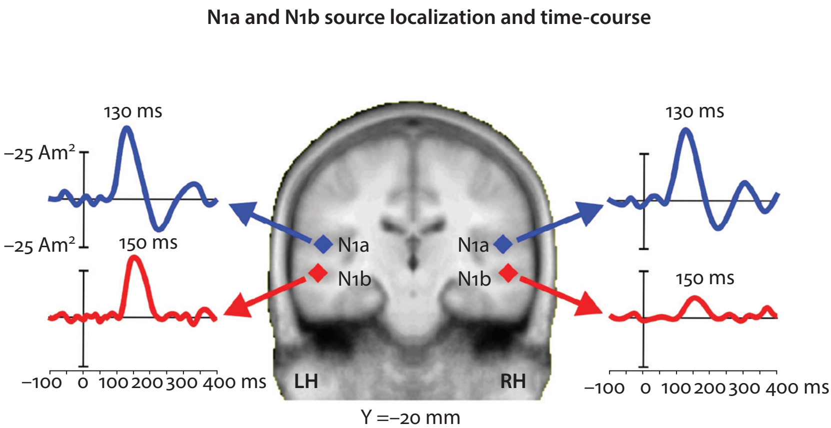


Figure 6. Representation of N1a (blue line) and N1b (red line) cortical generators and their time-course

*Source locations and time-course of the N1a and the N1b subcomponent. N1a is generated within the primary auditory cortex (A1) and the N1b within the superior temporal gyrus (B22). LH=left hemisphere, RH=right hemisphere.

during the auditory processing of the SI vowels (see Manca, Di Russo, Sigona & Grimaldi submitted for a deeper phonemotopic investigation). Specifically, we focused on the tonochronic maps related to temporally distinct processing of phonological relevant features (Roberts et al. 2000, 2004; Obleser et al. 2004a, 2004b; Scharinger et al. 2011) and on the hierarchical nature of the speech processes as originated in different auditory areas and controlled by hemispheric modulation (Hickok & Poeppel 2007). We discuss three important findings in turn: (i) the N1a and N1b subcomponents that we found in the N1 range; (ii) the amplitude and latency modulations of these subcomponents related to the vowel processing; and (iii) the generators of the N1a and N1b responses and their hemispheric asymmetry.

4.1 The N1a and N1b subcomponents

Our data confirm and extend MEG evidence: our main finding revealed a dynamic process flowing between two neural populations in both hemispheres within the typical range of the N1 component that has never been reported for vowels. This result strongly confirmed the tonochronic nature of auditory cortex in showing an early N1a response peaking from 125 to 135 ms bilaterally in the A1 (BA41) and a late N1b response peaking between 145 and 155 ms in the STG (BA22) with a leftward asymmetry. The idea of different morphologies of the N1 components has largely ascertained from the initial studies on non-speech stimuli (Woods 1995; Näätänen & Picton 1987). It is known that the N1 auditory component is a complex sum of multiple cortical generators and that six sub-components, at least, can describe the underlying activities. These sub-components show different values of latency, amplitude and cortical generators (Näätänen & Picton 1987: 5; Woods 1995) and are thought to be associated with different types of auditory information coding (Näätänen et al. 1987: 38). Following the work of Woods (1995: 103), the two N1 sub-components that well fit to our N1a and N1b are those labelled as N1'/P90 and N1c respectively. The former, maximally recorded from the fronto-central scalp, peaks between 85–110 ms, it is tangentially orientated and it generates in the A1; the latter, maximally recorded at mid-temporal electrodes, peaks about 130–170 ms and it has a radial orientation. However, our N1a showed latency slightly longer than N1'/P90 values, probably because vowels are marked by complex spectro-temporal properties and produce slower and more effortful cognitive operations than those required for non-speech stimuli generally used in previous studies. Magnetic and intracortical recordings demonstrated that late temporal activity could be estimated in the STG areas by a radial dipole (Wolpaw & Penry 1975; Picton et al. 1978; Wood & Wolpaw 1982), which is blind to MEG (Eulitz et al. 1995; Malmivuo et al. 1997). Hence, since EEG captures radial and tangential currents (Eulitz et al. 1995; Malmivuo et al. 1997), we assume that our N1s events can index the different steps of speech information processing in accordance with numerous imaging data (Hickok & Poeppel 2004; Rauschecker et al. 2009; Scott et al. 2013).

4.2 N1 amplitude modulation and tonochrony as reflected in the latency patterns

Intriguingly, both N1s component appeared to be sensitive to different dimensions of the vowel space. Furthermore, contrary to the studies on pure tones or tone bursts (Kodera et al. 1979; Biermann & Heil 2000) the rise times of our vowels did not affect the relative N1 latencies confirming the assumption of special rules for phoneme representation; likewise, the fall-times had no effects on the N1s amplitude as already shown in previous N1m studies (Gage et al. 1998).

As for amplitude, few MEG studies reported significant effects for N1m, probably due to practical issues with respect to the head-placement in the scanner and issues with normalizing amplitudes across participants (Obleser et al. 2003a; Shestakova et al. 2004; Scharinger et al. 2011; see Vihla & Eulitz 2003 for an EEG investigation of pseudo-words). The general finding was that low vowels (e.g., [a]) with close formant (F1-F2) peaks, exerted weaker response than high vowels marked by a strong inter-formant relationship (e.g., [i] or [u]) (but see Mäkelä et al. 2003). Accordingly, we found that both for N1a and N1b non-high [ɛ], [ɔ] and low [a] vowels elicited lower amplitude than high vowels [i], [u], showing a categorical effect for Height. Notwithstanding this, N1 reliable arrangement of cortical vowel representations for amplitude, we cannot address the question whether the spectral, the phonological or both characteristics are the major determinants of these findings. In our case, the formant frequencies strongly correlate with phonological features such as tongue height (cf. Table 1 and Fig. 1). Hence, the differences in the N1 amplitudes for [i, u] and [ɛ, a, ɔ] are compatible with a purely spectral extraction algorithm as well as with a more abstract phonological feature extraction algorithm (however, see Manca, Di Russo, Sigona & Grimaldi, et al. submitted for an analysis of the N1 source generators).

As far as latency is concerned, the matter results to be much complex as compared to previous MEG literature (Diesch et al. 1996, 2000; Roberts & Poeppel 1996; Poeppel et al. 1997; Roberts et al. 1998, 2000; 2004; Obleser et al. 2003a; Eulitz et al. 1995, 2004; Scharinger et al. 2011). The findings of these studies suggested that the N1m latency is a function of F1, thus vowels with low F1 values (e.g., the high [i], [u]) are later than vowels with high F1 values (e.g., the low [a]), reflecting a distinctive feature analysis for Height. Conversely, in the present study both N1 responses revealed the longest latency values for low vowel [a] suggesting that the latencies did not reflect a distinctive feature analysis for [high] and [low] (probably because of the close F2 values for [a] and [u], cf. Figure 1).

However, our findings may have a phonological explanation when referring to a feature analysis for Place. Actually, in the SI vowel system [a], [ɔ], and [u] are all specified for the [+back] feature and [ɛ], [i] for the [-back] feature; we showed that back vowels [a], [ɔ], and [u] peaked significantly 5 ms later than non-back vowels [ɛ], [i] both for N1a and N1b. This result is in line with the works of Obleser et al. (2004a, 2004b), which found that German back vowels [o] and [u] peaked later than non-back vowels [e], [ø] and [i]. The case of the SI vowel [a] was determinant for leading to phonological assumptions. While for N1a the latency of [a] was close to the latency of [u] and was significantly later than non-high [ɛ], [ɔ] and [i], in the N1b the latency of [a] was close to [ɔ] and [u] and significantly later than [ɛ], [i]. These patterns suggest that the activity contributing to the N1b response appears better explained by the F2 dimension and the related feature [±back]. Thus, the formant frequencies alone do not account for auditory processing of vowels when binary oppositions of phonological features play a crucial role in contrasting phonemes within a linguistic system (cf. Roberts et al. 2004). Although this is not the focus of this work, it is worth to note that a different modulation for the N1a and the N1b may be noted for the intracranial localization on the Talairach coordinates (see Table 3) and in particular on the anterior-posterior dimension (*y* axis). Traditionally, the *y* gradient is sensitive for Place along the F2 dimension, so that non-back vowels and consonants elicit N1m dipoles anterior to back vowels and consonants respectively (Obleser et al. 2003a, 2003b, 2004b; Obleser et al. 2006; Scharinger et al. 2011). Our results showed that for N1a back [u, ɔ] elicited anterior dipole locations and non-back [i, ɛ] vowels elicited posterior dipole locations, whereas the N1b displayed the reverse pattern: i.e., [i, ɛ] seem more anteriorized than [u, ɔ]. Crucially, the vowel [a] was the more posterior and resulted more close to [ɔ] and [u] than [ɛ] and [i] according to its specification for the feature [+back] (cf. Manca, Di Russo, Sigona & Grimaldi, submitted for a more detailed based on a mixed model statistical analysis).

To sum up, N1a and N1b amplitudes resulted responsive to the spectro-temporal properties associated with the phonological features that allow a vowel classification for Height, while only the N1b latencies resulted responsive to the spectro-temporal properties associated with the phonological features that allow a vowel classification for Place. Overall, these and previous results support the idea that the N1 latencies may be sensitive to F1 and F2 acoustic patterns and the associated distinctive features according to their functionality within phonological systems. In particular, our latency data support the idea that the N1a is tuned for spectro-temporal analysis whereas the N1b for the computation of phonological features (as we better we will discuss below).

4.3 The generators of the N1a and N1b and their hemispheric asymmetry

The hypothesis that our N1 subcomponents can index different steps of speech information processing is strengthened by the hierarchical organization we found. Actually, we showed that the N1a is bilaterally generated in the A1 (BA41) while the N1b in the STG with a strong leftward asymmetry (cf. Figure 6). The cortical areas involved in speech perception and the hemispheric asymmetry remain objects of debate. Scott and Johnsrude (2003), Rauschecker and Scott (2009) and Obleser and Eisner (2009) supposed the left lateralization of acoustic and phonological processes and the involvement of the STG, the STS, and the supramarginal gyrus for the detection of categorical differences between speech sounds (cf. also Woods et al. 2011). Hickok & Poeppel (2007), on the other hand, assumed a bilateral involvement of the two hemispheres from the middle to posterior portion of STS for phonological-level computation. Interesting clues of cortical selectivity of the STG to phonetic features of speech stimuli i.e., the syllables /ba/, /da/, and /ga/) derive from electrocorticographic (ECoG) recordings in patients undergoing awake cranial surgery (Chang et al. 2010). The results showed that during the encoding of linguistically relevant features, the cortical population is spatially organized to perceive sounds. As for the N1/N1m inquiry otherwise, few MEG studies have reported clear N1m intracranial origins and scarce evidence for a left hemispheric processing of speech sounds (but see Eulitz et al., 2004). When it occurred, the center of activity of the classical N1m component was generally identified in the supratemporal plane (Poeppel et al. 1996; 1997; Diesch et al. 1996; Eulitz et al. 2004) or in the planum temporale (Obleser et al. 2004b). However, a recent MEG study has reported sources of the activities generating the N1m responses in the STG and in the planum temporale (Inui et al. 2006). Thus, considering the amplitude and latency modulations, and that the N1a is generated in the A1 bilaterally whereas N1b in the STG with a left lateralization, we suggest that N1a is sensitive to the sensorial patterns of vowel stimuli and N1b is sharply tuned for the computation and representation of complex features that characterize particular stimulus categories. Overall, contrary to competing models of speech hemispheric activation (bilateral vs. left hemisphere), our data suggest a model where the dorsal-ventral pathway of auditory cortex gradually actives a leftward gradient as speech processing becomes more abstract for the phonological representation.

5. Conclusion

In searching for the neuronal correlates of SI vowels, we propose the existence of two dynamical integrated mechanisms for vowel encoding that give further insights into auditory information processing. We assume that after the extraction of the predominant acoustic cues in left and right auditory cortices, the acoustic information is encoded in terms of distinctive features predominately in auditory regions of the left hemisphere. Thus, we better characterized the hierarchical nature of speech processing suggested by imaging studies, and extended previous MEG results on the phonemotopic properties of auditory cortex. Actually, EEG system can represent an alternative way to understand how the fundamental units of languages mirror in the auditory cortices. We are aware that for a definitive confirmation of this scenario further studies are needed with much complex system of native and even non-native sounds. Anyway, it seems a promising way to investigate the functional-anatomic organization of speech computation and representation.

References

Biermann, S. & Heil, P. 2000. Parallels between timing of onset responses of single neurons in cat and of evoked magnetic fields in human auditory cortex. *Journal of Neurophysiology* 84(5): 2426–2439.

Böcker, K.B.E, Brunia, C.H.M. & van den Berg-Lenssen, M.M.C. 1994. A spatiotemporal dipole model of the stimulus preceding negativity prior to feedback stimuli. *Brain Topography* 7(1): 71–88. doi:10.1007/BF01184839

Boersma, P. & Weenink, D. 2010. *Praat: Doing Phonetics by Computer* [Computer program], Version 5.2. ⟨http://www.praat.org/⟩

Calabrese, A. 2011. Metaphony in Romance. In *The Blackwell Companion to Phonology*, Vol. 5, M. van Oostendorp, C.J. Ewen, E. Hume & K. Rice (eds), 2631–2661. Chichester: Wiley-Blackwell.

Chang, E.F., Rieger, J.W, Johnson, K., Berger, M.S., Barbaro, N. M., Knight, R. T., 2010. Categorical Speech Representation in Human Superior Temporal Gyrus. *Nature* 13(11): 1428–1432. doi:10.1038/nn.2641

Diesch, E., Eulitz, C., Hampson, S. & Ross, B. 1996. The neurotopography of vowels as mirrored by evoked magnetic field measurements. *Brain Language* 53: 143–168. doi:10.1006/brln.1996.0042

Diesch, E. & Luce, T. 1997. Magnetic fields elicited by tones and vowel formants reveal tonotopy and nonlinear summation of cortical activation. *Psychophysiology* 34: 501–510. doi:10.1111/j.1469-8986.1997.tb01736.x

Diesch, E. & Luce, T. 2000. Topographic and temporal indices of vowel spectral envelope extraction in the human auditory cortex. *Journal of Cognitive Neuroscience* 12: 878–893. doi:10.1162/089892900562480

Eulitz, C., Diesch, E., Pantev, C., Hampson, S. & Elbert, T. 1995. Magnetic and electric brain activity evoked by the processing of tone and vowel stimuli. *Journal of Neuroscience* 15: 2748–2755.

Eulitz, C., Eulitz, H. & Elbert, T. 1997. Differential outcomes from magneto-and electroencephalography for the analysis of human cognition. *Neuroscience Letters* 227(3): 185–188. doi:10.1016/S0304-3940(97)00333-9

Eulitz, C., Obleser, J. & Lahiri, A. 2004. Intra-subject replication of brain magnetic activity during the processing of speech sounds. *Cognitive brain research* 19(1): 82–91. doi:10.1016/j.cogbrainres.2003.11.004

Ferrero, F.E., Magno-Caldognetto, E., Vagges, K. & Lavagnoli, C. 1978. Some acoustic characteristics of the Italian vowels. *Journal of Italian Linguistics* 3(1): 87–96.

Gage, N., Poeppel, D., Roberts, T.P.L. & Hickok, G. 1998. Auditory evoked M100 reflects onset acoustics of speech sounds. *Brain Research* 814(1): 236–239. doi:10.1016/S0006-8993(98)01058-0

Gage, N., Roberts, T.P.L & Hickok, G. 2006. Temporal resolution properties of human auditory cortex: Reflections in the neuromagnetic auditory evoked M100 component. *Brain Research* 1069(1): 166–171. doi:10.1016/j.brainres.2005.11.023

Grimaldi, M. 2003. *Nuove ricerche sul vocalismo tonico del Salento meridionale. Analisi acustica e trattamento fonologico dei dati*. Alessandria: Edizioni dell'Orso.

Grimaldi, M. 2009. Acoustic correlates of phonological microvariations. The case of unsuspected highly diversified metaphonetic processes in a small area of Southern Salento (Apulia). In *Romance Languages and Linguistic Theory 2006. Selected papers from 'Going Romance', Amsterdam 7–9 December 2006* [Current Issues in Linguistic Theory 303], D. Torck & W.L. Wetzels (eds), 89–109. Amsterdam: John Benjamins. doi:10.1075/cilt.303.06gri

Halle, M. 2002. *From Memory to Speech and Back: Papers on Phonetics and Phonology 1954–2002*. Berlin: Mouton de Gruyter.

Hickok, G. & Poeppel, D. 2004. Dorsal and ventral streams: A framework for understanding aspects of the functional anatomy of language. *Cognition* 92(1): 67–99. doi:10.1016/j.cognition.2003.10.011

Hickok, G. & Poeppel, D. 2007. The cortical organization of speech processing. *Nature Reviews Neuroscience* 8(5): 393–402. doi:10.1038/nrn2113

Inui, K., Okamoto, H., Miki, K., Gunji, A. & Kakigi, R. 2006. Serial and parallel processing in the human auditory cortex: A magnetoencephalographic study. *Cerebral Cortex* 16(1): 18–30. doi:10.1093/cercor/bhi080

Kaas, J.H. & Hackett, T.A. 2000. Subdivisions of auditory cortex and processing streams in primates. *Proceedings of the National Academy of Sciences of the United States of America* 97(22): 11793–11799. doi:10.1073/pnas.97.22.11793

Kodera, K., Hink, R.F., Yamada, O. & Suzuki, J.-I. 1979. Effects of rise time on simultaneously recorded auditory-evoked potentials from the early, middle and late ranges. *International Journal of Audiology* 18: 395–402. doi:10.3109/00206097909070065

Maddieson, I. & Precoda, K. 1990. Updating upsid. *UCLA Working Papers in Phonetics* 74: 104–111.

Manca, A.D., Di Russo, F., Sigona, F. & Grimaldi, M. Submitted. Electrical brain responses mirror tonochrony, phonemotopic and hierarchical organization of auditory cortex.

Manca A.D., Di Russo F. & Grimaldi M. in press. Orderly organization of vowels in the auditory brain: The neuronal correlates of the Italian vowels. In *Proceedings of the XI Convegno Nazionale Associazione Italiana Scienze della Voce,* AISV. *Il farsi e il disfarsi del linguaggio*. Bologna.

Malmivuo, J., Suihko, V. & Eskola, H. 1997. Sensitivity distributions of EEG and MEG measurements. *IEEE Transactions of Biomedical Engineering* 44: 196–208. doi:10.1109/10.554766

Mäkelä, A.M., Alku, P. & Tiitinen, H. 2003. The auditory N1m reveals the left-hemispheric representation of vowel identity in humans. *Neuroscience Letters* 353: 111–114. doi:10.1016/j.neulet.2003.09.021

May, P.J.C. & Tiitinen, H. 2010. Mismatch negativity (MMN), the deviance-elicited auditory deflection, explained. *Psychophysiology* 47(1): 66–122. doi:10.1111/j.1469-8986.2009.00856.x

Mcdonald, J.J., Teder-Sälejärvi, W.A., Di Russo, F. & Hillyard, S.A. 2003. Neural substrates of perceptual enhancement by crossmodal spatial attention. *Journal of Cognitive Neuroscience* 15(1): 10–19. doi:10.1162/089892903321107783

Näätänen, R. & Picton, T. 1987. The N1 wave of the human electric and magnetic response to sound: A review and analysis of the component structure. *Psychophysiology* 24: 375–425. doi:10.1111/j.1469-8986.1987.tb00311.x

Näätänen, R. 1990. The role of attention in auditory information processing as revealed by the event-related potentials and other brain measures of cognitive function. *Behavioural Brain Science* 13: 201–288. doi:10.1017/S0140525X00078407

Obleser, J., Elbert, T., Lahiri, A. & Eulitz, C. 2003a. Cortical representation of vowels reflects acoustic dissimilarity determined by formant frequencies. *Cognitive Brain Research* 15(3): 207–213. doi:10.1016/S0926-6410(02)00193-3

Obleser, J., Lahiri, A. & Eulitz, C. 2003b. Auditory-evoked magnetic field codes place of articulation in timing and topography around 100 milliseconds post syllable onset. *Neuroimage* 20(3): 1839–1847. doi:10.1016/j.neuroimage.2003.07.019

Obleser, J., Lahiri, A. & Eulitz, C. 2004a. Intra-subject replication of brain activity during the processing of speech sounds. *Cognitive Brain Research* 19: 82–91. doi:10.1016/j.cogbrainres.2003.11.004

Obleser, J., Lahiri, A. & Eulitz, C. 2004b. Magnetic brain response mirrors extraction of phonological features from spoken vowels. *Journal of Cognitive Neuroscience* 16(8): 31–39. doi:10.1162/089892904322755539

Obleser, J., Scott, S.K. & Eulitz, C. 2006. Now you hear it, now you don't: Transient traces of consonants and their nonspeech analogues in the human brain. *Cerebral Cortex* 16(8): 1069–1076. doi:10.1093/cercor/bhj047

Obleser, J. & Eisner, F. 2009. Pre-lexical abstraction of speech in the auditory cortex. *Trends in Cognitive Sciences* 13(1): 14–19. doi:10.1016/j.tics.2008.09.005

Ohl, F.W. & Scheich, H. 1997. Orderly cortical representation of vowels based on formant interaction. *Proceedings of the National Academy of Sciences U.S.A*. 94: 9440–9444.

Pantev, C., Bertrand, O., Eulitz, C., Verkindt, C., Hampson, S., Schuierer, G. & Elbert, T. 1995. Specific tonotopic organizations of different areas of the human auditory cortex revealed by simultaneous magnetic and electric recordings. *Electroencephalography and Clinical Neurophysiology* 94(1): 26–40. doi:10.1016/0013-4694(94)00209-4

Picton, T.W., Woods, D.L. & Proulx, G.B. 1978. Human auditory sustained potentials, I: The nature of the response. *Electroencephalography and Clinical Neurophysiology* 45(2): 186–197. doi:10.1016/0013-4694(78)90003-2

Poeppel, D., Phillips, C., Yellin, E., Rowley, H.A., Roberts, T.P.L & Marantz, A. 1997. Processing of vowels in supratemporal auditory cortex. *Neuroscience Letters* 221: 145–148. doi:10.1016/S0304-3940(97)13325-0

Poeppel, D., Idsardi, W.J. & van Wassenhove, V. 2009. Speech perception at the interface of neurobiology and linguistics. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363(1493): 1071–1086. doi:10.1098/rstb.2007.2160

Rauschecker, J.P. & Scott, S.K. 2009. Maps and streams in the auditory cortex: Nonhuman primates illuminate human speech processing. *Nature Neuroscience* 12(6): 718–724. doi:10.1038/nn.2331

Roberts, T.P.L. & Poeppel, D. 1996. Latency of auditory evoked M100 as a function of tone frequency. *NeuroReport* 7: 1138–1140. doi:10.1097/00001756-199604260-00007

Roberts, T.P.L., Ferrari, P. & Poeppel, D. 1998. Latency of evoked neuromagnetic M100 reflects perceptual and acoustic stimulus attributes. *NeuroReport* 9: 3265–3269. doi:10.1097/00001756-199810050-00024

Roberts, T.P.L., Ferrari, P., Stufflebeam, S.M. & Poeppel, D. 2000. Latency of the auditory evoked neuromagnetic field components: Stimulus dependence and insights toward perception. *Journal of Clinical Neurophysiology* 17: 114–129. doi:10.1097/00004691-200003000-00002

Roberts, T.P.L., Flagg, E.J. & Gage, N.M. 2004. Vowel categorization induces departure of M100 latency from acoustic prediction. *NeuroReport* 15: 1679–1682. doi:10.1097/01.wnr.0000134928.96937.10

Romani, G.L., Williamson, S.J. & Kaufman, L. 1982. Tonotopic organization of the human auditory cortex. *Science* 216: 1339–1340. doi:10.1126/science.7079770

Saenz, M. & Langers, D.R.M. 2014. Tonotopic mapping of human auditory cortex. *Hearing Research* 307: 42–52. doi:10.1016/j.heares.2013.07.016

Scharinger, M., Idsardi, W.J. & Poe, S. 2011. A comprehensive three-dimensional cortical map of vowel space. *Journal of Cognitive Neuroscience* 23(12): 3972–3982. doi:10.1162/jocn_a_00056

Scott, S.K. & Johnsrude, I.S. 2003. The neuroanatomical and functional organization of speech perception. *Trends in Neurosciences* 26(2): 100–107. doi:10.1016/S0166-2236(02)00037-1

Scott, S.K. & McGettigan, C. 2013. Do temporal processes underlie left hemisphere dominance in speech perception? *Brain & Language* 127: 36–45. doi:10.1016/j.bandl.2013.07.006

Shestakova, A., Brattico, E., Soloviev, A., Klucharev, V. & Huotilainen, M. 2004. Orderly cortical representation of vowel categories presented by multiple exemplars. *Cognitive Brain Research* 21: 342–350. doi:10.1016/j.cogbrainres.2004.06.011

Stevens, K.N. 2002. Toward a model for lexical access based on acoustic landmarks and distinctive features. *Journal of Acoustical Society of America* 111(4): 1872–1891. doi:10.1121/1.1458026

Talavage, T.M., Sereno, M.I., Melcher, J.R., Ledden, P.J., Rosen, B.R. & Dale, A.M. 2004. Tonotopic organization in human auditory cortex revealed by progressions of frequency sensitivity. *Journal of neurophysiology* 91(3): 1282–1296. doi:10.1152/jn.01125.2002

Teder-Sälejärvi, W.A., McDonald, J.J., Di Russo, F. & Hillyard, S.A. 2003. An analysis of audio-visual crossmodal integration by means of event related potential (ERP) recordings. *Cognitive Brain Research* 14(1): 106–114. doi:10.1016/S0926-6410(02)00065-4

Teder-Sälejärvi, W., Di Russo, F., McDonald, J.J. & Hillyard, S.A. 2005. Effects of spatial congruity on audio-visual multimodal integration. *Journal of Cognitive Neuroscience* 17(9): 1396–1409. doi:10.1162/0898929054985383

Vihla, M. & Eulitz, C. 2003. Topography of the auditory evoked potential in humans reflects differences between vowels embedded in pseudo-words. *Neuroscience Letters* 338(3): 189–192. doi:10.1016/S0304-3940(02)01403-9

Virtanen, J., Ahveninen, J., Ilmoniemi, R.J., Näätänen, R. & Pekkonen, E. 1998. *Electroencephalography and Clinical Neurophysiology* 108: 291–298. doi:10.1016/S0168-5597(98)00006-9

Wolpaw, J.R. & Kiffin Penry, J. 1975. A temporal component of the auditory evoked response. *Electroencephalography and Clinical Neurophysiology* 39: 609–620. doi:10.1016/0013-4694(75)90073-5

Wood, C.C. & Wolpaw, J.R. 1982. Scalp distribution of human auditory evoked potentials. II. Evidence for overlapping sources and involvement of auditory cortex. *Electroencephalography and Clinical Neurophysiology* 54(1): 25–38. doi:10.1016/0013-4694(82)90228-0

Woods, D.L. 1995. The component structure of the N1 wave of the human auditory evoked potential. *Electroencephalography and Clinical Neurophysiology-Supplements Only* 44: 102–109.

Woods, D.L., Herron, T., Kang, X., Cate, A.D. & William Yund, E. 2011. Phonological processing in human auditory cortical fields. *Frontiers in Human Neuroscience* 5(00042): 1–15. doi:10.3389/fnhum.2011.00042

SECTION 2

Language variation

Feature values and the expression of variation

Pritha Chandra
Indian Institute of Technology Delhi

This paper proposes that feature values emerge dynamically from the interaction between features and the internal/structural and language-external environments. Feature values constitute a second, flexible layer around a selected sub-set of innate features, and effect linguistic variation within dialects and typologically related languages. Big, structural changes however originate from restricted changes in feature composition themselves, often the result of adding a new feature to the language-particular sub-set or repurposing some existing feature. Relevant analogies with biological variation are discussed in favor of the multi-level approach to linguistic variation proposed here.

1. Introduction

Recent minimalist developments (cf. Chomsky 1995, 2000) place most linguistic variation in the uninterpretable features of functional heads selected by individual languages. Initiated in Borer (1984), the focus on features (phi-features, EPP, Topic, Focus etc.) marks a major theoretical shift from structural parameters to the inflectional properties of lexical items. Its impact on theoretical syntax aside, the change has ramifications for a biolinguistic understanding of variation, some of which the present paper tries to address.[1]

Biolinguistics enables a critical appreciation of minimalist ideas on linguistic variation by facilitating interesting analogies between the variation-inducing mechanisms in language and the processes underling biological/phenotypic variation. Just as phenotypic variation demands a multi-level analysis including genetic constraints and mutations, and epigenetic mechanisms working with tandem with both internal and external environments, a complete understanding of linguistic variation, I suggest

1. I will be quick to clarify that the presentation here involves a weak biolingistic approach to variation in the sense of Boeckx and Grohmann (2007), in that the comparison between linguistic constructs and biological constructs stands more at an analogical level. See Benítez-Burraco & Boeckx (2014) for a strong biological approach to variation.

DOI 10.1075/la.235.05cha

here, requires a consideration of both features and feature values – with feature values being more responsive to internal and external environments than features that are selected for any given language from a universal set of features (Chomsky 1995).

I elaborate on this aspect of feature values in section two, beginning with a brief survey of the literature on feature-induced I-language variation. Features are understood as information bearing fixed units, whose values emerge from the dynamics of the computational system and in response to external, macro-events. Cases of structure-induced and macro-event triggered feature value variation are presented as evidence for a more dynamic interaction between these two distinct domains. The feature value level is then compared to the epigenetic layer in biology, which serves as an important interface between the internal and external worlds, in the generation of biological variation.

In section three, I illustrate how feature values create differences among dialects, and typologically and geographically close languages. A close examination of ergative case marking patterns, affected by person and number values, reveals that feature value variation between two or more dialects is either of the same magnitude or more than that observed between two geographically distant and typologically distinct languages. I also discuss how new languages, in contrast to dialects, are formed with a radical shift in the feature composition of the grammar. This is achieved either when the existing language chooses a new feature from the universal set of features or reanalyzes a given feature, thereby generating one or more new structural characteristics.

In section four, drawing on observations from previous sections, I offer some skeptical views on both structural parameter-driven and feature-driven comparative linguistic studies. My contention is that since features and structures are intricately linked in the creation of feature values, the two cannot be isolated from each other, raising questions on the recent structural/featural-parameter debates raging in generative literature. Comparative linguistics must instead gear more towards unraveling the various layers of the faculty of language, rather than aiming for language types and families.

Section five concludes the chapter.

2. Feature-values & the language Epigenome

The debate on structural[2] versus featural/micro variation is attracting a lot of attention in current generative literature. One group of researchers defends the presence

2. Structural parameters are also known as macro-parameters in the literature. Since we refer to language-external events as macro-events in this paper, we avoid using the term 'macro' for structural parameters here.

of conventional, structural parameters in a minimalist grammar (see Roberts & Holmberg 2005; Baker 2008; Holmberg & Roberts 2014; among others). The other group advocates a feature-driven understanding of variation, while relinquishing the traditional notions of both parameters and principles (Barbiers 2009, 2013; Kayne 2005, 2011, 2013, among others). The increasing focus on features in recent works also tallies well with a proliferation of interest in dialectal studies. Features are generally assumed to trigger local changes to structures; hence, dialectal differences (generally assumed to be, minor) become as relevant for linguistic studies as large-scale typological changes. Notwithstanding the concerns raised about minimalism's feature-centric approach (cf. Boeckx 2015), many therefore find the study of minuscule effects of features in and across dialects very useful for comparative syntax correlations.

Some recent works also suggest that the effects of structural parameters – big, typological variations – may be explained through a series of micro-parameters – defined in terms of different computations and feature values. To illustrate, Kayne (2011) takes issue with the structural *Directionality Parameter*, and derives its effects from multiple occurrences of the operations Agree and Move. This structural parameter – which dictates the position of the head vis-à-vis the complement in different languages – is at odds with Kayne's (1994) *Linear Correspondence Axiom* (LCA) that together with asymmetric c-command, imposes a universal Specifier-Head-Complement order onto syntactic trees. Kayne (2011) extends the LCA into minimalism and tries capturing its directionality effects through the asymmetric, syntactic operation Agree. This operation, as per Kayne, mimics the left to right directionality of parsing, and thereby obligatorily places the probe/head (H) to the left of the complement (C); see (1). Each instance of Merge essentially being a probe-goal relation, the natural order is obligatorily head-initial.

(1) Head and complement are invariably merged as ⟨H, C⟩.

For the S(pecifier)-H order, Kayne further places a restriction on second Merge, such that newly introduced arguments only merge to heads. Unlike conventional frameworks where the specifier merges to XP (containing H and a complement YP), Kayne merges it directly to H, with the result that two ordered units, as listed in (2), are formed. The principle in (3) is then used to impose a S-H-C order over the two units. Language-specific orders (e.g. SOV, VSO etc.) are then derived from this universal order through further (remnant) movement steps.

(2) ⟨S, H⟩, ⟨H, C⟩

(3) If H p-merges with X and also p-merges with Y, then X and Y must be on opposite sides of H.[3]

3. P-merge is the summation of Pair Merge and Immediate Precedence.

The primary objective of Kayne's efforts is to derive the effects of structural parameters from a multitude of agreement and movement steps on underlying structures – the base or kernel sentences that are themselves emergent results of primitive syntactic operations.[4] However, since operations such as Agree and Merge occur only on the behest of features (i.e. things move or agree to get values for their otherwise unvalued/uninterpretable features), the effects of structural parameters are primarily drawn from a cluster of featural or micro-level choices.

Importantly, minimalism recognizes two kinds of features – those that are valued/interpretable and those that are not. The interpretable ones include phi-features on nominal categories and wh, topic etc. on functional heads, while the uninterpretable ones involve structural Case on nominals[5] and phi-features on functional heads and are valued via checking (Agree) during the course of the derivation (Chomsky 2000). Minimalist grammar, as generally understood, is defined through this dichotomy between lexically pre-determined values and syntactically determined values. No credence is therefore given to the possibility that all features receive values in the syntax, and feature values are therefore much more flexible and subject to change, than the features themselves, that they are actually attributes of. In other words, while features in any given language form a subset of a Universal or fixed set of features (Chomsky 1995), feature-values are themselves, emergent properties of features and their dynamic interaction with structures and computations. They are not lexically pre-determined, and their flexibility often induces cross-linguistic variation.

Contra standard minimalist ideas, the literature bears evidence for a syntactically determined feature value level, distinct from the first and fixed layer of universal/innate features. Boskovic (2009), for instance, following Marušič et al. (2007), shows that first and second conjunct agreement in Serbo-Croatian receive a more principled explanation if grammatical (arbitrary) gender on nominals (e.g. 'village', 'town') is taken as a (valued) uninterpretable feature. Sidestepping the technical details of his analysis, the pertinent point to note in his account is that at least one value of gender is a pure structural construct – neither lexically pre-determined nor interpretable from the perspective of the semantic interface. On

4. In Chomsky's minimalist works, linear order is not built into syntactic tree building mechanisms such as Merge.

5. Structural case, in Chomsky's recent works (cf. Chomsky 2000) is a value (and not a feature) on the DP in return of phi-feature valuation/checking (via Agree) on a functional head. However, it is essential that every DP is given a case value before the structure containing it is shipped off to the interfaces. Moreover, there are studies suggesting that Case has a referential value at the semantic interface (cf. Hinzen 2014), which suggests that syntactically, it is just like an uninterpretable feature in need of a value that is read off by the interfaces.

a similar vein, Markovskaya (2012) demonstrates, through her data on Russian deverbal nominals, that the feminine and masculine values are 'assigned' to transitive and unergative structures respectively – the relevant context for the feminine value in this language being the presence of an overt or implicit object and the accompanying structures.

Similarly, it is contentious if the person feature on nouns/pronominals is already valued (as first/second/third person) when it enters the computational workspace or if it receives a value as per the syntactic configurations that host the nouns. Recent works (Béjar & Rezac 2003; Coon & Preminger 2012) contend that first and second person pronominals are required at certain structural positions (also dubbed as the *Person Licensing Condition*) for the semantic interface to interpret them appropriately. Third person pronominals have no such requirement. In short, values for the person feature are not lexically pre-determined nor primitive, interpretable constructs – they are sensitive to structures and computations.

We infer from these researches that feature values constitute a second, flexible layer around the more fixed, universal set of features in the grammar. I take this second layer of flexible feature values as the *modus operandi* for unleashing some amount of I-language variation, just as a cell's *epigenome* – the second layer of chemical tags covering the lower, inflexible genomic layer of DNA and histones – ushers in variation at the micro/sub-cellular level. Chemical reactions at the outer, epigenetic layer activate and deactivate instructions carried by the DNA at specific times and locations, generating different, but controlled outcomes. More specifically, signals, transcription factors administer the transcriptional activity of the genome, and physically attach to specific DNA sites. Epigenetic mechanisms regulate the ease with which these signals access the DNA – either tightening the DNA sites and making them inaccessible, or loosening them up and making them available to the signals. The epigenome thus serves as the interface between the environment and the genome and determines to what capacity the environment may regulate the genome.

The biology literature abounds with case studies illustrating the role of the epigenome. For example, it has been found that in rats, the activity of the genes in the liver is adversely affected by prenatal nutrient deprivation and enhanced hormonal signals associated with heightened levels of stress (Bateson et al. 2004; Gluckman & Hanson 2004; Jirtle & Skinner 2007; Meaney et al. 2007; Seckl & Holmes 2007). Such activities are traced to epigenetic responses to environmental factors, which in turn impact the genetic transcriptional activity. Interestingly, recent studies also show how the epigenome remains responsive to the environment during adult life. Rönn et al. (2008) undertake a cross-sectional study of DNA methylation at the COX7A1 locus in adults. They report more inter-individual variation in elderly (60 years old) individuals, suggesting that DNA methylation indeed changes with age, even into adulthood.

Just as with the genome/DNA-epigenome contrast in biology, in language too, features are information carrying fixed constructs, which have different realizations or values depending on the structures that contain them, relevant computational applications and external events. Feature values emerge from the influence that structural and external environments have on the features – they are therefore not fixed constructs and may be maneuvered through different phases of language acquisition and learning.

If UG is indeed layered, with a flexible feature value level, we expect to find instances of language change, where macro-events such as population movement and assimilation (as with bilingual/multilingual situations) directly impact feature values and structural configurations. These feature value modifications eventually lead to bigger and qualitative intra-language changes. Two such cases of feature-value changes in Middle English, brought about in reaction to macro-events leading to bilingual situations, are discussed next.

2.1 Macro-events and effects

While talking about internal and external motivations for linguistic variation, one is reminded of Newmeyer's (2005) *possible* and *probable languages*. The possible-probable language discussion is crucial for the question of variation – it highlights the constraints placed by both narrow syntax and external factors on the range of linguistic forms. Possible languages constitute the set of languages allowed by Universal Grammar, while probable languages are those that are determined by function and usage. Some possible languages may be dis-preferred by external factors, as also noted by Mathew Dryer in his (2007) review of Newmeyer's book. To illustrate, while a micro-level word order parameter, in cohort with other feature-driven computations, accounts for possible word orders, there are some preferred word order typologies among languages. Tomlin (1986) demonstrates that 87 percent of languages display either a SVO or a SOV order, and only 9 and 3 percent display VSO and VOS orders respectively. Further, only 1 percent has an OVS order, with no known language opting for an OSV order (cf. Greenberg 1963; Dryer 2005). These preferences or tendencies and the disfavored options are not fully explicable through micro-level I-language mechanisms. Preferences or tendencies may instead arise from additional, random, extra-linguistic variables, such as cognitive, functional, socio-cultural factors and historical contingencies (also see Gibson et al. 2013 for a functional take on word order preferences).

Various attempts have been made to link up these two – seemingly disparate – aspects of human language. Suggestions have ranged from getting these functional constraints "biologized" into UG, helping choose only 'optimal' grammars during language acquisition (Kiparsky 2008), to having them turn some parameters into "no choice parameters" ("offers that cannot be refused"), triggering off structured variation (Biberaur, Roberts & Sheehan 2014). Underlying both studies is the common conceptualization of the entire faculty of language as a fixed, monolithic entity and all variation as endogenous variation. However, evidence points out that grammars are more sensitive to external environments than originally thought, not only during the phases of child language acquisition, but also for adult learning. Language variation is not restricted to pre-puberty parameter settings, and is a combined effect of the flexible layer of the faculty of language behaving in response to external events. Some case studies are summarized and discussed below that suggest the same.

Word order change in Middle English is an interesting illustration of the involvement of (and constraints placed thereof, by) both macro events and micro-variables. In generative literature, the replacement of the Old English OV order to Middle English VO order is explained in terms of internal mechanisms. Roberts (1997), for instance, notes that word order change in the language was accompanied by a loss of case morphology, scrambling, verb movement and cliticization. One of the primary reasons for the multiple losses, Roberts argues, is the suppression of a morphological trigger for movement. In the original OV orders, an AgrO with a strong N feature initiated movement of DPs to its specifier. However, with the loss of case morphology, that morphological trigger became defunct and resulted in blocking DP movement. Roberts, following Lightfoot (1979, 1991), believes that language acquirers set the parameter for an AgrO-less structure (on encountering case-less configurations) and thus ushered in quick, concomitant structural modifications. In featural terms, this amounts to the speaker dropping a previously active N-feature from her grammar's feature set, resulting in the introduction of a slightly truncated structure. It is an instance of a big, typological variation where a feature itself, and not a feature value is at play. The resulting (Agro-less) clause structure in turn sets in a whole array of morphological and syntactic changes.

While internal, parametric settings had definite roles to play in English word order changes, macro-level influences in the change are not to be overlooked. Kida (2010) for instance, notices that while the trend towards VO in north England dialects continued undeterred, there was a sudden decrease in the VO patterns for both main and dependent clauses in some other dialects, as attested in the 1067–1121 entries of the *Peterborough Chronicle*, and the *Astrolabe of Geoffery Chaucer*. Kida attributes this variation to the dominant OV word order patterns in Norman French, especially in the dependent clauses. Since a co-existing population spoke this language, the shift to VO in Middle English in some areas slowed down considerably due to these external factors. The increasing number of bilingual speakers of both English and Norman French also contributed to the slow-down, with their dominant OV orders for the latter influencing the order in Middle English.

Word order optionality in Middle English variants illustrates the sensitivity of feature values to environmental events. Learners received ambiguous data from the environment, owing to population shift. These changes were recorded in the learner's grammar, prompting them to retain the feature values of the Agro-head, albeit optionally. This retention also meant that the Case on the DP object was allowed two different values – it either received a lexical case from the verb and remain in situ, or moved to Agro head, getting a structural accusative. The former derivation resulted in SVO sentences and the latter gave SOV structures. Thus, we have an instance of a language re-setting its feature values, in reaction to environmental stimuli. While speakers manipulated different feature values and simultaneously handled both options, children exposed to such data eventually selected the SVO grammar over the other. In other words, they made a one-time selection of features and completely undermined or eliminated the Agro head from their grammar. This radical, definitive shift in feature composition then led to many other novel characteristics to emerge, eventually paving the way for a new grammar.

There are many other examples in the literature that show that contact-induced language change is very prevalent in adult speech, often showing up as multiple choices in their grammars. Children acquirers then opt for one of these structures, and establish one phenomenon over the other. One important illustration is provided in Kroch, Taylor and Ringe (1997) and Kroch and Taylor (1997), who, drawing statistics from the *Penn-Helsinki Parsed Corpus of Middle English* (Kroch & Taylor 1994), suggest a possible answer for the loss of V2 phenomenon from Middle English. These studies show that there were two dialects of Middle English – a northern and southern one – each with its own peculiar structures. The northern dialect had V to C movement, generating $[_{CP}\text{XP}\ [_{C}\text{V}\ [_{TP}\text{Subject}]]]$ structures, with both NP and pronominal subjects following the raised verb. The southern dialect on the other hand, had V to T movement, with V3 structures such as $[_{CP}\text{XP}\ [_{C}\ [_{TP}\text{pro-Subject}\ _{T}\text{V}]]]$ with pronominal subjects. The verb however would precede nominal subjects that were obligatorily placed at the specifier of TP; i.e. structures such as $[_{CP}\text{XP}\ [_{C}\ [_{TP}\ _{T}\text{V}\ [_{VP}\ \text{Subject}]]]]$ were also available.

In contact-induced situations, adults were exposed to these two varieties, prompting northerners to try out some non-V2 structures and southerners to generate some V2 structures with pronominal subjects. In due time, the competing non-V2 grammar took over the V2 grammar, a structural characteristic that carries over to present day English, and has been noted as either 'chance' or arising from the "vicissitudes of social history" (also see Kroch 2001: 26). This however may not be a complete answer, as it fails to explain why in this V to T shift, both northerners and southerners obligatorily raised their NP-subjects to the specifier of TP and never opted for a VP-internal NP-subject, despite both options being available to them as positive evidence. Instead, these dialects chose to have their subjects move to the specifier of TP, while their verbs targeted the T head. The structural novelty therefore indicates a more radical transition of the T head in the language. In other words, the language speakers reanalyzed the T, endowing it with a strong EPP feature that forced overt DP movement, when their grammar opted for overt verb to T movement. The loss of V2 phenomenon in English is therefore another classic example of how grammatical changes are effected through internal mechanisms, in response to external environments.

3. Feature values and dialects

We now move to variations found among ergative patterns, indicating how dialects differ from each other by manipulating their feature values. I show here that feature value differences between dialects and typologically related and geographically proximate languages are, as much as (and sometimes more than) the feature value differences found between typologically unrelated and geographically distant languages.

Western Indo-Aryan languages such as Marathi, Gujarati, Nepali, Hindi-Urdu etc. (spoken in the north-western belt of India) are generally known as split-ergative languages, with ergative subjects and absolutive/accusative objects appearing in perfective structures (cf. Bhatt 2007; Deo & Sharma 2006; Legate 2012; Mahajan 2012; Subbarao 2012 among others). However, despite this overarching similarity, there are multiple differences between the languages and their dialects with regard to their ergative patterns, mostly emerging from differential feature values.

On a meso-level, languages such as Marathi differ from Hindi-Urdu by not hosting an overt ergative marker on the first and second person pronominal subjects; contrast (4) and (5) respectively:

(4) mi sita-la baghit-la
I-MASC sita-FEM-ACC see-PERF-NEUT-SG
'I saw Sita' (Deo & Sharma 2006)

(5) me-ne sita-ko dekhaa
I-MASC-ERG sita-FEM-ACC see-PERF-NEUT-SG
'I saw Sita'

The cross-linguistic differences in the ergative pattern can be explained with reference to the feature value differences in the two languages. Marathi first and second person feature values set off variation in its ergative domain – eliminating the possibility of marking these pronominals with an overt ergative marker. These same values also trigger ergativity loss in typologically related languages Punjabi and Gujarati,[6] but fail to influence Hindi-Urdu ergativity. In theoretical terms, this difference may be thus stated. While in Marathi, Gujarati and Punjabi, pronominals get their values at positions where ergative case cannot be assigned, Hindi-Urdu pronominals possibly have a person licensing head that is also an ergative case licenser. One possibility is that in the former set of languages, ergative case is assigned against a lower verbal head, which cannot license first and second person pronominals that generally require a full-blown TP structure for licensing. Hindi-Urdu on the other hand, may have their ergative subjects obligatorily move to the specifier of TP, with the head also licensing first and second person pronominals.

Interestingly, as with typologically related languages that vary substantially on feature values, any given language also has a number of feature value variations within its own grammar. These variations help isolate different dialects of that language. As for instance, the standard, Pune variety of Marathi has the person restriction on its ergative patterns. However, in its dialect Warhadhi Brahmani, ergativity is also sensitive to its number values. The dialect marks its transitive, perfect subjects with ergative in all three persons in the singular, but fails to mark first and second person transitive subjects in the plural. Dharwari, yet another dialect of the language, has no ergative marking on the transitive, perfect subject in any person.

A single grammar may therefore bifurcate into different grammars, based on differential feature values, perhaps under the influence of neighboring languages. A new variety or dialect may be thus generated from the introduction of an active number value in the grammar of the existing language, prompting some speakers to use only the number-person combined value for ergativity. Another dialect may emerge when some speakers opt for a grammar where the ergative alignment is completely lost in favor of a competing nominative case-alignment. Feature value differences thereby serve as important mechanisms for dialect formation.

Similar feature value differences are also found in ergative patterns elsewhere – among dialects of typologically unrelated and geographically distant languages. The same range of variations is found in Dyirbal, a Pama-Nyungan language spoken in Australia and its dialects (Dixon 1972, 1994; Legate 2002, 2012). Dyirbal ergative suffix *-pgu*, for instance, is absent on first and second person pronominals, very similar to what we find in Marathi.

(6)	n^{y}urra	pana-na/*pgu	bura-n
	you-PL-NOM	we-ACC	see-NON-FUT
	'We saw you all'		

6. Gujarati also has a number restriction on ergativity (see Deo & Sharma 2006 for more).

An interesting case of feature value variation is witnessed in its dialect Giramay, which places no such restriction on ergative marking, and morphologically marks its first and second person, ergative subjects (7)–(8).

(7) Ngadya/ngayba/nganya
I-ERG/I-NOM/Me-ACC

(8) Nginda/nginba/ngina
You-ERG/You-NOM/You-ACC

A member of the same family, Walpiri too makes no person-based ergativity distinction, allowing all its pronominals to carry an overt ergative marker (cf. Bittner & Hale 1996).

(9) nyuntulu-rlu ka-npa-ju ngaju nya-nyi
you-ERG PRES-2S-1s me-ABS see-NONPAST
'You see me'

(10) nyuntu ka-npa nparnka-mi
2S-ABS PRES-2S-SUBJ run-NONPAST
'You are running'

(11) ngaju ka-rna parnka-mi
me-ABS pres-1s run-NONPAST
'I am running'

In short, we witness that in the domain of ergativity alone, person and number value differences are sometimes quite substantial between dialects and closely related languages, while interesting similarities are found between unrelated languages. In other words, at a micro or feature value level, the magnitude of feature value variations between dialects and typologically close languages is as much as or sometimes more than the feature value differences between typologically distinct languages. By the same measure, two dialects can be as similar at the feature value level as two typologically unrelated languages.

3.1 On language creation

Continuing with the issue with feature value induced modifications, we now ask if these differences define both dialects and languages. Are feature value mechanisms enough to explain new language creation and if not, what else is required?

The micro-variationist's understanding is that dialects and new languages are all created via the same feature triggered processes. This method echoes the *evo-devo* understanding of biological variation, wherein divergent gene (RNA/protein) expression, responsible for species-internal development and variation is taken to correlate with morphological variations among members of different species. Phylogenetic trees are thus constructed, based on the developmental processes of different organisms. Extended to languages and feature values, it would imply that feature value differences underlie both dialect development as well as new language formation. Dialects however, despite substantial feature value differences, are mutually comprehensible and do not have big, structural differences that we find among different languages. One therefore needs to critically examine if feature value differences alone contribute to the evolution or creation of new grammars and languages. My contention is that there are points of qualitative leap – mostly triggered by changes in the underlying feature sub-set – such that a new language evolves with significant differences from its mother language.

In generative literature, language typologies (amounting to big, structural differences) are assumed to emerge from different settings of structural parameters. One such study is that by Baker (2008) who allows both features and structural parameters to occupy the same grammatical space, albeit with different functions. Features lead to small-scale changes, while structural parameters lead to big, typological changes. Baker then draws an interesting analogy between linguistic, structural differences and species differences or formation. He observes that structures in different languages fall into neat clusters or types, with very little variation (or noise) between the two. Depicted in (12), head-initial and head-final languages, for instance, are generally consistent across all categories. Inconsistent languages with head-initial/head-final order at the verbal level and the reverse at the prepositional level are very few.

(12) a. V-O and P-NP: 417 languages (consistent languages)
b. O-V and NP-P: 427 languages (consistent languages)
c. V-O and NP-P: 38 languages (inconsistent languages)
d. O-V and P-NP: 10 languages (inconsistent languages)

Baker suggests that such neat distribution of languages is reminiscent of Stephen Jay Gould's *punctuated equilibrium*, where transitions between species types are not smooth or continuous, but show a sudden transition from one stable cluster of properties to another cluster of properties (Eldredge & Gould 1972; Gould 2002). This however may not be the complete picture, since as Gould also very categorically states, there are several cases of intermediary forms that paleontologists have to answer for. As with species evolution, where one finds fossil records of mainly stable clusters but also rare and transitional forms, languages too – at any given point – tend to exhibit both neat/'consistent' and 'inconsistent' patterns. It is therefore possible for some languages to opt out of a binary choice and instead exhibit mixed word orders; Arabic with its SVO and VSO orders being a classic example (see Alexiadou & Anagnostopoulou 1998; Soltan 2007). Baker considers these inconsistencies as "noise" emanating from features, while the consistencies are all attributed to structural parameters.

However, given that there is a close link between structures and feature values, with the latter themselves emerging from features in interaction with structures and syntactic operations, the role of features and feature values in bringing in big (critical) changes should not be ruled out. More precisely, instead of holding them responsible for only minor, and mostly inconsistent patterns, they should be examined carefully in their dynamic interplay with structures. The puzzle, of course, is if features are fixed from a universal set, what are the feature-induced mechanisms for large-scale changes? The answer is feature regulation.

Feature regulation may be understood to constitute a change in the feature sub-set of the language. Modification to the featural base happens when a given feature is either added or eliminated from the feature sub-set of a language. For illustration, many Eastern Indo-Aryan languages (e.g. Bangla, Oriya, Magadhi, Maithili) had simultaneous loss of ergative marking on subjects along with the complete loss of a gender feature. Given that ergativity in (western) Indo-Aryan is defined mainly on terms of overt subject marking, accompanied by gender and number object marking on the verb, languages of the eastern branch lost the ergative alignment and a host of other structural features, on losing out a single gender feature (see Chatterji 1926 for illustrations). This shift is a case of a radical structural overhaul brought about the loss of a single feature.

New features can also be added to the grammar, or already existing ones can be reanalyzed. Reanalysis as a mechanism of grammar change is widely accepted, and it often affects different aspects of the grammar such as constituency, hierarchical structure, category labels and grammatical relations (cf. Harris & Campbell 1995). To cite a few examples (see Lightfoot 1979), the premodals of Old English were reanalyzed in the 16th century, as modals in Modern English to create structures like 'I may go' and 'I will go' from 'I may will go'. Similarly, reanalysis affected grammatical relations in Middle English, transforming structures such as 'Him likes pears' (OVS) into present day structures 'He likes pears' (SVO). Such modifications of the base (features) – leading to large-scale changes – are not unique to the human language system. In biology too, gene mutations often lead to major morphological changes often associated with species formation.

Biology faces the same challenge to explain variation with a universal base. The genomic basis for all species is essentially the same, and yet we see immense biological diversity around us. The answer provided to us is that despite similarities, differences emerge by modifying the regulation of gene expression or transcription (see Wittkopp 2013 and citations therein, for a detailed summary of the relevant literature).

Gene expression involves the transcription of DNA sequence into RNA, which is (usually) further translated into a protein before the gene becomes functional in the cell, and impacts the phenotype of an organism. How much RNA is produced and at which site, is controlled by the gene's cis-regulatory DNA sequences and trans-regulatory factor proteins. It has been found that cis-regulatory sequences are more active in expression divergence among members of different species, whereas trans-regulatory factor proteins have a greater role to play in expression divergence among members of the same species.

It is also noticed that the basal promoter sequences of the cis-regulatory DNA sequences, which bind to transcription and are entrusted with protein translation, are more conserved. On the other hand, the enhancer sequences that are bound by transcription factors and activate expression from the basal promoter in a subset of cells or under a subset of environmental conditions, are less conserved and more likely to harbor mutations.

Many of the enhancer sequence mutations are deleterious and are deleted by selection. Often, despite modifications, their functions remain the same, as with the extensively changed enhancer driving expression of the *Drosophilla* eye retaining its original function. However, some enhancer sequence changes do bring in structural differences and this can be a single mutation or amount to multiple mutations. As for instance, in *Drosophilla*, deletion in an enhancer of the *desatF* gene contributes to an expression divergence by surprisingly creating novel binding sites that allows an unknown transcription factor to activate expression. New enhancers sometimes evolve *de novo*, driving novel expressions. But most often, novel enhancers evolve from preexisting enhancers through duplication and divergence, transposition and cooption, the last being the most common process through which old enhancers are repurposed with new functions.

In short, in both language and biology, we find evidence for mutations or modifications in the (featural/genomic) base, that activates new sites, with new resultant functions. Therefore, while the feature-set of a language is a one-time selection (recall Chomsky 1995), a change in the featural composition during language acquisition has the potential to trigger massive feature value differences and radical structural changes, to the extent that completely new grammars are formed from the old, existing ones.

To end, features are more conserved than feature values, with the latter even undergoing changes in adult grammars, owing to external pressures. Dialectal variations often ensue from such feature value differences. Features on the other hand, do sometimes change, especially in early stages of language acquisition, with wide-scale implications for the said grammar.

4. Some thoughts on comparative linguistics

Our perspective of the faculty of language as a two-layered system of features and feature values, both not immune to modification (though one more conserved than the other) raises questions about the objectives one should set for comparative linguistics, i.e. whether or not language classification into types or families is a fruitful venture.

Comparative linguists aim at relating languages and identifying families, based on their surface similarities and differences.[7] In recent years, the debate on comparative (generative) linguistics has been taken up at the structural versus featural parameter levels, with most defending one over the other. However, given the intricate relation between features, feature values and structures, it is necessary to redefine our methods for achieving these goals.

The literature has recently seen multiple efforts in this direction. Microvariationists, for instance, note a problem in identifying dialects, owing to their substantial surface-level, individual, structural differences that defy any attempt to classify them as a group. Kayne (2013) opines that dialects are syntactically very different from each other and should therefore be deemed as separate languages. He criticizes Dunn et al. (2011) for their rough estimate of the total number of world languages at 5000, claiming that this is far too short of the actual number, which he estimates to be more than 500,000. He illustrates with the example of Northern Italy, which alone has at least 25 languages that are individuated solely on the basis of the syntax of subject clitics (Renzi & Vanelli 1983). For Kayne, each surface-level structural difference indicates an independent linguistic system, with interesting commonalities at a deeper (UG) level, and it is the job of comparative linguists to unravel the true nature of this system. More specifically, he submits that comparative linguistic data should serve as evidence for the internal architecture of the grammar machine. Cross-linguistic generalizations should be used to restrict the set of hypothesis about the language faculty.

Much in consonance with Kayne's vision of comparative linguistics, I suggest that the focus should be on closely examining the language faculty in its variations. Detailed comparisons of linguistic data must be taken to critically assess our standard assumptions about grammar, its internal structure and computations. The goal of relating languages and identifying language families, on the other hand, may not be easily attainable, since at the micro or featural level, language classification into types or families is impossible. No two languages are dialects or even

7. See Longobardi & Guardino (2009) for phylogenetic relatedness among languages, drawing on syntactic parameters.

members of the same family, based on just their feature values. We cannot justify the categories of 'group' or 'family' etc., by simply looking for feature value and grammatical similarities and differences.

The language classification problem reminds us of a similar problem that biologists have with defining categories like 'group' or 'race' at the genetic (micro)-level, specifically after the results of the "Big Science" genome Project initiated in the late nineteen eighties. One of the main goals of this project was to identify all of the roughly 100,000 genes of the human genome. The results of the project, published in February 2001, settled the question on the existence of races: it confirmed that biology does not support the concept of races. Human beings share more than ninety-nine percent of their DNA with other species, with only a minute percentage of genes making up for radical, qualitative differences between human and non-human species. Moreover, individuals within a single racial group exhibit approximately eighty-five percent of human genetic variation. Of the remaining fifteen percent, around five percent account for variation within classically defined human "races," (e.g. the French versus the Ukrainians, the Japanese versus the Koreans) and around six to ten percent for differences between the classically defined geographical races, as identified by traits such as skin color, hair form, and nose shape (e.g. the Caucasians versus the Africans). Even with these traits that co-vary in many populations, co-variance does not show any sharp peaks. Such co-variance finds continuous variation across the globe. Races are therefore not meaningful biological constructs at the genetic level. Similarly, language types and families are not meaningful featural constructs.

More criticism for these constructs come from the biolinguistic camp, with Benítez-Burraco and Boeckx (2014) suggesting that the usual parameters or objects of comparison such as languages, dialects, sociolects may ultimately fail to serve their purpose and give very little insight on the biological foundations of the faculty of language. They then go on to say that are "deeper layers of variation to explore and to understand" (pp. 122) that comparative (bio)linguistics should focus on. The present study, though not at the same level of granularity evident in Benítez-Burraco and Boeckx's work, corroborate their claim about the existence of "deeper layers of variation", by highlighting the differences between features and feature values, and their differential behavior in response to external environment.

Traditionally, UG is understood as a homogeneous, unchanging entity, with features and/or parameters available for some restricted cross-linguistic variation. However, feature values themselves have been shown here to be emergent properties of narrow syntax – they are sensitive to computations, structural configurations and external events, while features, though highly conserved, are also allowed some modification, through a new sub-set selection or reanalysis. The faculty of language is therefore not a monolithic object, an idea that is also voiced in Vercelli and Piatelli-Palmarini (2008) and Lohndal and Uriagereka (2010). Vercelli and Piatelli-Palmarini, drawing on interesting instances of biological flexibility and sensitivity to environmental stimuli, clearly state that the faculty of language too, as a biological construct, has a common core (Universal Grammar), with other plastic, dynamic, epigenetic mechanisms to copious (yet restricted) amount of cross-linguistic variation.

In our multi-layered conception of grammar, the flexible epigenome is the layer where the fixed information-bearing features are variously manifested as feature values, sensitive to computations and the environment. This layer is mostly responsible for variations that are often found in dialect situations. Radical, structural differences, leading to new language creations, are often associated with a change in the featural sub-set when selected by a linguistic population. UG remains fixed, but the featural sub-set of a language sometimes incorporates changes that have non-trivial consequences for a given language.

Lastly, as in biology, where external factors influence the expression of genes, with subsequent phenotypic variation, in language too, external factors have an immense role to play in the expression of features. Abrupt changes brought about by environmental, social and geographical factors set off concurrent changes in feature expressions or feature values. The pool of feature values for any given language, at any given point of time, is therefore amenable to change under influence of both internal and external factors. These processes together, beget variation among languages.

5. Conclusion

In the end, this paper puts forth a view of the language faculty as parallel to any other biological system. A biolinguistic understanding of human language and variation also has implications for comparative linguistics and its objectives, some of which the present paper also discusses, while defending a non-monolithic view of grammar.

Acknowledgments

I thank Anna Maria Di Sciullo and an anonymous reviewer for very helpful comments. I am also grateful to the audience in Kolkata University, Jadavpur University, and the Indian Institutes of Technology at Delhi and Ropar for elaborate discussions on a previous draft of the paper.

References

Alexiadou, A. & Anagnostopoulou, E. 1998. Parametrizing AGR: Word order, V-movement, and EPP-checking. *Natural Language and Linguistic Theory* 16(3): 491–539. doi:10.1023/A:1006090432389

Baker, M.C. 2008. The macroparameter in a microparametric world. In *The Limits of Syntactic Variation* [Linguistik Aktuell/Linguistics Today 132], Theresa Biberauer (ed.), 351–374. Amsterdam: John Benjamins. doi:10.1075/la.132.16bak

Barbiers, S. 2009. Locus and limits of syntactic microvariation. *Lingua* 119(11): 1607–1624. doi:10.1016/j.lingua.2008.09.013

Barbiers, S. 2013. Where is syntactic variation? In *Language Variation – European Perspectives* IV [Studies in Language Variation 14], P. Auer, J.C. Reina & G. Kaufmann (eds), 1–26. Amsterdam: John Benjamins. doi:10.1075/silv.14.01bar

Bateson, P., Barker, D., Clutton-Brock, T., Deb, D., D'Udine, B., Foley, R.A., Gluckman, P., Godfrey, K., Kirkwood, T., Mirazón Lahr, M., McNamara, J., Metcalfe, N.B., Monaghan, P., Spencer, H.G. & Sultan, S.E. 2004. Developmental plasticity and human health. *Nature* 430(6998): 419–421. doi:10.1038/nature02725

Béjar, S. & Rezac, M. 2003. Person licensing and the derivation of PCC effects. In *Romance Linguistics: Theory and Acquisition* [Current Issues in Linguistic Theory 244], A. T. Pérez-Leroux & Y. Roberge (eds), 49–62. Amsterdam: John Benjamins. doi:10.1075/cilt.244.07bej

Benítez-Burraco, A. & Boeckx, C. 2014. Universal Grammar and biological variation: An agenda for comparative biolinguistics. *Biological Theory* 9(2): 122–134. doi:10.1007/s13752-014-0164-0

Bhatt, Rajesh. 2007. Ergativity in the Modern Indo-Aryan languages, Handout of talk given at the MIT Ergativity Seminar. ⟨http://people.umass.edu/bhatt/papers/mit-nov2007-handout.pdf⟩

Biberauer, T., Roberts, I. & Sheehan, M. 2014. No-choice parameters and the limits of syntactic variation. In *Proceedings of WCCFL 31,* R. Santana-LaBarge (ed.), 46–55. Somerville MA: Cascadilla Press.

Bittner, M. & Hale, K. 1996. Ergativity: Towards a theory of a heterogeneous class. *Linguistic Inquiry* 27: 531–604.

Boeckx, C. 2015. *Elementary Syntactic Structures: Prospects of a Feature-Free Syntax*. Cambridge: CUP.

Boeckx, C. & Grohmann, K.K. 2007. The Biolinguistics manifesto. *Biolinguistics* 1: 1–8.

Borer, H. 1984. *Parametric Syntax. Case Studies in Semitic and Romance Languages*. Dordrecht: Foris.

Boskovic, Z. 2009. Unifying first and last conjunct agreement. *Natural Language and Linguistic Theory* 27(3): 455–496. doi:10.1007/s11049-009-9072-6

Chatterji, S.K. 1926. *The Origin and the Development of the Bengali Language*. Calcutta: Calcutta University Press.

Chomsky, N. 1995. *The Minimalist Program*. Cambridge MA: The MIT Press.

Chomsky, N. 2000. Minimalist inquiries: the framework. In *Step by Step: Essays on Minimalist Syntax in Honor of Howard Lasnik,* R. Martin, D. Michaels & J. Uriagereka (eds), 89–155. Cambridge MA: The MIT Press.

Coon, J. & Preminger, O. 2012. Towards a unified account of person splits. In *WCCFL 29: Proceedings of the 29th West Coast Conference on Formal Linguistics*, J. Choi (ed.), 310–318. Somerville MA: Cascadilla Press.
Deo, A. & Sharma, D. 2006. Typological variation in the Ergative morphology of Indo-Aryan languages. *Linguistic Typology* 10(3): 369–418. doi:10.1515/LINGTY.2006.012
Dixon, R.M.W. 1972. *The Dyirbal Language of North Queensland*. Cambridge: CUP. doi:10.1017/CBO9781139084987
Dixon, R.M.W. 1994. *Ergativity*. Cambridge: CUP. doi:10.1017/CBO9780511611896
Dryer, M.S. 2005. Order of subject, object, and verb. In *World Atlas of Language Structures,* B. Comrie, M.S. Dryer, D. Gil & M. Haspelmath (eds), 330–333. Oxford: OUP.
Dryer, M.S. 2007. Review of Frederick J. Newmeyer, Possible and Probable Languages: A Generative Perspective on Linguistic Typology. *Journal of Linguistics* 43(1): 244–252. doi:10.1017/S0022226706254586
Dunn, M., Greenhill, S.J., Levinson, S.C. & Gray, R.D. 2011. Evolved structure of language shows lineage-specific trends in word-order universals. *Nature* 473(7345): 79–82. doi:10.1038/nature09923
Eldredge, N. & Gould, S.J. 1972. Punctuated equilibria: an alternative to phyletic gradualism. In *Models in Paleobiology*, T.J.M. Schopf (ed.), 82–115. San Francisco CA: Freeman Cooper.
Gibson, E., Piantadosi, S.T., Brink, K., Bergen, L., Lim, E. & Saxe, R. 2013. A noisy-channel account of crosslinguistic word-order variation. *Psychological Science* 24(7): 1079–1088. doi:10.1177/0956797612463705
Gluckman, P.D. & Hanson, M.A. 2004. Developmental origins of disease paradigm: A mechanistic and evolutionary perspective. *Pediatric Research* 56(3): 311–317. doi:10.1203/01.PDR.0000135998.08025.FB
Gould, S.J. 2002. *The Structure of Evolutionary Theory*. Cambridge MA: Harvard University Press.
Greenberg, J.H. 1963. Some universals of grammar with particular reference to the order of meaningful elements. In *Universals of Language: Report of a Conference Held at Dobbs Ferry*, J.H. Greenberg (ed.), 73–113. Cambridge MA: The MIT Press.
Harris, A.C. & Campbell, L. 1995. *Historical Syntax in Cross-linguistic Perpective*. Cambridge: CUP. doi:10.1017/CBO9780511620553
Hinzen, W. 2014. On the rationality of case. *Language Sciences* 46(Part B): 133–151. doi:10.1016/j.langsci.2014.03.003
Holmberg, A. & Roberts, I. 2014. Parameters and three factors of language design. In *Linguistic Variation in the Minimalist Framework*, M. Carme Picallo (ed.), 61–81. Oxford: OUP. doi:10.1093/acprof:oso/9780198702894.003.0004
Jirtle, R.L. & Skinner, M.K. 2007. Environmental epigenomics and disease susceptibility. *Nature Reviews Genetics* 8: 253–262. doi:10.1038/nrg2045
Kayne, R. 1994. *The Antisymmetry of Syntax*. Cambridge MA: The MIT Press.
Kayne, R. 2005. Some notes on comparative syntax, with special reference to English and French. In *The Oxford Handbook of Comparative Syntax*, G. Cinque & R. Kayne (eds), 3–69. Oxford: OUP.
Kayne, R. 2011. Why are there no directionality parameters. In *Proceedings of the 28th West Coast Conference on Formal Linguistics,* M. Byram Washburn, K. McKinney-Bock, E. Varis, A. Sawyer & B. Tomaszewicz (eds), 1–23. Somerville MA: Cascadilla Press.

Kayne, R. 2013. Comparative syntax. *Lingua* 130: 132–151. doi:10.1016/j.lingua.2012.10.008

Kida, Ireneusz. 2010. On how Norman-French hindered the development of English word order towards VO. In *Aspects of the History of English Language and Literature: Selected Papers Read at SHELL 2009*, O. Imahayashi, Y. Nakao & M. Ogura (eds), 285–292. Frankfurt: Peter Lang.

Kiparsky, P. 2008. Universal constrain change, change results in typological generalizations. In *Linguistic Universals and Language Change,* J. Good (ed.), 23–53. Oxford: OUP. doi:10.1093/acprof:oso/9780199298495.003.0002

Kroch, A.S. 2001. Syntactic change. In *The Handbook of Contemporary Syntactic Theory*, Mark Baltin & Chris Collins (eds), 699–730. Oxford: Blackwell.

Kroch, A.S. & Taylor, A. (eds). 1994. *Penn-Helsinki Parsed Corpus of Middle English*. Philadelphia PA: Department of Linguistics, University of Pennsylvania.

Kroch, A.S. & Taylor, A. 1997. Verb movement in Old and Middle English: Dialect variation and language contact. In *Parameters of Morphosyntactic Change*, A. van Kemenade & N. Vincent (eds), 297–325. Cambridge: CUP.

Kroch, A., Taylor, A. & Ringe, D. 1997. The Middle English verb-second constraint: A case study in language contact and language change. In *Textual Parameters in Older Languages* [Current Issues in Linguistic Theory 195], S. Herring, P. van Reenen & L. Schoesler (eds), 353–391. Amsterdam: John Benjamins. doi:10.1075/cilt.195.17kro

Legate, J. 2002. Walpiri: Theoretical Implications. Ph.D. dissertation, MIT.

Legate, J. 2012. Types of ergativity. *Lingua* 122: 181–191. doi:10.1016/j.lingua.2011.10.014

Lightfoot, D. 1979. *Principles of Diachronic Syntax*. Cambridge: CUP.

Lightfoot, D. 1991. *How to Set Parameters: Arguments from Language Change*. Cambridge MA: The MIT Press.

Lohndal, T. & Uriagereka, J. 2010. The logic of parametric theories. *Theoretical Linguistics* 36(1): 69–76. doi:10.1515/thli.2010.004

Longobardi, G. & Guardiano, C. 2009. Evidence for syntax as a signal of historical relatedness. *Lingua* 119(11): 1679–1706. doi:10.1016/j.lingua.2008.09.012

Mahajan, A.K. 2012. Ergatives, antipassives and the overt light v in Hindi. *Lingua* 122(3): 204–214. doi:10.1016/j.lingua.2011.10.011

Markovskaya, E. 2012. Derivational account of gender in deverbal nominals. In *Slavic Languages in Formal Grammar. Proceedings of FDSL 8.5*, Markéta Ziková & Mojmír Dočekal (eds), 135–148. Frankfurt: Peter Lang.

Marušič, F., Nevins, A. & Saksida, A. 2007. Last-conjunct agreement in Slovenian. In *Proceedings of Formal Approaches to Slavic Linguistics: The Toronto Meeting 2006*, R. Compton, M. Goledzinowska & U. Savchenko (eds), 210–227. Ann Arbor MI: Michigan Slavic Publications.

Meaney, M.J., Szyf, M. & Seckl, J.R. 2007. Epigenetic mechanisms of perinatal programming of hypothalamic-pituitary-adrenal function and health. *Trends in Molecular Medicine* 13(7): 269–277. doi:10.1016/j.molmed.2007.05.003

Newmeyer, F.J. 2005. *Possible and Probable Languages: A Generative Perspective on Linguistic Typology*. Oxford: OUP. doi:10.1093/acprof:oso/9780199274338.001.0001

Renzi, L. & Vanelli, L. 1983. I pronomi soggetto in alcune varietà romanze. In *Scritti linguistici in onore di G.B. Pellegrini*, P. Benincà, M. Cortelazzo, A. Prosdocimi, L. Vanelli & A. Zamboni (eds), 120–145. Pisa: Pacini.

Roberts, I. 1997. Directionality and word order change in the history of English. In *Parameters of Morphosyntactic Change*, A. van Kemenade & N. Vincent (eds), 397–426. Cambridge: CUP.

Roberts, I. & Holmberg, A. 2005. On the role of parameters in Universal Grammar: A reply to Newmeyer. In *Organizing grammar: Linguistic Studies in Honor of Henk van Riemsdijk*, H. Broekhuis, N. Corver, R. Huybregts, U. Kleinhenz & J. Koster (eds), 538–553. Berlin: Mouton de Gruyter.

Rönn, T., Poulsen, P., Hansson, O., Holmkvist, J., Almgren, P., Nilsson, P., Tuomi, T., Isomaa, B., Groop, L., Vaag, A. & Ling, C. 2008. Age influences DNA methylation and gene expression of COX7A1 in human skeletal muscle. *Diabetologia* 51: 1159–1168. doi:10.1007/s00125-008-1018-8

Seckl, J.R. & Holmes, M.C. 2007. Mechanisms of disease: Glucocorticoids, their placenta metabolism and 'fetal' programming of adult pathophysiology. *Nature Clinical Practice Endocrinology & Metabolism* 3(6): 479–88. doi:10.1038/ncpendmet0515

Soltan, U. 2007. On Formal Feature Licensing in Minimalism: Aspects of Standard Arabic Morphosyntax. Ph.D. Dissertation, University of Maryland College Park.

Subbarao, K.V. 2012. *South Asian Languages: A Syntactic Typology*. Cambridge: CUP. doi:10.1017/CBO9781139003575

Tomlin, R.S. 1986. *Basic Word Order. Functional Principles*. Cambridge: CUP.

Vercelli, D. & Piatelli-Palmarini, M. 2008. Language in an epigenetic framework. In *Of Minds and Language*, M. Piattelli-Palmarini, J. Uriagereka & P. Salaburu (eds), 97–107. Oxford: OUP.

Wittkopp, P.J. 2013. Evolution of gene expression. In *The Princeton Guide to Evolution*, J.B. Losos (ed.), 413–419. Princeton NJ: Princeton University Press.

Object pronouns in the evolution of Romanian

A biolinguistic perspective

Anna Maria Di Sciullo & Stanca Somesfalean
Université du Québec à Montréal

We examine pronominal objects in Old Romanian and show that the fluctuation in their position (pre-/post-verbal) and in their form (clitic/strong pronoun) is the result of the Directional Asymmetry Principle (DAP), a complexity-reducing principle proposed in Di Sciullo (2011), according to which language evolution is symmetry breaking. We show that DAP is sensitive to both derivational and representational complexity. Under its effects, on grounds of derivational complexity reduction, Romanian lost the discourse-driven verb movement that yielded enclisis. On grounds of representational (sensori-motor) complexity reduction, Romanian lost the use of strong pronouns in contexts that now only allow clitics. Thus, a fluctuating phase in the evolution of pronominal objects is followed by a phase where a preponderant use is attested (i.e. proclitics in Modern Romanian). We confirm previous findings on the diachronic development of the Romanian DP under the effects of DAP, showing the role of complexity reduction in language change.

1. Issue

In Old Romanian (OR, 16th–18th century), object personal pronouns can be post-verbal, (1a), (2a), (3a), and pre-verbal (4a), (5a), with what looks like[1] a strong preference for a post-verbal positioning for both clitics and strong pronouns. In contrast, Modern Romanian (MR) manifests an exclusive proclitic use in the same contexts (1b), (2b), (3b), (4b), (5b).

(1)	a.	*cu*	*slavă*	*priimişi*	***mine*** […]	(Coresi, 137r)
		with	glory	received	me.ACC.1SG.	

1. In the corpus we examined.

Di Sciullo, A.M. & Somesfalean, S. 2015. Object pronouns in the evolution of Romanian: a biolinguistic perspective. In *Formal Approaches to DPs in Old Romanian,* V. Hill (ed.). 269–290. Leiden: Brill.

DOI 10.1075/la.235.06sci

b. *cu* *slavă* ***mă*** *primişi* (MR)
with glory CL.me.ACC.1SG. received
'With glory you have received me.'

(2) a. *Doamne,* *cîntec* *nou* *cînt* ***ţie***, […]. (Coresi, 274r)
Lord, song new sing PRON.DAT.2SG

b. *Doamne,* *cântec* *nou* ***îţi*** *cânt* […]. (MR)
Lord, song new CL.DAT.2P.SG. sing
'Lord, a new song I sing to you.'

(3) a. […] *fără* *dereptate* *mînară-**mă*** […] (Coresi, 238v)
without reason led=CL.ACC.1SG.

b. […] *fără* *dereptate* ***mă*** *mînară* (MR)
without reason CL.ACC.1SG. led
'Without reason (they) led me'

(4) a. *nu* ***mă*** *ruşinez* *cînd* *caut* […] (Coresi, 231v)
not CL.REFL.1SG. embarrass when search

b. *nu* ***mă*** *ruşinez* *cînd* *caut* […] (MR)
not CL.REFL.1SG. embarrass when search
'(I) am not ashamed when (I) search'

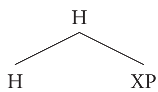
(5) a. *Şi* *acestu* *sfat* ***îi*** *da* […] (Amiras, 253v)
and this advice CL.DAT.3SG. give

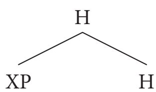
b. *Şi* *acest* *sfat* ***îi*** *dădea* […] (MR)
and this advice CL.DAT.3SG. give
'And he gave him this piece of advice'

We assume that linguistic variation, including diachronic change, is dependent on the effects of feature valuation, which may vary between languages as well as in the course of the development of a given language. The fluctuation in word order between pre- and post- positions for a given category in a projection chain is a function of the availability of both a valued and an unvalued feature F, giving rise to movement if F is unvalued, and not otherwise. We interpret this choice as a point of symmetry and we explore the effect of factors that are external to the Language Faculty on the reduction of complexity brought about by this choice, as well as its gradual elimination over time. Specifically, we examine the fluctuation in the position of the object pronoun in OR illustrated above, and propose that it is an instance of the Directional Asymmetry Principle (DAP), a complexity-reducing principle proposed in Di Sciullo (2011) and linked to the symmetry-breaking laws active in the natural world (Lewontin 1970, 1974; Graham, Freeman & Emlen 1993; Palmer, 2004, a.o.). A biolinguistic explanation for a diachronic phenomenon has the advantage of further bridging the explanatory gap between language development and biology.

2. An instance of the Directional Asymmetry Principle

Symmetry breaking is part of the natural laws affecting the evolution of the shape of biological organisms. Seen as a dynamic force external to the Language Faculty, it provides a biolinguistic explanation for language variation and evolution with respect to the position of a head and its dependent. A head-dependent structure includes a prominent element, the head (H). H can be to the right or to the left of its dependent (XP), as in (6), which depicts the position of H with respect to its sister for simplicity; however the position of H with respect to XP is set in an extended projection chain of H. It has been observed that both (6a) and (6b) are attested at some stage of the historical development of languages, while in a subsequent stage only one of the two options is available. In order to account for this phenomenon, the Directional Asymmetry Principle is formulated in Di Sciullo (2011) as in (7), where symmetry breaking applies to the availability of structures such as (6a) or (6b) in the course of language diachronic development.

(6) a. 

b. 

(7) *Directional Asymmetry Principle* (DAP)
Language evolution is symmetry breaking:
fluctuating asymmetry is followed by directional asymmetry.
Fluctuating asymmetry (random left or right positioning of a head) >
Directional asymmetry (exclusive left or right positioning of a head).

Di Sciullo (2011) provides evidence that DAP makes correct predictions for language historical evolution on the basis of the development of possessive pronouns from Genitives in the evolution of Classical Greek to Modern Greek and Greek dialects, as well as in the evolution of Latin to Italian and Italian dialects. Namely, the pre- and post-nominal positions are possible for the Genitive theme in Classical Greek, while only the post-nominal position is possible in Modern Greek. This is also the case for the possessive clitics in Modern Greek and Grico, a Greek dialect spoken in the Italian regions of Calabria and Puglia, as well as in Modern Italian and in dialects spoken in the regions of Abruzzo, including Pescasseroli, Fallo and Arielli. The predictions of DAP have also been shown to cover the development of prepositions in Indo-European languages in Di Sciullo and Nicolis (2013), and the development of the definite determiner in Romanian in Di Sciullo and Somesfalean (2013).

According to DAP, language evolution is symmetry breaking. Symmetry introduces choice-points, thus instability in a system that seeks to eliminate it in order to reinstate an asymmetrical stable state. The effects of symmetry breaking in language historical development are legible at the sensory-motor interface. As predicted, the fluctuating stage of pronoun position in OR is followed by a phase where a preponderant location is attested: in MR the predominant use of the object personal pronoun clitic is preverbal, i.e. proclitic.[2]

The OR use of enclitics, the development of Differential Object Marking (DOM), and the rise of Clitic Doubling (CD) constructions are all phenomena that have been addressed and discussed in recent works (Zafiu 2014; Hill 2013; Chiriacescu & Von Heusinger 2009; Alboiu & Hill 2012; Von Heusinger & Onea Gaspar 2008, a.o.). We consider some of these facts in a broader perspective, as instances of language evolution processes. The notion of language evolution goes beyond the classical notion of language change and grammaticalization (Roberts & Roussou 2003) by incorporating recent results from evolutionary developmental biology. This incorporation has both descriptive and explanatory advantages over classical notions of language change and grammaticalization. The descriptive advantage is that fluctuating stages are predicted to occur and can be described systematically. The explanatory advantage is that questions such as why languages change and why grammaticalization exists can be addressed on the basis of the existence of general laws governing the development and evolution of biological form.

3. Analysis

3.1 Enclisis in OR

Enclisis is a generalised characteristic of OR, evidenced not only with pronominal objects, as seen in examples (1a), (2a), (3a), but also with verbal clitics, i.e. auxiliaries, as in (8a) below, and adverbial clitics. While we mention the other constructions marginally in our analysis, this paper is concerned with the behaviour of pronominal objects only.

(8) a. ***ales-au*** *12 oameni de țară* (Amiras, 249r)
chosen-AUX.2PL. 12 men of country

b. ***au ales*** *12 oameni de țară* (MR)
AUX.2PL. chosen 12 men of country
'They have chosen 12 countrymen'

The massive use of enclitics in OR may seem like instances of Wackernagel's law, very strong in Slavic languages and assumed to have greatly influenced the written Romanian language (Frâncu 2009). However, Alboiu and Hill (2012) argue that Wackernagel's law is not active in OR, given the fluctuation in the placement of

2. While post-verbal strong pronouns exist in MR, they are part of DOM/CD constructions, i.e. the presence of the clitic is obligatory.

clitics in OR, i.e. clitics are not consistently in second position (cf. ex. (9), from Alboiu & Hill 2012); clitics may also be preverbal (cf. ex. (10) from Alboiu & Hill 2012), and finally, the rise of proclitics is independent of Wackernagel's law. They conclude that the enclisis that characterises OR is discourse-driven.

(9) *cu* *pizmă* *huluiia-**l*** (Frâncu 2009: 277)
with hate cursed-CL.3SG.M.
'cursed him with hate'

(10) ***să*** *vedea* *că* *după* *acest* *război*
CL.REFL saw that after this war
fără *noroc* […] (Ureche/Panaitescu 1958: 115)
without luck
'one could see that after this war without luck […]'

Our focus in this paper is a particular case of the enclisis that characterises OR, namely of pronominal objects. Moreover, OR allows for both preverbal and post-verbal pronominal objects, a fluctuation thus coexists at a given moment in the evolution of Romanian, illustrated in (11) below. Interestingly, while the pronominal object enclisis is wide-spread in OR – for both clitics and strong pronouns, the tendency in MR is towards the use of clitic objects, exclusively preverbal. Object strong pronouns, when used, can only be doubling constituents (i.e. the presence of the preverbal clitic is necessary for CD). This is illustrated in (12).

(11) a. *pădzească* ***tine*** *cel* *mare* *domnul* *şi*
protect PRON.ACC.2SG. the great lord=DEF and
te *alduiască* […] (Frag.Tod. 4r)
CL.ACC.2SG. bless

b. ***te*** *pădzească* ***pe*** ***tine*** *cel* *mare* *domnul* *şi*
CL.ACC.2SG. protect DOM you the great lord.DEF. and
te *alduiască* (MR)
CL.ACC.2SG. bless
'May the great Lord protect you and bless you.'

(12) From –CD in OR to +CD in MR

Old Romanian	**Modern Romanian**	**English**
*primiişi **mine*** receive PRON.ACC.1SG.	***mă** primişi (pe mine)* CL.ACC.1SG. receive (DOM PRON.ACC.1SG.)	'you received **me**'
*cînt **ţie*** sing PRON.DAT.2SG.	***îţi** cânt (ţie)* CL.DAT.2SG. sing (PRON.DAT.2SG.)	'I sing **to you**'
*mînară-**mă*** led-CL.ACC.1SG.	***mă** mînară* CL.ACC.1SG. led	'they led **me**'

We provide an account for the observed fluctuation of the position of pronominal objects in OR and of the MR tendency towards proclisis. This reinforces previous findings about the same trend in the evolution of the Romanian DP, as shown in Di Sciullo & Somesfalean (2013). Specifically, we have shown that MR is in a phase of directional asymmetry with respect to the behaviour of the Gen/Dat forms of the definite determiner. Thus, while Nom/Acc forms of the definite determiners have reached a phase of directional asymmetry (i.e. enclisis), the Gen/Dat forms are still allowing fluctuation, with a strong tendency towards proclisis. These two patterns of evolution are summarised in (13) below, from Di Sciullo & Somesfalean (2013).

(13) Evolution of the **Nominative/Accusative** form of the definite determiner:

Phase 1 – ***fluctuating asymmetry***:
Danubian Latin prenominal and postnominal demonstratives (from Graur 1929)

Prenominal:

(i)	*homo*	*ille*	*bonus*
	man.NOM	that.NOM	good.NOM

'That good man.'

Postnominal:

(ii)	*ille*	*homo*	*bonus*
	that.NOM	man.NOM	good.NOM

'That good man.'

Phase 2 – ***directional asymmetry***:
Stabilization of postnominal definite article in Old and Modern Romanian

(i) a.	*om**ul***	*bun*		(MR)
	man.DEF.NOM/ACC	good		

'the good man'

b.	*carte**a***	*din*	*librarie*
	book.DEF.NOM/ACC	from	bookstore

'the book from the library'

(ii) a.	*acesta*	*iaste*	*ce*	*aud*	*cuvînt**ul*** […]	(Tetra. 43v)
	this	is	what	hear	word.DEF.ACC	

'this is the word I hear'

b.	*să*	*nu*	*poftești*	*vecinului*	*tău […],*
	SUBJ	not	covet	neighbor.DEF.DAT	your

nece	*fecior**ul**,*	*nece*	*bo**ul**,*	*nece*	*asin**ul**, […]*	(Î.C.5r)
neither	boy.DEF.ACC	nor	OX.DEF.ACC	nor	ass.DEF.ACC	

'To your neighbour, you shall not covet the son, the ox or the ass.'

Prenominal Nom/Acc definite articles are not attested in OR or MR

(iii)	**ul*	*om*	*bun*
	DEF.NOM/ACC	man	good

'the good man'

(14) Evolution of the **Oblique Genitive/Dative** form of the definite determiner:

Phase 1 – ***fluctuating asymmetry***:
Prenominal and postnominal definite determiners in Old Romanian

Prenominal:

(i) ***lui*** *Hotchevici*
DEF.DAT/GEN.M.SG. Hotchevici

(ii) ***ei*** *Maria*
DEF.DAT/GEN.F.SG Maria
DEF.DAT/GEN.F.SG. Maria

Postnominal:

(iii) *Radu**lui***
Radu.DEF.DAT/GEN.M.SG.

(iv) *Mari**ei***
Maria.DEF.DAT/GEN.F.SG.

(v) *băiatu**lui***
boy.DEF.DAT/GEN.M.SG.

(vi) *copil**ei***
girl.DEF.DAT/GEN.F.SG.

Phase 2 – (**strong tendency of**) ***directional asymmetry***:
Prenominal definite determiner /prepositional marker in Modern Romanian[3,4]

(i) ***lui/lu'*** *Ioan*
DEF.DAT/GEN.M.SG.Ioan

(ii) ***lui/lu'*** *copil /copilul*[5]
DEF.DAT/GEN.M.SG. boy/the girl

(iii) ***lui/lu'*** *fată* /fata
DEF.DAT/GEN.M.SG. girl/the boy

---

3. *la* is also a possible substitution for the Dative Case marked DP that can be employed with both masculine and feminine forms. However, while for most speakers *lu(i)* is best followed by a definite noun, *la* is mostly followed by an indefinite.

4. *lu'* is a phonetically shortened form of *lui*.

5. When the prepositional marker is used, the definite forms seem to be more easily acceptable than the indefinite forms. Still, for some speakers of Romanian the following constructions are acceptable:

(i) *I-am spus lu' copil ă nu întârzie.*
cl.DAT-have.1 told DEF.DAT child SUBJ not to.be.late
'I have told the child not to be late.'

(ii) *I-am spus şi la fată.*
CL.DAT-have.1 told also to girl
'I have also told the girl.'

Romanian constructions with definite determiners allowed us to confirm the prediction of DAP, i.e. that a directionality is observed in the evolution of the language from an older stage to a modern stage: while the fluctuating asymmetry is brought about by a choice in the valued or unvalued properties of Case features in Old Romanian, the symmetry brought about by these choice points is gradually eliminated in the modern stage of the language, where eventually only one of the two options remains available.

Based on these conclusions, we expect DAP to be active also in the evolution of Romanian pronominal object constructions, with the effect of reducing complexity. In what follows we will appeal to two notions of complexity proposed in Di Sciullo (2012):

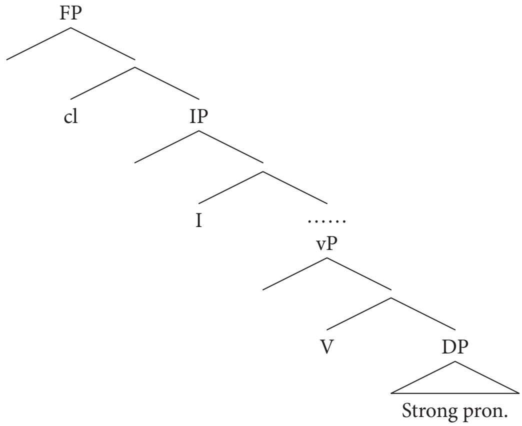
i Internal complexity (I-complexity) is derived by the operations of the Language Faculty and is measured in terms of length of derivations. Thus, a derivation of a linguistic expression that involves fewer operations will be preferred over a more 'costly' derivation on grounds of computational efficiency.
ii External complexity (E-complexity) is legible at the sensori-motor (SM) interface and is calculated in terms of density of representations, which is not limited to string linear measure, but includes supra-segmental material such as tone, as discussed in Di Sciullo (2005), and stress. Thus, a representation that contains less SM material will be less 'costly' on grounds of representational efficiency.

We propose that the change in the pattern of pronominal objects from OR to MR is the result of a bi-fold complexity reduction mechanism, namely the reduction of both I-complexity, which is basically derivational, and the reduction of E-complexity, which is basically representational. We now turn to the structure of the constructions under investigation and discuss their complexity. We will first discuss I-complexity (henceforth, derivational complexity) and then E-complexity (henceforth, representational complexity).

3.2 Derivational complexity

We assume that pronouns are determiners, as in Postal (1969), and that clitics and strong pronouns differ in their level of complexity, as in Kayne (1991, 1994); Uriagereka (1995); Cardinaletti & Starke (1999); Sportiche (1999); Di Sciullo (1990); Di Sciullo & Aguero (2008), a.o. More specifically, we assume, with Uriagereka (1995), that pronominal clitics, as anchors on new information, are in the head of a functional projection at the periphery of IP, illustrated below in (15). As mentioned above, we assume that movement is driven by feature checking/valuation (cf. Chomsky 1995, 2000, 2001; Pesetsky & Torrego 2006; a.o.). We will not discuss the feature checking/valuation in the derivations, as the identification of the features checked/valued is orthogonal to our discussion.

(15)

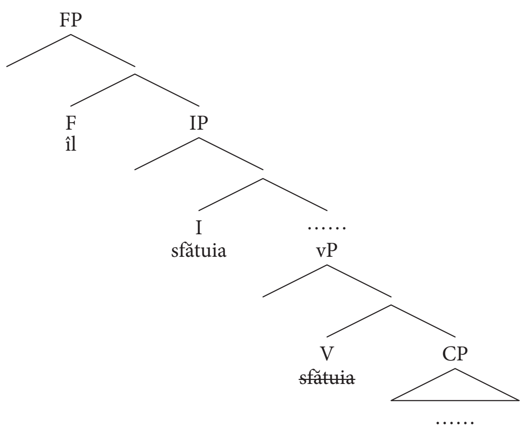


Thus, in a construction such as (16) below, the clitic is in (Head,FP) and the proclitic positioning of the object pronoun follows, as illustrated in (17).

(16)	*[…]Costantin Ciobanul […],*		*de*	*altă*	*parte,*
	Constantin Shepherd.DEF		on	other	side
	îl	***sfătuia***	*să*	*vie […]*	(Amiras, 253v)
	CL.ACC.3SG.M.	advise	SUBJ	come	

'Constantin The Shepherd, on the other hand, advised him to come back'

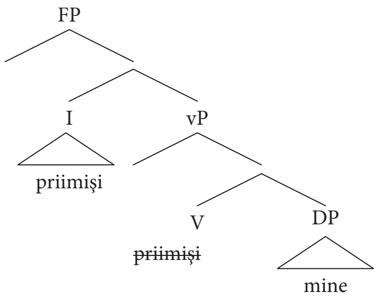
(17)



We illustrate the strong pronoun object example (18) with the structure in (19) below.

(18) *[…] cu slavă priimişi* ***mine****.* (Coresi, 137r)
with glory received PRON.ACC.1SG.
'With glory you received me.'

(19)



However, as mentioned above, OR also presents evidence of postposed clitic constructions in declaratives, as in (20) below.

(20) a. *Domnul fereaşte-****te*** *de tot răul.* (Coresi, 248v)
Lord.DEF protects-CL.ACC.2SG. from all harm
'The Lord protects you from all harm.'

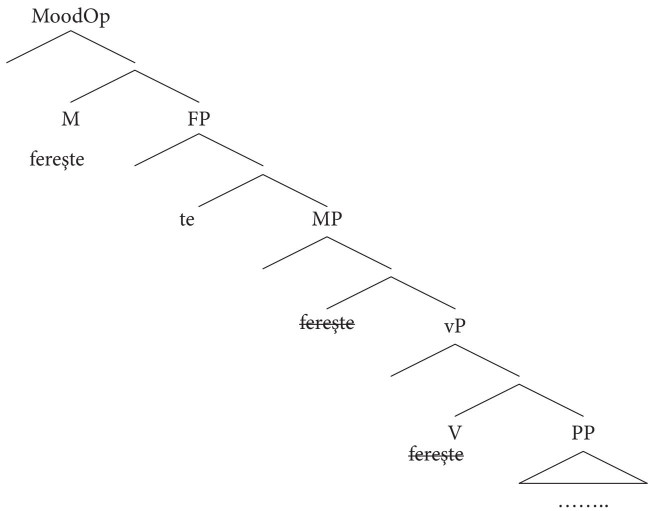
b. *Domnul* ***te*** *fereşte de tot răul.* (MR)
Lord.DEF CL.ACC.2SG protects from all harm
'The Lord protects you from all harm.'

We analyse these as instances of verb movement, in the sense of Emonds (1978); Pollock (1989), a.o., a movement that is still active in MR, but only in imperative and gerund constructions, such as (21), illustrated in (22) with a structure based on Isac (1998).[6]

(21) *Fereşte-****te*** *de soare!* (MR)
protect.IMP.2SG-CL.ACC.REFL.2SG from sun
'Protect yourself from the sun!'

6. In Isac (1998) the (Modern) Romanian verb moves to Mood projection, while the subjunctive particles, imperatives and gerunds move to a higher MoodOp projection in order to check strong irrealis features.

(22)



The question that immediately arises is what drives generalized V-to-C in OR. We assume that V-to-C in OR is discourse-related, as in Alboiu & Hill (2012). Adopting a cartographic approach (Rizzi 1997), the authors analyse V>clitic order (i.e. all instances of enclisis in OR : verb>auxiliary clitics, V>adverbial clitics, V>pronominal clitics,) as the result of verb movement to a focus head, triggered for discourse purposes, an optional movement that depends on whether certain discourse features (i.e. a focus operator feature optionally associated with the CP field) are present in the derivation. In their analysis, four types of focus operators (following Hohle 1992; Krifka 2007; Richter & Mehlhorn 2006) are present in OR and operator feature checking is satisfied either by constituent movement to (Spec,FocP) – for instance, a *wh*-phrase – or by head-to-head movement of the verb to Foc – in which case the operator is null. Thus, V>clitic order obtains when the verb moves higher than the tense-bearing projection T, to Foc, for checking emphatic focus (EF) or verum focus (VF) features. This analysis predicts that the V>clitic order would be optional in declaratives, as in (23), obligatory in yes/no questions, as in (24), and excluded in *wh*-questions, as in (25).

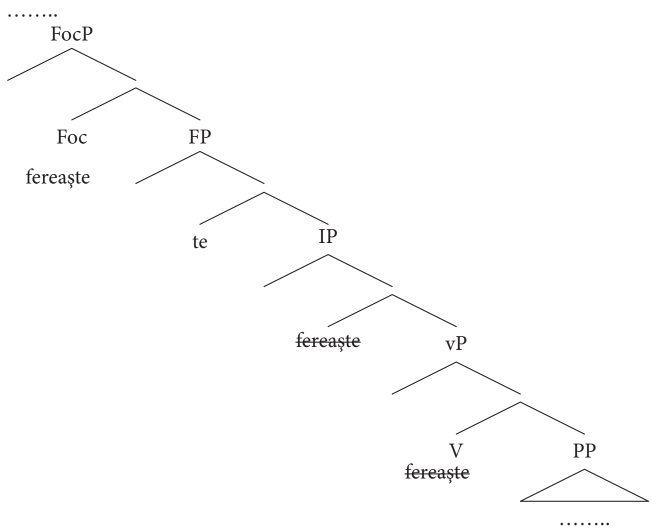
(23) a. *afla-**să*** *această țară […]* (Ureche/Panaitescu 1958: 67)
happened-cl.refl this country
'This country happened to…'

b. ***să*** *vedea că după acest război […]* (Ureche/Panaitescu 1958: 115)
cl.refl.3 saw that after this war
'You could see that after this war…'

(24) *Cunoşti-**mă*** *pre* *mine,* *au* *ba ?* (Neculce/Iordan 1955: 120)
know-CL.ACC.1SG. DOM PRON.ACC.1SG. or not
'Do you recognize me or not ?'

(25) *Cum* ***ar*** *hi* *împăratu* *să* *hie* *drag* *tuturora ?* (Costin/Panaitescu 1979: 33)
how AUX. be king.DEF SUBJ be dear all.DAT
'How should the king be to be loved by all?'

Thus the partial structure of an OR declarative such as (20a), for instance, would look like (26) below, where the verb moves to Foc.[7]

(26)


The fact that MR still allows stylistic, highly focused expressions where indicatives or conditionals precedes the clitic, as in (27)–(28) below, is an argument in favour of such an analysis, where the preverbal position of the verb is associated with an emphatic reading.

(27) *Pare-**se*** *că* *vrea* *să* *plece.* (MR)
seems-CL.REFL that wants SUBJ leave.3
'It seems that (s)he wants to leave.'

(28) *Mira-**m-aş*** *că* *vine* *şi* *ea!* (MR)
wonder-CL.REFL.1SG-AUX.1SG that comes also PRON.NOM.3SG.F.
'I would be surprised if she came along.'

7. The constituents preceding FocP are in a topicalised projection TopP. The proposed cartography of the OR clause in Alboiu & Hill (2012) is TopP>FocP>FinP/IP>TP. We differ from their clause structure assumptions only with respect to clitic placement: while they place clitics adjoined to T, we have them in F, as in Uriagereka (1995), above IP. We also assume Long Head Movement (Rivero 1991, a.o.), ensuring that the verb is able to move to higher projections such as FocP.

We adopt this movement of the verb to a Focus projection in order to derive the V>clitic constructions. These constructions are attested started from mid-17th century. In the constructions involving strong pronominal arguments, on the other hand, the verb may also move, but not as high as FocP. Zafiu (2014) and Alboiu and Hill (2012) show that 16th century OR does have (non-emphatic) verb movement but it targets a lower projection than FocP, namely to FinP (the equivalent of IP in our structures).

Based on our assumptions on derivational complexity mentioned above and the structures in (17), (19) and (26), the derivation of cl>V or V>strong pronoun constructions involves fewer operations than the derivation of V>cl constructions, where the verb has moved to FocP. It follows that the derivation of (17), as well as that of (1), (2), (3b) is less costly from a computational point of view than the derivation of (26), as well as that of (3a), hence it is preferable for efficiency reasons. Thus, in a fluctuation period such as the one observed in OR, our analysis predicts that given DAP and the fact that the derivation of post-verbal clitic objects is more derivationally costly, proclisis will be preferred. Our prediction is confirmed by MR data.

3.3 Representational complexity

We have seen that verb movement yields variation in the position of pronominal objects in OR. But we have not said anything about the variation in the choice between a strong and a clitic form of the object pronoun in the evolution of Romanian, cf. the contrast between (1a), (2a) and (1b), (2b). What drives the choice of a clitic over a strong pronoun in the evolution of Romanian? Why are patterns (29a) and (29d) – i.e. with strong object pronouns – attested in OR, rather than simply (29b) and (29e) – i.e. with clitic objects, which incidentally is also what survived in highly stylistic MR (cf. (29c) and (29f))?

(29) Summary of diachronic changes

<table>
<tr><th>Old Romanian
(strong pronoun use)</th><th>Modern Romanian
(clitic use)</th></tr>
<tr><td>a) primiişi mine
received.2SG PRON.ACC.1SG.</td><td>b) mă primişi (pe mine)
CL.ACC.1SG. receive (DOM PRON.ACC.1SG.)
c) stylistic: primişi-mă
receive-CL.ACC.1SG.</td></tr>
<tr><td>d) cînt ţie
sing PRON.DAT.2SG.</td><td>e) îţi cânt (ţie)
CL.DAT.2SG. sing (PRON.DAT.2SG.)
f) stylistic: cîntu-ţi
sing-CL.DAT.2SG.</td></tr>
</table>

We believe the answer to this question lies in the degree of complexity at the SM interface that differentiates strong pronouns and clitics. In other words, the choice of a strong pronoun (in OR) implies the choice of a more complex SM form, an option which is gradually eliminated in favour of a less complex form, in our case, a clitic (in MR). This implies that DAP is equally sensitive to another measure of complexity, i.e. E-complexity.

Numerous studies have investigated the difference in structure between strong pronouns and clitics. Cardinaletti & Starke (1999), Déchaine & Wiltscko (2002), Di Sciullo (2005), a.o., have proposed systems where the visible lack of structure in the clitic form is the reflection of a deficient internal structure. The fact that deficient pronouns have an impoverished structure is shown by their morpho-phonological form (*l, i,* etc.), while strong pronouns are more articulated, often including determiner forms (*lui, ei*, etc.). Since features have a morphological reflex in the theory we are adopting, we should expect that clitics lack encoding some of the features that are present in the strong forms. In other words, the features of the clitic should constitute a subset of the features of the strong pronoun. The exact feature argued to be deficient in clitics as opposed to strong pronouns may differ according to the approach. It has been proposed that Romance clitics lack encoding a [person] feature, cf. Uriagereka (1995), a.o. In Cardinaletti and Starke (1999), the difference between strong pronouns and deficient ones is the presence/absence of the Case projection in their structure. In Déchaine and Wiltschko (2002) strong pronouns and clitics have a different categorical status.

We adopt Di Sciullo (2005), where the internal structure of functional elements is an operator shell. The upper layer of the shell is the locus of the operator feature, such as a wh- or a th- operator, and the lower layer is the locus of the restrictor of the variable bound by the operator. The difference between strong and weak pronouns is the occurrence of a Focus feature in the upper part of the Op-Shell in the case of strong pronouns, and its absence in the case of weak pronouns. Thus it is the presence of a Focus feature in the structure of the strong pronouns that makes them differ from the clitic counterpart, as the Op-Shells in (30) illustrate.

(30) a. [Op_D F [α Re β]] strong pronoun
Foc phi-features

b. [Op_D F [α Re β]] clitic
phi-features

Considering the upper layer of the OP-shells in (30), the pronominal operator ($Op_{D)}$ is associated with a focus feature (Foc) in the case of a strong pronoun (30a), but not in the case of a clitic, (30b). The F head is the locus of the variable bound by the operator. The variable is linked to its restrictor (Re) in the lower layer of the Op-Shell. For example, with pronouns, Re can be +Human, e.g. *he/him* or – Human, e.g. *it*. The dependent of the restrictor is associated with phi-features, including person, number, gender and Case. In this framework, "the Op-Shell covers the morphological properties of [±Q] elements, including question words and complementizers, and [±D] elements, including definite, indefinite, and expletive determiners, demonstratives and pronouns, which have the same asymmetric form." (Di Sciullo 2005: 121). The morphological form of the functional elements differs however with respect to their feature structures.

The difference in SM representational complexity may not always arise from string-linear properties. In our case, while a string-linear difference is visible in certain forms of the strong pronoun/clitic pair, such as *mine* PRON.ACC.1SG. vs. *mă* CL.ACC.1SG., this difference may not be obvious in other forms, such as *ţie* PRON.DAT.2SG. vs. *îţi* CL.DAT.2SG. On the other hand, the notion of density of SM representations encompasses string-linear properties and supra-segmental features, in our case stress. Thus, in both *mine/mă* and *ţie/îţi* pairs, for instance, only the strong pronoun can bear stress. This difference in SM representational complexity leads to the preference of the clitic (the less complex form) over the strong pronoun (the more complex form).

Our analysis predicts that, whenever a choice is possible, a clitic will be preferred over a strong pronoun, which concurs with what is found in L1 acquisition studies (Granfeldt & Schlyter 2004). It also concurs with principles such as Avoid Pronoun (Chomsky 1981) or Minimise Structure (Cardinaletti & Starke 1999, essentially stating that whenever a weak pronoun is available it must be chosen over a stronger pronoun). In the constructions under examination here, after a period of fluctuation in OR where both strong and clitic object pronouns coexist in a given configuration, only the clitic form survives in later stages of the language. As mentioned above, this is not to say MR doesn't have strong pronouns. As shown in (29b) and (29e), MR allows strong pronouns, but only in CD constructions, i.e. the presence of the clitic is required.[8] In other words, the default pronominal argument seems to be the clitic, and when the strong pronoun is present, DOM is too. Irimia (2015) shows that strong pronouns have indeed different properties in OR as opposed to MR. Namely, while DOM and CD are not obligatory in OR, they are in MR. She links this difference to the levels of prominence active in the language at a given point in time. While in MR the DOM constructions are subject to both the animacy and the definiteness scale, presumably in OR the definiteness scale is not fully implemented, yielding a variable behaviour of strong pronouns. Thus, it may be the case that, as the later stages of Romanian impose more constraints on the presence of the strong pronouns (i.e. DOM becoming increasingly obligatory),

8. One could wonder why these doubling cases are not subject to DAP. It is generally assumed that CD structures are highly emphatic and thus motivated on grammar external grounds.

the choice of pronominal arguments gradually reduces to clitic forms, a 'simpler' choice on both E-complexity and I-complexity grounds.

3.4 Summary

Our study of the change in form of pronominal objects constructions from OR to MR reveals that they are the result of two phenomena: on one hand, there is an a optional, discourse-related movement of the verb to a position higher than the tense-bearing node; on the other hand, there is a choice between strong and clitic forms of the object pronoun. We propose that the form of the pronominal object constructions in the evolution of Romanian is the result of the reduction of two types of complexity:

i I-complexity or derivational CI complexity (as a measure of the number of syntactic operations that apply in the derivation of a linguistic expression)

Under its effect, MR gradually lost the verb movement motivated by discursive features.[9] The only verb movement to a projection higher than the tense-bearing node that is still attested in MR is not discourse-related (i.e. not optional), but motivated by syntactic-feature checking/valuation in imperative and gerund constructions.

ii E-complexity or representational SM complexity (as a measure of the SM density of a representation)

Under its effect, MR gradually lost the choice of strong pronouns in favour of clitics in argument positions (i.e. examples such as (29a), (29d) are disallowed, in favour of (29b) and (29e)), independently of verb movement.

The combined effect of the two complexity-reduction mechanisms is the complete loss of postverbal strong pronouns (without DOM) in MR.

4. Conclusion

We have proposed that the change in the pattern of pronominal objects from OR to MR is the result of DAP, a complexity-reduction mechanism sensitive to both derivational and representational complexity. We further confirmed its effects in the evolution of Romanian. We have shown that in addition to derivational

9. Reminiscent of these are cases of stylistic emphasis in MR such as in (27) and (28) above, crucially involving clitics.

complexity reduction, representational complexity reduction is also a factor of language change.

Acknowledgements

This work is supported in part by funding from the Social Sciences and Humanities Research Council of Canada to the Major Collaborative Research on Interface Asymmetries, grant number 214-2003-1003, and by funding from the FQRSC on Dynamic Interfaces, grant number 137253.

Sources

Amiras	Simonescu, D. (ed.). 1975. *Cronicile medievale ale României. Vol. 9*. Bucharest: Editura Academiei.
Coresi	Toma, S. (ed.). 1976. *Coresi, Psaltirea slavo-română (1577) în comparaţie cu psaltirile coresiene din 1570 şi din 1589*. Bucharest: Editura Academiei.
Costin	Panaitescu, P.P. (ed.). 1979. *Miron Costin, Letopiseţul Ţării Moldovei*. Bucharest: Editura Minerva.
Frag.Tod.	*Fragmentul Todorescu*. In Buză, E., G. Chivu, M. Georgescu, I. Ghetie, A. Roman-Moraru & F. Zgraon (eds.). 1982. *Texte româneşti din secolul al XVI-lea*. Bucharest: Editura Academiei.
Î.C.	*Întrebare creştinească*. In Buză, E., M. Georgescu, A. Mareş & F. Zgraon (eds.). 1994. *Crestomatia limbii române vechi. vol I (1521–1639)*. Institutul de lingvistica Bucuresti.
Neculce	Iordan, I. (ed.). 1955. *Ion Neculce, Letopiseţul Ţării Moldovei*. Bucharest: Editura de Stat.
Tetra.	*Tetraevanghel*. In Buză, E., M. Georgescu, A. Mareş & F. Zgraon (eds.). 1994. *Crestomatia limbii române vechi. Vol I (1521–1639)*. Institutul de lingvistica Bucuresti.
Ureche	Panaitescu, P.P. (ed.). 1958. *Grigore Ureche, Letopiseţul Ţării Moldovei*. Bucharest: Editura de Stat.

References

Alboiu, G. & Hill, V. 2012. Early Modern Romanian and Wackernagel's law. *Journal of the Linguistic Association of Finland* 25: 7–28.

Cardinaletti, A. & Starke, M. 1999. The typology of structural deficiency: A case study of the three classes of pronouns. In *Clitics in the languages of Europe*, van Riemsdijk (ed.), 145–235. Berlin/New York: Mouton de Gruyter.

Chiriacescu, S. & von Heusinger, K. 2009. Pe-marking and referential persistence in Romanian. In *Focus at the Syntax-Semantics Interface. Working Papers of the SFB 732*, Vol. 3, A. Riester & E. Onea (eds). Stuttgart: University of Stuttgart.

Chomsky, N. 2001. Derivation by phase. In *Ken Hale: A Life in Language*, M. Kenstowicz (ed.), 1–52. Cambridge MA: The MIT Press.

Chomsky, N. 2000. Minimalist inquiries. In *Step by Step*, R. Martin, D. Michaels & J. Uriagereka (eds), 89–155. Cambridge MA: The MIT Press.

Chomsky, N. 1995. *The Minimalist Program*. Cambridge MA: The MIT Press.

Chomsky, N. 1981. *Lectures in Government and Binding* [Studies in Generative Grammar 9]. Dordrecht: Foris.

Déchaine, R.-M. & Wiltschko, M. 2002. Decomposing pronouns. *Linguistic Inquiry* 33: 409–422. doi:10.1162/002438902760168554

Di Sciullo, A.M. 2012. Perspectives on morphological complexity. In *Morphology. (Ir)regularity, Frequency, Typology* [Current Issues in Linguistic Theory 322], F. Kiefer, M. Ladanyi & P. Siptar (eds),105–135. Amsterdam: John Benjamins. doi:10.1075/cilt.322.06sci

Di Sciullo, A.M. 2011. A biolinguistic approach to variation. In *The Biolinguisitic Entreprise. New Perspectives on the Evolution and Nature of the Human Language Faculty,* Di Sciullo & C. Boeckx (eds).

Di Sciullo, A.M. 2005. *Asymmetry in Morphology*. Cambridge MA: The MIT Press.

Di Sciullo, A.M. 1990. On the properties of clitics. In *Binding in Romance*. *Canadian Journal of Linguistics,* A.M. Di Sciullo & A. Rochette (eds), 209–223. Oxford: OUP.

Di Sciullo, A.M. & Nicolis, M. 2013. Third factor in the development of P. In *NELS 42. Proceedings of the 42nd Meeting of the North East Linguistic Society*, S. Keine & S. Sloggett (eds). Amherst MA: GSLA.

Di Sciullo, A.M. & Somesfalean, S. 2013. Variation in the position of the definite determiner in Romanian: A biolinguistic perspective. In *Romance Linguistics in the Pacific: Variation in Time and Space*. Special Issue of the *Australian Journal of Linguistics* 33(2): 121–139. doi:10.1080/07268602.2013.814526

Di Sciullo, A.M. & Aguero Bautista, S. 2008. The delay of condition B effect and its absence in certain languages. *Language and Speech* 51: 77–100. doi:10.1177/00238309080510010601

Emonds, J. 1978. The verbal complex V′-V in French. *Linguistic Inquiry* 9: 49–77.

Frâncu, C. 2009. *Gramatica limbii române vechi (1521–1780)*. Iasi: Demiurg.

Graham J., Freeman, D.C. & Emlen, J.M. 1993. Antisymmetry, directional asymmetry, and dynamic morphogenesis. *Genetica* 89: 121–137.

Granfeldt, J. & Schlyter, S. 2004. Cliticisation in the acquisition of French as L1 and L2. In *The Acquisition of French in Different Contexts: Focus on Functional Categories* [Language Acquisition and Language Disorders 32], J. Paradis & P. Prévost (eds), 333–370. Amsterdam: John Bejamins. doi:10.1075/lald.32.15gra

Graur, A. 1929. A propos de l'article postposé. *Romania* 55: 475–481.

Hill, V. 2013. The direct object marker in Romanian: A historical perspective. *Romance Linguistics in the Pacific: Variation in Time and Space*. Special Issue of the *Australian Journal of Linguistics*. 33(2): 140–151. doi:10.1080/07268602.2013.814527

Höhle, T. 1992. Über Verum Fokus in Deutschen. *Linguistische Berichte Sonderheft* 4: 112–141.

Irimia, M. 2015. DPs in Adjectival Small Clauses in Romanian: a Diachronic Perspective. In *Formal Approaches to DPs in Old Romanian*, V. Hill (ed.), 290–328. Leiden: Brill.

Isac, D. 1998. Sentence Negation in English and Romanian: a Syntactic and Semantic Approach. Ph.D. Dissertation. University of Bucharest.

Kayne, R. 1994. *The Antisymmetry of Syntax*. Cambridge MA: The MIT Press.

Kayne, R. 1991. Romance clitics, verb movement, and PRO. *Linguistic Inquiry* 22: 647–686.

Krifka, M. 2007. Basic notions of information structure. In *Interdisciplinary Studies of Information Structure* 6, C. Fery, G. Fanselow & M. Krifka (eds). Potsdam: University of Potsdam.

Lewontin, R. 1970. The units of selection. *Annual Review of Ecology and Systematics* 1: 1–14.

Lewontin, R. 1974. *The Genetic Basis of Evolutionary Change*. New York: Columbia University Press.

Palmer, A.R. 2004. Symmetry breaking and the evolution of development. *Science* 306: 828–833.

Pesetsky, D. & Torrego, E. 2006. Probes, goals and syntactic categories. In *Proceedings of the Seventh Tokyo Conference on Psycholinguistics*, Y. Otsu (ed.), 25–60. Tokyo.

Pollock, J.-Y. 1989. Verb movement, Universal Grammar, and the structure of IP. *Linguistic Inquiry* 20: 365–424.

Postal, P.M. 1969. On so-called 'pronouns' in English. In *Modern Studies in English: Readings in Transformational Grammar*, D.A. Reibel & S.A. Schane (eds), 201–224. Englewood Cliffs NJ: Prentice Hall.

Richter, N. & Mehlhorn, G. 2006. Focus on contrast and emphasis: Evidence from prosody. In *The Architecture of Focus*, V. Molnar & S. Winkler (eds), 347–373. Berlin: Mouton de Gruyter. doi:10.1515/9783110922011.347

Rizzi, L. 1997. The fine structure of the left periphery. In *Elements of Grammar*, L. Haegeman (ed.), 281–339. Dordrecht: Kluwer.

van Riemsdijk, Henk (ed.). 1999. *Clitics in the Languages of Europe*. Berlin: Mouton de Gruyter.

Rivero, M.L. 1991. Long head movement and negation: Serbo-Croatian vs Slovak and Czech. *The Linguistic Review* 8: 319–351. doi:10.1515/tlir.1991.8.2-4.319

Roberts, I. & Roussou, A. 2003. *Syntactic Change. A Minimalist Approach to Grammaticalization*. Cambridge: CUP. doi:10.1017/CBO9780511486326

Sportiche, D. 1999. Pronominal clitic dependencies. In van Riemsdijk (ed.), 679–708.

Uriagereka, J. 1995. Aspects of the syntax of clitic placement in Western Romance. *Linguistic Inquiry* 26: 79–123.

von Heusinger, K. & Onea Gaspar, E. 2008. Triggering and blocking effects in the diachronic development of DOM in Romanian. *Probus* 20: 67–110.

Zafiu, R. 2014. Auxiliary encliticization in the 16th century Romanian: Restrictions and regularities. *Linguistica Atlantica* 33(2): 71–86.

The interplay of silent nouns and (reduced) relatives in Malay adjectival modification*

Manuel Español-Echevarría
Université Laval

This paper considers parametric variation in the area of adnominal adjectival modification from the viewpoint of Malay. Cinque (2010) has shown that, in spite of the great deal of variation found in adjectival modification, it is possible to identify two main classes with clear-cut syntactic and semantic properties: direct and indirect modification. Working on a restricted subset of adjectival classes, namely intersective, subsective and evaluative adjectives, we put forward a general proposal aiming to characterize in a precise way the syntactic distinction between these two main types of adjectival modification. Our proposal crucially involves the presence of silent/overt nouns, cf. Kayne (2005), and a possessive relation in the case of direct modification, and (reduced) relatives for indirect modification. Under the set of proposals put forward in this paper, variation will mostly follow from (a) externalization, cf. Berwick and Chomsky (2011), Chomsky (2010), Richards (2008), Di Sciullo (2015), and (b) the set of silent nouns available, a "lexical parameter" of a quasi-inflectional nature, cf. Chomsky (2001).

0. Introduction

Starting with influential work by R. Kayne, cf. Kayne (2005 et seq.), silent categories have been shown to play a major role in language variation.[1] Under an asymmetric view of language design where FL is an efficient computational system

* This research is supported in part by funding from the FQRSC on Dynamic Interfaces, Principal Investigator Anna Maria Di Sciullo, grant number 137253. I would like to thank Ashrafiqin Ahmad for her judgements and insights concerning the data in this paper. I am also indebted to Anna Maria Di Sciullo for her insightful comments on a preliminary version of this paper, as well as Antonia Androutsopoulou for discussing with me many of the ideas in this paper. All errors remain my own.

1. We adopt here Kayne's (2006:75) view according to which variation occurring within languages is exactly of the same sort as the one found across languages. See also Sigurðsson (2004) for the pervasiveness of silence in natural language.

DOI 10.1075/la.235.07esp

at the SEM-interface, but treats the mapping to PHON as a secondary process, it seems quite plausible to assume that silent categories are, at least in part, a by-product of externalization. This is in fact the position taken in Di Sciullo (2015) where the overt/silent character of constituents is ruled by a *Minimize Externalization* principle, see Section 4 below, cf. also Chomsky (2010). Nonetheless, as it will be claimed in Section 4, silent categories may also play a role in parametric variation due to their featural properties, as any other lexical category entering syntactic derivations, cf. Borer (1984), Chomsky (2001, 2004) a.o.[2]

In this paper, we will investigate the syntax of the two basic types of adnominal adjectival modification: direct and indirect adjectival modification, cf. Cinque (2010), a.o. We will focus on Malay adjectival modifiers. Malay adjectival modifiers display a set of syntactic properties which allow us to pinpoint some crucial aspects of these two types of modification. On the one hand, higher or indirect modifiers involve a relative clause featuring the complementizer *yang*. On the other hand, lower or direct modifiers are shown to be combined with the modified NP through an intervening nominal head, which remains silent in the general case, but has a phonetic realization under precise circumstances; for instance, whenever it undergoes syntactic movement. We will claim that these nominal heads, usually silent, are crucial in the syntactic derivation of direct modification cross-linguistically.[3] We will also argue that direct and indirect modification in Malay is determined by the semantic type of the modification associated with the adjective. Although indirect modification is available to (almost) all adjectives, only intersective and subsective adjectives, as opposed to evaluative ones, are compatible with direct modification. In addition, we investigate the relation between the silent noun in the adjectival modifier and the head noun, and we will conclude that this relation is mediated by a possessive relation. This treatment of Malay data leaves the door open for a more generalized approach to direct, intersective, modification in terms of silent noun modification plus possession.

---

2. The two cases just presented do not exhaust the ways in which silent categories interact with the computational system yielding variation. Kayne (2006), for instance, argues that the overt or silent nature of MUCH, cf. Jackendoff (1977), Corver (1997), depends on whether MUCH has been moved to the edge of a phase.

3. These nominal heads may be also overt with intersective and subsective adjectives in Romance, as for instance *color/colore* in the Spanish and Italian examples in (i):

(i) a. ¿De qué color es la mesa?

b. Che colore ha il tavolo?
"Which is the color of the table?"

The paper is organized as follows. The first section offers a brief overview of the two types of Malay adjectival modifiers discussed in the paper. In Section 2, we will consider a subset of adjectives in Malay, namely evaluative, subsective and intersective adjectives, and it will be shown that the set of possible modification configurations associated with an adjective is partially determined by the semantic class of the adjective. Section 3 will deal with the merging of direct and indirect modification in the DP. The fourth section will be devoted to the syntax of silent nouns which may be overt under certain conditions in direct modification contexts in Malay. The paper closes with a final section on the main conclusion of this research.

1. Two types of adjectival modification in Malay

Malay shows two basic types of adjectival modification illustrated in (1)–(2):

(1) a. kasut merah itu
shoes red the/this
"the red shoes"

b. ?/??kasut yang merah itu
shoes COMPL red the/this
"the red shoes"

(2) a. sebuah buku yang baik
a-CL book COMPL good
"a good book"

b. ??/*sebuah buku baik
a-CL book good
"a good book"

Color adjectives, such as *merah* "red", can directly combine with the head noun, cf. (1a), whereas evaluative adjectives, such as *baik* "good", require the occurrence of the complementizer *yang*[4] in order to modify the head noun, as shown by the contrast in (2).[5] We take the two patterns of adjectival modification in (1)–(2) to be an instance of the well-attested distinction between direct and

4. See Section 2.1 below, as well as Hung (1987), Cole & Hermon (1995) and Wong (2008) for the complementizer status of *yang*.

5. Judgments concerning (1b) are not always clear. Contrastive focus on the adjective definitively improves the acceptability of the indirect modification alternative with color and other intersective adjectives. See Footnotes 11 and 12 below for discussion.

indirect modification,[6] where the pattern in (1) corresponds to the case of direct modification and the one in (2) to indirect modification. Accordingly, they show many of the syntactic properties identified in Cinque (2010) for each one of the modification types. For instance, direct modifiers must appear closer to the noun, cf. Cinque (2010: 28), when both types of modifiers co-occur:

(3) a. kasut merah yang cantik itu
shoes red COMPL nice the/this
"the nice red shoes"

b. *kasut yang cantik merah itu
shoes COMPL nice red the/this
"the nice red shoes"

The contrast in (3) shows that the direct modification adjective *merah* "red" must be closer to the noun than the indirect modification adjective *cantik* "nice". In addition, the direct modification pattern in (1) is much more restricted than the one associated with indirect modification, cf. (2a). Direct modification is limited to one modifier per DP in Malay, whereas indirect modification is recursive, as shown in the following examples:

(4) a. *sebiji bola merah besar
one-CL ball red big
"a big red ball"

b. *sebiji bola besar yang ber-warna merah
one-CL ball big COMPL VRB-color red
"a big red ball"

(5) Seorang perempuan muda yang tinggi yang ber-bangsa Melayu
one-CL woman young COMPL tall COMPL VRB-race Malay
"a young tall Malay woman"

The ungrammaticality of (4a) illustrates the lack of recursion of direct modification in Malay, whereas (5) shows that the number of indirect modifiers is in principle unlimited.[7]

---

6. See Sproat & Shih (1988) and Cinque (2010) among many others for discussion.

7. We will leave the ban against stacking direct adjectival modifiers in Malay for further research. This seems to be a feature associated with postnominal adjectives in languages like Thai, Nung, cf. Simpson (2005), or Somali, cf. Bendjaballah and Cabredo Hofherr (2006). However, such limitation is not observed in many languages with postnominal adjectival modification, as shown in the following Basque DP from Artiagoitia (2006: 110):

(i) lorontzi txinatar zuri txiki bat
vase Chinese white small one
"a small white Chinese vase"

2. The relation between the modification type and the semantic properties of the adjective

The occurrence with an adjective of one, or both, of the modification patterns introduced in the preceding section is partially determined by the semantic properties of the modifying adjective. We distinguish in this respect three main categories: evaluative or subject-comment adjectives, intersective adjectives, and subsective or relative adjectives, cf. Kamp (1975), Bierwisch (1989), Scott (2002) among others. This latter category shows an intermediate status, exhibiting syntactic properties characteristic of both the first two categories.

2.1 Evaluative adjectives

Bierwisch (1989) characterizes evaluative adjectives as denoting non-quantifiable descriptive properties.[8] As shown in Section 1, direct modification is in general disallowed with evaluative adjectives, cf. (2) and (6):[9]

(6) a. sebuah artikel yang baik
one-CL article COMPL good
"a good article"

---

8. Evaluative adjectives are the highest category of adjectives among those dealt with in this paper, according to Scott's (2002) hierarchy of adjectival functional projections above NP in English, cf. (i):

(i) Subject-comment (evaluative) > ?evidential > size > length > height > speed > depth > width > weight > temperature > ?wetness > age > shape > color > nationality/origin > material > compound element.

Where "A > B" indicates "A is structurally higher than B".

9. Direct modification with evaluative adjectives seems possible with kind-denoting NPs, as in the examples in (i):

(i) a. Dia orang penting dalam pertubuhan kami.
3SG person important in organization POSS.1PL
"He is an important person in our organization".

b. Bukan senang jadi perempuan cantik.
NEG easy be woman beautiful
'It's not easy to be a beautiful woman.'

c. Tontoni filem-filem menarik di TV3.
watch films interesting on TV3
"Don't miss interesting films on TV3".

We leave this interaction for further research.

b. *sebuah artikel baik
one-CL article good
"a good article"

These modifiers are introduced in attributive contexts by the complementizer *yang*, which is absent in predicative contexts, as shown in (7):

(7) Artikel itu (*yang) baik.
article the/this COMPL good
"The article is good".

The complementizer status of *yang* is confirmed by its occurrence in full-fledged relative clauses, cf. (8), as well as by it heading certain cases of +*wh* CP,[10] as shown in (9):

(8) Wanita yang sedang berjalan itu memakan epal.
Women COMPL PROG walk the/this eat apple
"The women who are walking are eating apples."

(9) Siapa-kah yang membeli buku itu?
who-Q COMPL ACT-buy book the/this
"Who bought the book?" cf. Wong (2008: 111)

Given the complementizer status of *yang*, we would like to claim that indirect modification in Malay always involves a (reduced) relative clause. This result coincides with Cinque's (2010) syntactic interpretation of indirect modification.

2.2 Intersective adjectives

This category covers a variety of adjectives belonging to different lexical classes, such as color, shape, material or origin. In all these cases, the property denoted by the adjective does not change depending on the modified noun, nor seems to be context dependent. In Malay, this type of adjectives, as opposed to evaluative

10. In particular, those CPs hosting a displaced subject. Compare the acceptability of (9) with the ungrammaticality of (i), cf. Wong (2008: 111):

(i) *Apa-kah yang Mary membeli?
what-Q COMPL Mary ACT-buy
"What did Mary buy?"

In (i), an object has been displaced to Spec, C_0 yielding an ungrammatical result.

adjectives, directly modify a nominal projection as shown in (10)–(13), see also (1):[11]

(10) a. meja bulat itu SHAPE
table round the
"the round table"

b. ??meja yang bulat itu
table COMPL round the
"the round table"

(11) a. kasut hijau itu COLOR
shoes green the
"the green shoes"

b. ?/??kasut yang hijau itu
shoes COMPL green the
"the green shoes"

(12) a. pelajar Melayu itu ORIGIN
student Malay the
"the Malay student"

b. *pelajar yang Melayu itu
student COMPL Malay the
"the Malay student"

---

11. Examples like those in (10b) and (11b) are ok if the adjective receives a contrastive focus interpretation. Let us consider in this respect the dialogue in (i):

(i) A: Kamu suka kasut yang mana?
2SG like shoes COMPL which
Yang merah atau yang hijau?
COMPL red or COMPL green
"Which shoes do you like? The red ones or the green ones?"

B: Saya lebih suka kasut yang merah itu.
1SG more like shoes COMPL red the
"I prefer the red ones."

All the occurrences of *merah* "red" and *hijau* "green" in (i) receive a contrastive focus interpretation and require the complementizer *yang*. We assume that these cases involve some sort of derived indirect modification, where the intersective adjective, i.e. *merah* "red" or *hijau* "red" in (i), has moved to a DP-internal focus projection linked to the occurrence of *yang*. Nonetheless, we leave this issue for further research.

(13) a. meja kayu itu MATERIAL
table wood the
"the wooden table"

b. *meja yang kayu itu
table COMPL wood the
"the wooden table"

The sequence *yang+A* as NP-modifier yields marginal results in some cases, cf. (10b) and (11b), as well as fully ungrammatical ones, such as (12b) and (13b).[12] However, the problem with the (b) sequences in (10)–(13) does not seem to reside in the indirect modification *per se*, but rather in some internal aspect of the modifying relative clause. Consider in this respect the following alternatives to (10b), (11b), (12b) and (13b) below:

(14) a. meja yang ber-bentuk bulat itu
table COMPL VRB-form round the
"the round table"

b. kasut yang ber-warna hijau itu
shoes COMPL VRB-color green the
"the green shoes"

c. pelajar yang ber-bangsa Melayu itu
student COMPL VRB-race Malay the
"the Malay student"

---

12. The contrast in the judgments obtained for the examples (10b) and (11b) on the one hand and (12b) and (13b) on the other seems to be related to a contrastively focused interpretation of the adjectival modifier, cf. Footnote 11 above. Origin and material modifiers are disallowed in contexts requiring a focused interpretation of the modifier, as shown in (i) for the origin adjectives *cina* "chinese" and *melayu* "malay":

(i) A: Kamu suka pelajar yang mana?
2SG like student COMPL which
"Which student do you like?
??Yang Melayu atau yang Cina?
COMPL Malay or COMPL Chinese
"The Malaysian one or the Chinese one?"

B: *Pelajar yang Melayu itu
student COMPL Malayan the
"The Malaysian one."

Compare the judgments in (i) to those obtained for shape and color adjectives in focused contexts, cf. (i) in Footnote 11 above.

d. meja yang ber-jenis kayu itu
table COMPL VRB-type wood the
"the wooden table"[13]

The examples in (14) show that form, color, origin and material modifiers can be introduced by means of a relative clause. However, this relative clause, with the complementizer *yang,* must contain in the case of intersective adjectives a sort of classifier noun, *bentuk* "form", *warna* "color", *bangsa* "race" and *jenis* "type/sort" in (14a), (14b), (14c) and (14d) respectively, which gets verbalized by the verbal prefix *ber*. We would like to claim following Kayne (2005: 213) that intersective modifiers, as opposed to evaluative ones, always involve a classifier noun, which may be silent, as in (10a), (11a), (12a) and (13a) above, or phonetically overt, as in the examples in (14). We claim that this silent noun is at the core of what we have labeled direct modification, and its absence is precisely what seems to exclude evaluative adjectives from direct modification.[14]

2.3 Subsective adjectives

In contrast to intersective adjectives, the denotation of subsective or relative adjectives is always determined in relation to the noun they modify, cf. Kamp and Partee (1995). The adjective *big,* for instance, has a different denotation depending on whether it modifies the noun *ant* or the noun *elephant.*[15] Under the label

13. Material modifiers, such as *kayu* "wood", and in contrast with other intersective adjectives, show an additional form of modification, illustrated in (i):

(i) meja jenis kayu itu mahal
table type wood the/this expensive
"The/this wooden table is expensive."

In (i), there is no *yang* complementizer, nor verbalizer prefix, i.e. *ber*. The constituent *jenis kayu* "type/kind wood" is also possible in predicative contexts, as shown in (ii):

(ii) Meja itu jenis kayu
table the/this type wood
"The/this table is a wooden one."

We leave for further research this additional feature of material modifiers in Malay.

14. See Section 4 below for further discussion.

15. The denotation of subsective adjectives, as opposed to that of intersective adjectives, is also context dependent, cf. Chierchia & McConnell-Ginet (2000), as shown by the interpretation of *big* in a case such as (i):

(i) Max has made a big snowman this winter.

of subjective adjectives, we can include a number of adjectival lexical classes, such as those of size, height, length, temperature, age or speed. All these lexical classes constitute the "middle field" in Scott's (2002) hierarchy of adjectival projections, cf. Footnote 8 above. They occupy an intermediate space in between the lower intersective and thematic classes and the higher class of evaluative adjectives. The cluster of syntactic properties of subsective adjectives in Malay reproduces this intermediate status. Consider the cases in (15)–(16):

(15) a. Kopi panas itu — TEMPERATURE
coffee hot the
"the hot coffee"

b. Kopi yang panas itu
coffee COMPL hot the
"the hot coffee"

c. *Kopi yang ber-suhu panas itu
coffee COMPL VRB-temperature hot the
"the hot coffee"

(16) a. Meja besar itu — SIZE
table big the
"the big table"

b. Meja yang besar itu
table COMPL big the
"the big table"

c. * Meja yang ber-saiz besar itu
table COMPL VRB-size big the
"the big table"

Subsective adjectives, such as *panas* "hot" or *besar* "big", share with evaluative adjectives the possibility of indirect modification, involving the complementizer *yang* only, cf. (15b)–(16b) and (6a) above, and with intersective adjectives the possibility of direct modification, cf. (15a)-(16a) and (10a) above. On the other hand, they contrast with evaluative adjectives in that they allow direct modification, cf. (15a)-(16a) and (6b), and with intersective adjectives in that they (a) disallow

In the context in (i), the denotation of *big* is relative to the average size of snowmen, but it is also sensitive to contextual factors, such as the age of Max, for instance. The comparison class with respect to which *big* is interpreted depends on whether Max is a seven year old kid or an adult.

the modification *yang+verbalizer+noun*,[16] cf. (15c)–(16c) and (14b), and (b) allow indirect modification involving the complementizer *yang* only, cf. (15b)–(16b) and (10b) in Section 2.2.

3. The derivation of direct and indirect adjectival modifiers

In the preceding sections, we have shown that there exists in Malay a relation between the semantic properties of adjectival modifiers and two different forms of modifying configurations: direct modification and indirect modification (i.e. *yang*-relativization). In this section, we will provide evidence showing that each one of these modifying configurations is merged at different points in the derivation of a DP.

Direct modifiers are always closer to the head noun than indirect modifiers in Malay, cf. Section 1 above. This is a typical feature distinguishing direct modifiers from indirect modifiers crosslinguistically, cf. Cinque (2010) for discussion. The examples in (17) illustrate this distinction:

(17) a. Se-buah meja kayu yang cantik yang ber-warna hijau
one-CL table wood COMPL beautiful COMPL *ber*-color green
"a beautiful green wooden table"

b. *Se-buah meja yang cantik kayu yang ber-warna hijau
one-CL table COMPL beautiful wood COMPL *ber*-color green
"a beautiful green wooden table"

16. The *yang+ber-N* indirect modification pattern is sometimes allowed with subsective adjectives such as *besar* "big". Consider for instance the case in (i):

(i) seluar yang bersaiz besar itu
pants COMPL VRB-size big/large the/this
"the large pants"

We do not have any account of why the pattern of modification typical of intersective adjectives is allowed in the case of the subsective adjective *besar* "big" in (i). In any event, this possibility is related to the marginal status of direct modification in the relevant context, as shown in (ii):

(ii) ??seluar yang besar itu
pants COMPL big/large the/this
"the large pants"

As opposed to what we observed in (16a), direct modification is degraded in (ii). We leave this point for further research.

c. *Se-buah meja yang cantik yang ber-warna hijau kayu
one-CL table COMPL beautiful COMPL *ber*-color green wood
"a beautiful green wooden table"

The examples in (17) involve one case of direct modification, i.e. *kayu* "wooden", and two cases of indirect modification, i.e. *yang cantik* "beautiful" and *yang berwarna hijau* "green". The ungrammaticality of (17b) and (17c) suggests that the direct modifier must appear the closest to the head noun *meja* "table".[17]

A second piece of evidence illustrating the same point comes from possessive DPs involving adjectival modification. The example in (18) illustrates a simple possessive DP in Malay, without determiner but with a definite meaning, cf. Ahmad (2012):

(18) kasut Ashra
shoes Ashra
"Ashra's shoes"

The possessor, *Ashra* in (18), appears after the possessed noun. We assume, following Kayne (1994), that (18) involves movement of a projection containing the noun *kasut* "shoes" to a CP-like projection above the TP projection hosting the possessor, i.e. *Ashra*. Something along the lines in (19):

(19) [CP [XP kasut]$_i$ C$_0$ [TP [DP Ashra] T$_0$ t$_i$]].

which corresponds to Kayne's (1994) derivation of *a book of John's*. Under this set of basic assumptions, let us consider the more complex cases of possessive DPs involving adjectival modification in (20)–(21):

(20) a. kasut merah Ashra
shoes red Ashra
"Ashra's red shoes"

b. kasut Ashra yang ber-warna merah
shoes Ashra COMPL VRB-color red
"Ashra's red shoes"

c. *kasut yang ber-warna merah Ashra
shoes COMPL VRB-color red Ashra
"Ashra's red shoes"

17. However, since all modifiers in (17) are postnominal, it could be argued that the ungrammaticality of (17b) and (17c) is due to the fact that indirect modifiers are phonologically heavier than the direct modifier *kayu* "wooden" and, therefore, they tend to appear at the rightmost boundary of the DP.

(21) a. *article baik Ashra
article good Ashra
"Ashra's good article"

b. article Ashra yang baik
article Ashra COMPL good
"Ashra's good article"

c. *article yang baik Ashra
article COMPL good Ashra
"Ashra's good article"

(20c) and (21c) show that relativized modifiers are disallowed in the position preceding the possessor.[18] In addition, in the cases in which an adjective cannot enter in direct modification, i.e. evaluative adjectives (cf. Section 2.1), there is no way to include the modifier in the pre-possessor position, cf. (21a). Assuming the derivation in (19) for Malay possessive DPs, the ban on indirect modifiers in the pre-possessor position in (20) and (21) should be understood as a consequence of the fact that indirect modifiers are not merged inside the projection XP moved to the Spec of C_0 in (19). (22) captures the relevant aspects of the proposed derivation for (20a):

(22) $[_{CP}\ [_{XP}\ [_{NP}$ kasut$]_i\ [_{dP}\ [_{AP}$ merah$]\ t_i]]_j\ C_0$ [TP [DP Ashra] $T_0\ t_j$]].

(22) includes the XP constituent in the pre-possessor position, i.e. (23):

(23) $[_{XP}\ [_{NP}$ kasut$]_i\ [_{dP}\ [_{AP}$ merah$]\ t_i]]$.

In (23), the NP *kasut* has been extracted out of dP as a byproduct of the more general displacement process leading to the initial position of NPs in Malay DPs. The label "dP" for the relevant projection has been adopted from Cinque (2010: 34), where this projection constitutes the boundary between direct modification, merged inside dP, and indirect modification, merged externally to dP.[19] Crucially, indirect modifiers involving (reduced) relatives with *yang* are not merged inside dP. This property of dP explains the ban on indirect modifiers of all types in pre-possessor position observed in (20)–(21).[20]

---

18. Davies and Dresser (2005) have made the same observation for Javanese, see also Vander Klok (2013).

19. We would like to note at this point that, given our analysis of the Malay data, we depart from Cinque (2010) on what counts as an indirect modifier. In particular, we have concluded that evaluative adjectives and probably subsective adjectives should be considered indirect modifiers, at least in Malay.

20. We leave for further research the question of whether the indirect modifier in (20b)–(21b) has been stranded by the movement of XP, or alternatively, is pair-merged with the CP containing the possessor, cf. (19).

4. Direct modifiers and silent nouns

Kayne (2005: 212–213) proposes that color adjectives are modifiers of a silent or unpronounced noun, i.e. COLOR. It seems to us that this proposal can be easily extended to other intersective adjectives, such as shape adjectives, material adjectives or origin adjectives, see (10)–(13) above, which could presumably modify SHAPE, MATERIAL or ORIGIN silent nouns. This approach allows, in our view, for a direct account of the "ridigity" of intersective modification, in the sense that the interpretation of these modifiers is not noun dependent, nor context dependent. These two properties would follow from the fact that only intersective adjectives modify a silent noun.[21]

The set of Malay data we have considered in the preceding sections offers some insight on the syntax of these silent nouns and their relation with direct and indirect modification. In Section 2.2, we introduced indirect, relative clause modifiers involving an intersective adjective in Malay, cf. (14). We include the relevant examples under (24) for convenience:

(24) a. meja yang ber-bentuk bulat itu
table COMPL VRB-form round the
"the round table"

b. kasut yang ber-warna hijau itu
shoes COMPL VRB-color green the
"the green shoes"

c. pelajar yang ber-bangsa Melayu itu
student COMPL VRB-race Malaya the
"the Malay student"

d. meja yang ber-jenis kayu itu
table COMPL VRB-type wood the
"the wooden table"

The examples in (24) all involve a nominal head. i.e. *bentuk* "form", *warna* "color", *bangsa* "race" and *jenis* "type/kind" which matches Kayne's notion of silent noun. As we have shown before, cf. Section 2, intersective modifiers contrast with subsective modifiers and evaluative modifiers in that in the latter no counterpart of the relevant noun is available, as shown in (25):

---

21. If follows from this that evaluative adjectives (and perhaps also subsective adjectives, but see the discussion below) modify the overt noun heading the DP (through some form of relative clause), and not a silent noun. This would give a direct account of why the qualia structure of a noun seems to be open with respect to evaluative modification, cf. Katz (1966), Pustejovsky (1995), Jackendoff (1997), but closed off with respect to intersective modification.

(25) a. article yang baik itu — EVALUATIVE, cf. (6a)
article COMPL good the
"the good article"

b. meja yang (*ber-saiz) besar itu — SUBSECTIVE – SIZE
table COMPL VRB-size big the
"the big table"

With respect to the contrast between (25a) and the examples in (24), it can be argued that, from a semantic point of view, there is no noun, silent or not, associated to *article* that can anchor the modification introduced by the evaluative adjective *baik* "good". In this case, the noun *article* itself anchors syntactically the modification introduced by *baik* "good", cf. Footnote 19. An account along these lines does not seem available for subsective adjectives. The nominal *saiz* "size" included in *bersaiz* "VRB-size" could arguably be an appropriate head to be modified by the adjective *besar* "big" in (25b). Before coming back to this point, we would like to provide some additional details of our analysis of the examples in (24).

In the relative clauses in (24), the nominal denoting the "dimension", that is FORM, COLOR, RACE, TYPE, etc., of the head noun to be modified by the intersective adjective, must appear preceded by the morpheme *ber-*. *Ber-* is a verbal suffix deriving verbs from nouns or adjectives. This prefix has two main derivational meanings: (a) the morphological output denotes an action or state involving the nominal base, as in *basikal* "bycicle" – *berbasikal* "to cycle", and (b) the morphological output denotes a possessive relation between the base nominal and the external argument of the resulting verb, as shown in the example (26):

(26) Orang kaya itu berkereta besar.
man rich the/this VRB-car big
"This rich man has a big car."

We assume that the noun *kereta* "car" incorporates into the verbal possessive prefix *ber-*, stranding the adjective *besar* "big", as shown in (27):

(27) $[_{vP}\ [_{v0}$ ber $[_{N0}$ kereta$]_i]\ [_{NP}$ [besar] $t_i]]$.

We claim that the *ber-* in (27) is akin to the one we find in the examples in (24). In (27), and also in (24), the relativization of the head noun essentially triggers a context of possessor raising.[22] The relevant aspects of the proposed derivation for (24a) and related cases are represented in (28b):

22. I am indebted to Antonia Androutsopoulou (p.c.) for this idea.

(28) a. meja yang ber-bentuk bulat itu
table COMPL VRB-form round the
"the round table"

b. $[_{CP}\ [_{NP}\ \text{meja}]_i\ [_{C0}\ \text{yang}]\ [_{AGRS}\ t_i\ [_{vP}\ [_{v0}\ \text{ber-}[_{n0}\ \text{bentuk}]_j]$
$[_{FP}\ t_i\ F_0\ [_{XP}\ [_{AP}\ \text{bulat}]\ t_j\ t_i]]]]]].$

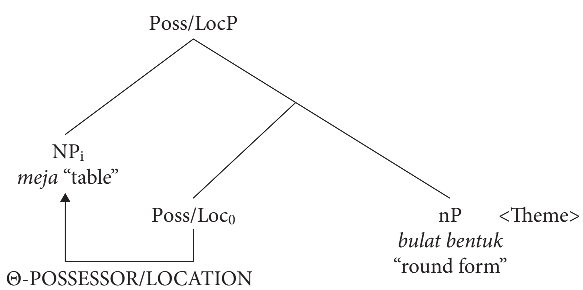
(28b) captures essentially two derivational processes: (a) the displacement of the NP *meja* "table" to C, headed by *yang*, and (b) the incorporation of *bentuk* "form" into the prefix *ber*. From the proposed analysis follows the unacceptability of (29), cf. (26):

(29) *Orang kaya itu berkereta baik.
man rich the/this VRB-car good
"The/this man has a good car."

(29) is unacceptable because the basic domain from which *kereta* "car" should raise, according to our analysis, is not possible, cf. (2b). That is, the adjective *baik* "good" cannot be combined with the NP through direct modification.

In the structure in (28b), we did not give any details about our claims concerning the relation between the adjective *bulat* "round", the dimensional nominal *bentuk* "form" and the head noun *meja* "table"; that is, all the material inside our XP in the second line of (28b). We propose that the relation between these three elements should be split into two domains.[23] First, we have the relation between the adjective and the dimensional noun, *bulat* "round" and *bentuk* "form" in (28), and second, the relation between [*bulat bentuk*] and the noun *meja* "table". With respect to the first domain, we would like to claim that the relation between the two nominals, the dimensional noun and the head noun, is mediated by a possessive/locative relation, as shown in (30):[24]

(30)



23. In line with Kayne's (2005:213) claim that in the sequence *a red* COLOR *car*, the adjective modifies color and not the head noun *car*.

24. For the purposes of this paper we will not discuss to what extent, in the spirit of Freeze (1992), Larson & Cho (2003) and Ackema & Marelj (2012), among others, a Possession relation can be assimilated to Theme-Location.

This possessive/locative relation should be the source of the type of HAVE/BE alternation found in wh-questions involving intersective and subsective adjectives in Romance, as shown in the Spanish examples in (31):

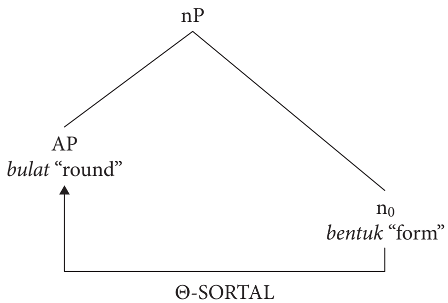
(31) a. *(De) qué color es esta mesa?
"What color is this table?"

b. (*De) Qué color tiene esta mesa?
"What color is this table?"

These examples show that the preposition *de* and possessive *tener* "have" are in complementary distribution, which suggests that the preposition has been incorporated into *tener*.[25]

With respect to the relation between dimensional nouns, *bentuk* "form" in (28b), and adjectives, *bulat* "round", we propose that dimensional nouns contain a SORTAL interpretable feature which makes the adjective an argument of this type of nouns. Relative or subsective adjectives, typically gradable adjectives, involve dimensional nouns endowed with a particular subcase of SORTAL features which are the DEGREE features, cf. (32):

(32)



The approach sketched implies that, to a certain extent,[26] we move away from a theory of direct adjectival modification in which APs are merged into the specifier of a "strictly" functional projection. Instead, we claim that APs are merged into partially non-functional projections, i.e. nPs, headed by silent or pronounced nominals such as *bentuk* "form" in (30). In sum, intersective modification may

25. See also Amritavalli (2007) and Jayaseelan (2007) for the role of possession in the make-up of adjectives in Kannada.

26. The main reasons for not claiming that dimensional nouns are not heads of functional projections are (a) their denotation is clearly linked to encyclopedic knowledge, i.e. forms, sizes, origins, colors, etc., and (b) they are arguments of a possession/location relation according to our analysis. In spite of that, dimensional nouns belong to what Kayne (2008a) calls category *y* of lexical items (or closed class), but without initially unvalued features.

involve, in the general case, not only a silent noun, but also a possessive relation between the silent noun and the head noun, i.e. *bentuk* "form" and *meja* "table" in (28a).[27]

Concerning the conditions ruling the overt or covert character of dimensional nouns such as *bentuk* "form", we observe that these elements are overt precisely in the prefixed cases, and thus, we claim that overt dimensional nouns follow from the affixal nature of *ber-*, requiring an overt or pronounced base. In the case of the Spanish examples in (31), it can be argued that the overt realization of the noun COLOR is condition by *wh*-movement. Both instances of overt dimensional noun fall under Di Sciullo (2015) principle of *Minimize Externalization*. In the Spanish examples, one of the copies of the *wh*-color phrase must externalize, and in the Malay case, externalization is necessary for affixation, beside to the displaced character of the silent noun in the relevant cases, cf. (28b). This line of analysis

27. Another sort of interaction between adjectival modification and possession is attested in a somewhat different context in Malay. Collins (1983) notes that in some varieties of non-standard Malay often referred to as Low Malay or Market Malay, the possessive verb *punya* is used in both possessive contexts and adjectival modification contexts. The examples in (i)-(ii) present the relevant cases in standard Malay and non-standard Malay:

(i) a. rumah saya (Standard Malay)
house 1s
"my house"

b. saya punya rumah (Non-standard Malay)
1s POSS house
"my house"

(ii) a. orang gila (Standard Malay)
man crazy
"a crazy man"

b. gila punya orang (Non-Standard Malay)
crazy POSS man
"a crazy man"

Both examples in (i)-(ii) involve movement of the postnominal modifier above *punya*. Abdullah (1969) considers the examples in (b) a literal translation from Chinese, probably thinking of Chinese *de* appearing in both indirect modification and possessive contexts. Ashra Ashrafiqin (p.c.) also informs me that the (b) examples are more commonly uttered by Chinese Malaysians speaking Malay. However, Collins (1983) casts doubts on this "transfer" approach showing that in Ambonese Malay all possessive modification follows the pattern in (ib). In addition, *punya* is not used with adjectival modifiers in Ambonese Malay. Finally, I would like to note that nowadays (iib) is used mainly with evaluative and subsective adjectives and involves emphatic focus on the adjective, according to Ashrafiqin Ahman (p.c). That is, (iib) should be more accurately translated as *What a crazy man!*

accounts for the contrast between the examples in (24) and the examples in (30), where there is no affix and the relevant nouns remain silent:

(30) a. meja BENTUK bulat itu
table FORM round the
"the round table"

b. kasut WARNA green itu
shoes COLOR green the
"the green shoes"

c. pelajar BANGSA Melayu itu
student RACE Malay the
"the Malay student"

d. meja JANIS kayu itu
table KIND wood the
"the wooden table"

Let us consider now the key properties of modification by evaluative and subsective adjectives in the light of the proposal we have put forward. First, we consider the typical pattern of evaluative adjectives in (31):

(31) a. article yang baik itu
article COMPL good the
"the good article"

b. *article baik itu
article good itu
"the good article"

Direct modification is disallowed in these cases, cf. (31b), because there is no associated silent noun which can be modified by the evaluative adjective *baik* "good", i.e. there is no lexicalized dimension on which something can be *good* or *bad,* and as a consequence, there are no dimensional nouns associated to evaluative adjectives. This very property accounts also for the type of indirect modification found in (31a), without overt noun in between *yang* and the adjective, nor *ber*- prefix. Finally, we consider the pattern of modification associated with subsective adjectives in (32), cf. (15):

(32) a. Meja besar itu
table big the
"the big table"

b. Meja yang besar itu
table COMPL big the
"the big table"

c. *Meja yang ber-saiz besar itu
table COMPL VRB-size big the
"the big table"

Subsective modifiers involve a silent noun, allowing therefore for direct modification, cf. (32a). However, no possessive relationship seems to be available[28] in these cases, yielding the ungrammaticality of (32c) and a relative clause modification with no verb, cf. (32b) (or alternatively an unpronounced copula).[29]

5. Conclusion

In the preceding sections we have investigated the occurrence of direct and indirect modification for a subset of adjectives, i.e. evaluative, subsective and intersective ones, in Malay. We have shown in Section 2 that the occurrence of direct and indirect modification is in part determined by the semantic nature of the adjective. In addition, we have described the possible adjectival modification patterns for each class of adjectives. We have also shown, through the analysis of the interaction between adjectival modifiers and possessives, cf. Section 3, that it is possible to establish a derivational space in the DP where direct modifiers are merged. This point is far from obvious under other possible analyses, since indirect modification, spelled out in terms of relative clause formation, is always available for most adjectives in Malay. In Section 4, we have investigated the precise syntactic mechanisms involved in direct modification. We have provided some additional evidence for a syntactic account of direct modification in terms of modification of a silent noun by the adjective along the lines in Kayne (2005). This evidence is mainly based on the consideration of a class of indirect modification contexts in Malay in which silent nouns must become overt. We have also concluded that intersective modification should involve a possession relation between the modified silent noun and the head noun. As a result of the proposed analysis of direct modification, we have been able to provide a basic account of what enables direct modification and what forces indirect modification for each one of the classes of adjectives under consideration. Variation in the surface of direct and indirect modification will be the result of the set of available silent nominals, since they trigger the possibility of direct modification, the marked case, and the conditions

28. It could also be the case that there is a different type of relation [silent noun-head noun] involved in the case of subsective adjectives from that argued for in the case of intersective modifiers. We leave this issue for further research.

29. This line of reasoning can also accommodate the special cases of subsective modification pointed out in Footnote 13. These cases would simply involve an intersective treatment of subsective adjectives.

on externalization of silent categories. These have been shown to follow from third factor conditions related to externalization.

References

Ackema, P. Marelj, M. 2012. To have the empty theta-role. In *The Theta System*, M. Everaert, M. Marelj & T. Siloni (eds), 227–250. Oxford: OUP.

Ahmad, A. 2012. L'acquisition de la définitude en français langue étrangère par les apprenants malais. MA Thesis, Université Laval.

Amritavalli, R. 2007. Syntactic categories and lexical argument structure. In *Argument Structure* [Linguistik Aktuell/Linguistics Today 108], E. Reuland, T. Bhattacharya & G. Spathas (eds), 49–62. Amsterdam: John Benjamins. doi:10.1075/la.108.07amr

Artiagoitia, X. 2006. Basque adjectives and the functional structure of the Basque noun phrase. *ASJU* XL(1–2): 107–132.

Bendjaballah, S. & Cabredo Hofherr, P. 2006. Modification of the noun in Somali: Comparative evidence from other Cushitic languages. *Proceedings of the Berkeley Linguistic Society* 27: 27–38. doi:10.3765/bls.v27i1.1104

Berwick, R.C. & Chomsky, N. 2011. The Biolinguistic Program: The current state of its development". In *The Biolinguistic Enterprise: New Perspectives on the Evolution and Nature of the Human Faculty,* A.M. Di Sciullo & C. Boeckx (eds), 19–41. Oxford: OUP.

Bierwisch, M. 1989. The semantics of gradation. In *Dimensional Adjectives,* M. Bierwisch & E. Lang (eds), 71–261. Berlin: Springer. doi:10.1007/978-3-642-74351-1_3

Borer, H. 1984. *Parametric Syntax: Case Studies in Semitic and Romance Languages.* Dordrecht: Foris.

Chierchia, G. & McConnell-Ginet, S. 2000. *Meaning and Grammar: An Introduction to Semantics.* Cambridge MA: The MIT Press.

Chomsky, N. 2004. Beyond explanatory adequacy. In *Structures and Beyond,* A. Belletti (ed.), 104–131. Oxford: OUP.

Chomsky, N. 2001. Derivation by phase. In *Ken Hale: A Life in Language*, M. Kenstowicz (ed.), 1–52. Cambridge MA: The MIT Press.

Chomsky, N. 2010. Poverty of stimulus: Unfinished business. In *Universals and Variation: Proceedings of GLOW in Asia VIII 2010*, M. Gao (ed.), 1–17. Beijing: Beijing Language and Culture University Press.

Cinque, G. 2010. *The Syntax of Adjectives*. Cambridge MA: The MIT Press. doi:10.7551/mitpress/9780262014168.001.0001

Cole, P. & Hermon, G. 1995. Is wh-in-situ really in-situ? Evidence from Malay and Chinese. In *Proceedings of the Thirteenth West Coast Conference on Formal Linguistics*, R. Aranovich, W. Byrne, S. Preuss & M. Senturia (eds), 189–204. Stanford CA: CSLI.

Collins, J.T. 1983. Syntactic change in Ambonese Malay: The possessive construction. In *Studies in Malay Dialects*, J.T. Collins (ed.), 28–41. Badan Penyelenggara Seri NUSA, Universitas Atma Jaya.

Corver, N. 1997. Much-support as last resort. *Linguistic Inquiry* 28: 119–64.

Davies, W. & Dresser, C. 2005. The structure of Javanese and Madurese determiner phrases. Paper presented at AFLA XII, UCLA.

Di Sciullo, A.M. 2015. On the domain specificity of the human language faculty and the effects of principles of computational efficiency: Contrasting human language and mathematics. *Revista Linguistica* 11(1): 28–56.

Freeze, R. 1992. Existentials and others locatives. *Language* 68: 553–59. doi:10.2307/415794

Hassan, A. 1969. Bahasa melayu pasar di Malaysia barat. *Dewan Bahasa* 13: 207–218.

Hung, H. 1987. Lexical and Functional Categories in Bahasa Malaysia. MA thesis, University of Toronto.

Jackendoff, R. 1977. *X′-Syntax: A Study of Phrase Structure*. Cambridge MA: The MIT Press.

Jackendoff, R. 1997. *The Architecture of the Language Faculty*. Cambridge MA: The MIT Press.

Jayaseelan, K.A. 2007. The argument structure of the dative construction. In *Argument Structure* [Linguistik Aktuell/Linguistics Today 108], E. Reuland, T. Bhattacharya & G. Spathas (eds), 37–48. Amsterdam: John Benjamins. doi:10.1075/la.108.06jay

Kamp, H. 1975. Two theories about adjectives. In *Formal Semantics for Natural Language*, E.L. Keenan (ed.), 123–155. Cambridge: CUP. doi:10.1017/CBO9780511897696.011

Kamp, H. & Partee, B. 1995. Prototype theory and compositionality. *Cognition* 57: 129–191. doi:10.1016/0010-0277(94)00659-9

Katz, J. 1966. *The Philosophy of Language.* New York NY: Harper & Row.

Kayne, R.S. 1994. *The Antisymmetry of Syntax.* Cambridge MA: The MIT Press.

Kayne, R.S. 2005. *Movement and Silence*. Oxford: OUP. doi:10.1093/acprof:oso/9780195179163.001.0001

Kayne, R.S. 2006. On parameters and on principles of pronunciation. In *Organizing Grammar: Linguistic Studies in Honor of Henk van Riemsdijk*, H. Broekhuis, N. Corver, R. Huybregts, I. Kleinhenz & J. Koster (eds), 289–299. Berlin: Mouton de Gruyter. doi:10.1515/9783110892994.289

Kayne, R.S. 2008a. Antisymmetry and the lexicon. In *Linguistic Variation Yearbook* 8, J. Rooryck & J. van Craenenbroeck (eds), 1–31. Amsterdam: John Benjamins. doi:10.1075/livy.8.01kay

Larson, R. & Cho, S. 2003. Temporal adjectives and the structure of possessive DPs. *Natural Language Semantics* 11 : 217–247. doi:10.1023/A:1024915400586

Pustejovsy, J. 1995. *The Generative Lexicon.* Cambridge MA: The MIT Press.

Richards, M. 2008. Two kinds of variation in a minimalist system. In *Linguistische Arbeitsberichte* 87, F. Heck, G. Müller & J. Trommer (eds), 133–162. Leipzig: University of Leipzig.

Scott, G.-J. 2002. Stacked adjectival modification and the structure of nominal phrases. In *Functional Structure in DP and IP: The Cartography of Syntactic Structures*, Vol. 1, G. Cinque (ed.), 91–120. Oxford: OUP.

Simpson, A. 2005. Classifiers and DP structures in Southeast Asia. In *The Oxford Handbook of Comparative Syntax*, G. Cinque & R. Kayne (eds), 806–838. Oxford: OUP.

Sigurðsson, H. Á. 2004. Meaningful silence, meaningless sounds. *Linguistic Variation Yearbook* 4: 235–259.

Sproat, R. & Shih, C. 1988. Prenominal adjectival ordering in English and Mandarin. In *Proceedings of NELS 18,* J. Blevins & J. Carter (eds), 465–489. Amherst MA: GSLA.

Vander Klok, J. 2013. On the nature of adjectival modification: A case study in Javanese. In *NELS 40: Proceedings of the Fortieth Annual Meeting of the North East Linguistic Society,* S. Kan & C. Moore-Cantwell (eds), 227–238. Amherst MA: GLSA.

Wong, B.E. 2008. Wh-questions in Malay: An explanation for the restriction of extraction to subject position with Yang. *3L: Language, Linguistics, Literature – The South East Asian Journal of Language Studies* l4: 81–94.

SECTION 3

Language (acquisition and) impairments

A study on an alleged case of Spanish SLI and the founder effect

Anna Gavarró & Myriam Cantú-Sánchez
Universitat Autònoma de Barcelona

According to Villanueva et al. (2008), the incidence of Specific Language Impairment in the child population of a Chilean South Pacific island is 35%, five to seven times higher than in the continental population. While this research pinpointed a relationship between the children's genetic profile and SLI, it failed to provide much detail as regards their linguistic performance. The goal of our research is to start filling this gap through the administration of a series of language tests carried out on the children of the island. The tests are intended to measure areas of linguistic development formerly identified as vulnerable in Spanish SLI and include non-word and sentence repetition, the use of determiners and the production of relative clauses. Our preliminary results show some age effect but no difference between the children of islander ascent and those of continental origin.

1. Introduction

The object of this study is an island located in the South Pacific Ocean, 667 km from the coast of Chile. Though the archipelago to which the island belongs was discovered in 1574, people only settled on this one island, which was first colonised in 1750, abandoned in 1850 and then colonised again in 1877.

It is currently inhabited by the descendants of that last colonisation, who have been the object of recent research due to their unusual genetic features. The registry of the population of the island is available starting in 1902, when the first descendants of the 1877 settlers were born. At the time of the 2002 census, the population of the island was 663 inhabitants. As argued in various papers (Villanueva et al. 2008, 2010, 2011, 2014 and 2015), this isolated island population represents an instance of the founder effect, whereby genetic drift occurs when a new population is established by a very small number of individuals, and the genetic peculiarities carried by some of them become more prevalent than they would be in the general population. In this particular case, it is argued that two brothers among the eight founding families carried a genetic abnormality leading

DOI 10.1075/la.235.08gav

to Specific Language Impairment (SLI). In this paper we present the results of our research on the linguistic development of a large sample of the child population of the island.

The paper is organised as follows. In Section 2 we provide the background to our work, both regarding SLI and the findings of previous research on the island population. In Section 3 we detail our study, describing the subjects tested and the experiments designed and carried out. In Section 4 we present the results, and in Section 5 we discuss them in relation to former studies and draw our conclusions.[1]

2. Background

2.1 The study of SLI

Specific Language Impairment (henceforth SLI) constitutes an extremely valuable source of information on language acquisition, as a developmental pathology that

1. We wish to thank the children who took part in the study as well as their teachers. We are also grateful to the Spanish Ministry of Economy and Competitiveness project FFI2014-56968-C4-1-P for funding, and to Ester Boixadera and Anna Espinal for their help with the statistics. Thanks as well to Anna Maria Di Sciullo and the audience at 'Biolinguistic Investigations on the Language Faculty', which took place 26–28 January 2015 in Pavia, Italy, for their suggestions.

affects the otherwise fast, early and unproblematic development of language. There is substantial evidence of the genetic nature of SLI, largely thanks to twin and linkage studies (Stromswold 2001; Bishop 2002). Just like any pathology affecting development in biology, the study of SLI should shed light on the mechanisms of growth and the primitives underlying the faculty itself. This is the reason why SLI has received increasing scholarly attention in recent years.

Within the population diagnosed with SLI, two profiles are differentiated. One, often referred to as phonological SLI, results from deficits in phonological short-term memory (Bishop 1996; Newbury et al. 2005), and is linked to a region of chromosome 16 (SLI Consortium 2002, 2004). On the other hand, syntactic SLI was first identified as inducing a prolonged Optional Infinitive stage (Rice, Wexler & Cleave 1995; Rice & Wexler 1996).

The manifestation of SLI is known to vary across languages. For example, while an Extended Optional Infinitive stage is typical of non-null subject languages such as English, French and German, in null subject languages such as Catalan, Italian and Spanish no such extended Optional Infinitive stage is found (see Bottari et al. 1998; Gavarró 2012). In itself this crosslinguistic variation is revealing, as it implies that the child is sensitive to language-particular properties. In the interpretation of Rice and Wexler (1996), this means that the child has established the language-specific properties of the target language (e.g., the (non-)null subject language parameter) and discrepancies with the adult are to be attributed to maturational factors. The principle subject to maturation that they endorse is the Unique Checking Constraint (1), which applies in typically developing children until the age of 3 (Wexler 1998), but for a prolonged period in children with SLI.

(1) Unique Checking Constraint (in children in the Optional Infinitive stage)
The D-feature of DP can only check against one functional category.

An optional infinitive results from a derivation in which either Tense or Agreement is deleted, thus dispensing with an uninterpretable feature. In this way the derivation is not in conflict with the UCC (or with any principle affecting the mechanisms at play in a grammatical derivation). In what follows we explore Spanish SLI under the assumptions of the UCC.

2.2 Spanish SLI

As noted, though Optional Infinitives are a very reliable marker for SLI in non-null subject languages, since Spanish is a null subject language, we cannot resort to this marker. However, the same mechanisms that operate in Optional Infinitives generalise over cases of clitic omission in languages such as Catalan, French and Italian (Gavarró, Torrens & Wexler 2010). These languages display object clitic omission until age 3 in typically developing children but for a longer period in SLI children (Jakubowicz et al. 1998; Gavarró 2012). By hypothesis, double checking takes place in an adult derivation of an object clitic construction – due to checking in the Cl(itic)P and in some lower functional projection carrying participle agreement. Nevertheless, Spanish clitic derivations do not involve double checking (for lack of participle agreement) and the UCC thus correctly predicts adult clitic production in both typically developing and SLI children. As a consequence, clitic omission is not a marker of Spanish SLI (Gavarró 2012; Cantú-Sánchez in prep.).

Following Wexler (1998), we might expect auxiliary omission to occur in Spanish at the UCC stage, but it is not attested in the spontaneous production of Spanish-speaking children with SLI (see Cantú-Sánchez in prep.). The reasons why this prediction of the UCC is not fulfilled in Spanish SLI remain for future research.

Hence, finding a marker for syntactic SLI is notably difficult for Spanish. One empirical domain for which there is some indication of a deficit is DP. Determiner production has been reported in the literature to induce high error rates in several languages including German (Clahsen 1992), Italian (Bottari et al. 1998; Leonard et al. 1992; Bortolini et al. 1997), Spanish (Restrepo & Gutiérrez-Clellen 2001), Swedish (Hansson et al. 2003) and Dutch (Bol & Kuiken 1987; Orgassa 2009). Agreement within DP between A and N has been seldom investigated, but there is some evidence as well for delay in German, Swedish and Dutch (Clahsen 1992; Orgassa 2009). In Orgassa's (2009) study on Dutch, SLI groups produced higher omission rates of definite determiners than TD children and overgeneralisations of the common determiner *de* (2) to neuter contexts (3). In adjectives, *-e* generalised to contexts where a null form was the target (4), but the reverse error was rarely attested.

(2) *de groene appel*
the-common-gender green apple

(3) *het groete mes*
the-neuter big knife

(4) *een groot glas*
a big glass

Briefly, errors did not occur at random. Rather, they indicated that there was a default agreement form (perhaps the analogue of an optional infinitive in the nominal domain). Further, no problem was found with adjectival inflection in predicative contexts. We entertain the possibility that these phenomena relate to the Optional Infinitive stage, and can be accounted for in terms of the Unique Checking Constraint (as first entertained in Wexler 2002).

Let us assume a structure such as that in (5), based on the functional features postulated by Picallo (2008) for Romance DPs: Class is a functional projection instantiated in Romance by Gender [± fem], Num (number) can be [± pl]. These two features need to be valuated in the course of the derivation, and match the Gender and Number features of the N. The movement of the N allows us to capture the postnominal position of Romance adjectives (see Picallo 2012).

(5) [DP D [… [NumP N Num [ClassP ~~N~~ Class [NP (AP) ~~N~~]]]]]

Unlike in the cases of Optional Infinitives and clitic omission, the constituent which moves here is a head, N, not a phrase. This would necessitate a modification of the UCC, which we do not pursue here. However, the configuration is reminiscent of that in Hagstrom's account of child Korean scrambling (Hagstrom 2002).

If a UCC analysis is adopted, we expect problems within DP to occur at the same time as optional infinitives and object clitic omission (if the languages fulfil the conditions for these to occur) – yet, as Jakubowicz et al. (1998) and Bottari et al. (1998) already pointed out, article omission and clitic omission do not always co-occur in SLI. If SLI is characterized as an Extended UCC stage, then TD young children would be predicted to have problems with DP-internal checking mechanisms. Nonetheless, there is only limited evidence to that effect (De Houwer 1990; Polišenská 2005 for Dutch, Mills 1986 for English and German). In line with the work cited above, Cantú (in prep.) finds deviant agreement within DP in her examination of spontaneous production in Mexican Spanish SLI.

In our experimental design we address the performance of children under the assumptions of the UCC – and test the children in these and other, apparently unrelated, areas considered in the literature on SLI.

2.3 A South Pacific isolate

The novelty of this study lies in the fact that we investigate an island thought to exemplify the founder effect, an important source of information on genetics and phenotypic variation. According to Villanueva et al. (2008), the incidence of SLI in the child population of the island is around 35%, that is, 5 to 7 times higher than its incidence in the continental population. This is explained as a consequence of the founder effect: 75% of the impaired subjects were descendants of two founder brothers and were identified with a genetic variant with its main locus on chromosome 7q (Villanueva et al. 2011). While the genetic profile of the population has been thoroughly investigated, the research in question does not provide much detail regarding the children's linguistic performance. The goal of the present study is therefore to start filling this gap and consider the linguistic performance of the current child and adolescent populations on the island.

There is evidence that complex genetic factors are the source of SLI. For the time being, four separate loci for SLI (SLI1, SLI2, SLI3, SLI4) and three associated genes (CNTNAP2, ATP2C2, CMIP) have been identified in the literature. The goal of Villanueva et al. was to find a link between SLI and variants of regions in the genome in the island's population.

The tests used by Villanueva and colleagues to evaluate the children's linguistic development were the *Test para evaluar los procesos fonológicos de simplificación* (TEPROSIF) and the *Test Exploratorio de Gramática Española de Toronto* [Toronto Exploratory Test of Spanish Grammar] (details of both tests in their Spanish versions are given in Appendix 1). The children were also administered an intelligence test (the Columbia Mental Maturity Scale), and hearing impairment was ruled out by means of basic pure tone and bone conduction threshold audiometry testing. Family history was also recorded. Children were considered to be affected by SLI if their scores on the language development tests were more than 2 SD below the scores expected at their age, except if in addition they scored below the 80th percentile in the non-verbal IQ test (in which case they were classed not as SLI but rather as 'language delayed').

Of the 145 children in the island population, all children aged between 3 and 8 took part in the study, a total of 66 children. Of these, 40 were descendants of the original 1877 settlers (henceforth 'islander'), while the remaining 26 were the children of inhabitants of the Chilean mainland (henceforth 'continental').

> They [Villanueva et al. 2008] found that 35% of the founder-related children (14 of 40) were affected by specific language impairment. (…) A further 27.5% of the founder-related child population (11 of 40) had language abilities below that expected for their age but presented additional developmental concerns or low non-verbal IQ precluding a diagnosis of SLI. The remaining 37.5% of founder-related children (15 of 40) had typical language development.
>
> (Villanueva et al. 2015: 24).

Villanueva et al. (2015: 24) specify that children diagnosed with SLI presented 'deficits across grammatical, morphosyntactical and receptive aspects of language, but not dialectic variations in intonation, vocabulary and phonology', thus indicating that phonological SLI was not characteristic of this population.

On the genetic side, DNA was extracted from 125 individuals (including probants, sibs, half-sibs and parents) and the analysis conducted showed that, of all the individuals diagnosed with SLI, 84% were descendants of two founder brothers. The incidence of SLI in the population of continental origin fell within the standard limits of this pathology in the general population.

The parametric study did not identify any single allele, either dominant or recessive, with linkage with SLI. However, by means of a non-parametric study, Villanueva et al. identified five affected regions, chromosomes 6, 7, 12, 13 and 17, which appear to be identifiable with the genome-wide techniques used. Of these, 6q, 7q and 12 are highly significant. In this region of 7q, a 2-SNP haplotype is found with high frequency in individuals with a language deficit. Nonetheless, no linkage was observed to chromosomes 16 or 19, which have been previously implicated in SLI. In their most recent work, Villanueva et al. (2015) have pursued their genetic study of the population and found some similarities between the population of the island studied and individuals diagnosed with SLI elsewhere.

3. Our study

Just as Villanueva et al. (2008, 2010, 2011, 2014, 2015) centred their work around the genetic profile of the population under scrutiny, we focus on the linguistic performance of the island's children, all the more necessary because little information is provided in the works published on the results of the language tests performed.

3.1 Subjects

The field work reported in this section was carried out by M. Cantú in April 2014. The goal was to test the whole child population of the island (and ideally also the adult population), but for reasons of time and other constraints only 45 children took part in the experiments designed, representing 35.4% of the child population of the island at the time of testing. Details of the subjects appear in Table 1.

Table 1. Subjects

Origin#	#	Gender	Age range	Mean age
islander.	31	16 girls, 15 boys	4.17–14.83	8.19
continental	14	7 girls, 7 boys	4.75–13.83	8.89

There was no statistically significant difference in age between the islander and continental groups. Males and females were also equally represented in the sample. Eight of the children included in our study had also taken part in the Villanueva et al. (2008) study, of which one had been diagnosed as typically developing on that occasion and three others developmentally delayed in general; the remaining four had not been tested (Villanueva p.c.).

Because some age groups were underrepresented in our sample, in the second part of the results we focus on the age groups for which we have a more representative sample of the population (see Table 2). These correspond to 4- to 8-year-olds. There are no statistically significant differences in age between the two groups.

Table 2. Subjects in the age range of 4.1 to 8.9

	Islander	Continental
4-year-olds	5	1
5-year-olds	3	2
6-year-olds	4	1
7-year-olds	5	0
8-year-olds	5	1
total	22 (10 females, 12 males)	5 (2 females, 3 males)

A group of 10 adults from continental Chile was tested as a control group.

3.2 Experimental design

We designed and conducted nine linguistic tests, covering a large range of linguistic domains, as follows.

Two tasks targeted performance in areas known to be problematic for children with phonological SLI, namely vocabulary retrieval and non-word repetition. The competence underlying them does not belong to core-syntactic knowledge, but, as mentioned above, has been identified as impaired in a subset of SLI children (Bishop et al. 1996; Newbury et al. 2005).

A third task was morphological, the elicitation of plural marking in Spanish, but was not expected to be problematic for children with SLI, based on results for Spanish-speaking SLI children (see Grinstead et al. 2008). For all we know, morphological competence is spared in SLI.

The remaining five tasks targeted syntactic capabilities. The use of determiners, prepositions, and gender and number agreement within DP have all been reported to be impaired in various studies on Spanish SLI (Restrepo & Gutiérrez-Clellen 2001; Auza & Morgan 2013; Anderson et al. 2009; Bedore & Leonard 2001, 2005). An analysis of D and gender and number agreement phenomena has been given in Section 2, and under those assumptions we predicted delay in these areas for SLI children.

Crosslinguistically, SLI is often identified by means of sentence repetition tasks (Chiat et al. 2013), and grammaticality judgment tasks. Two such tasks were designed for Spanish.

Finally, because Novogrodsky and Friedmann (2006) showed for Hebrew that children with SLI were impaired in the comprehension and production of relative clauses, object relative clauses in particular, and the same observation has since been made for other languages, we replicated Novogrodsky and Friedmann's design for relative clause elicitation for Spanish (see also Girbau & Schwartz 2007). At present there is no account that generalises over both this deficit and the UCC-related deficits discussed in Section 2.

Importantly, two of our tasks are comparable to the two first used by Villanueva et al. (2008), the TEPROSIF and *Test Exploratorio de Gramática Española de Toronto*. The former is comparable to our test 2 and the latter includes a repetition task like our test 7. We do not provide a comprehensive list of all experimental items, but examples of the methods employed and the number of items per task appear in Appendix 2.

Since each of the 55 subjects (including the 10 adult controls) was expected to provide answers to 219 items, we would expect 12,045 data points. Given that some answers were not provided (and some children missed some tests, etc.), we actually collected a total 11,658 answers.

3.3 Procedure

The children in the study attended the island's only school, and testing took place in a quiet room (the school's library), over two or three sessions, given the large number of tests performed. The guidelines of the Helsinki Declaration were followed, children taking part in the experiments only if they were willing to participate and a signed authorisation form was provided by their parents.

3.4 Statistical methods

For the analysis we took into account (i) age group, (ii) task and (iii) origin: (islander vs. continental). Individual results are also reported. Scoring depended on the task. The statistical analysis of the results was performed by the Servei d'Estadística Aplicada of the UAB, with SAS v9.3 software (SAS Institute Inc., Cary, NC, USA); significance level was set at 0.05 unless otherwise indicated.

4. Results

In this section we present results for all children tested. Unfortunately, for some age groups we had few participants; this was so mainly for the age groups that had already participated in the Villanueva et al. (2008) study. For two of the younger groups, we had larger samples, as mentioned above, and in the second part of this section we focus on those groups, 4-year-olds to 8-year-olds. Adults responded correctly 100% of the time, confirmation of the validity of our testing materials. Therefore their results do not appear in subsequent sections.

4.1 Overall results

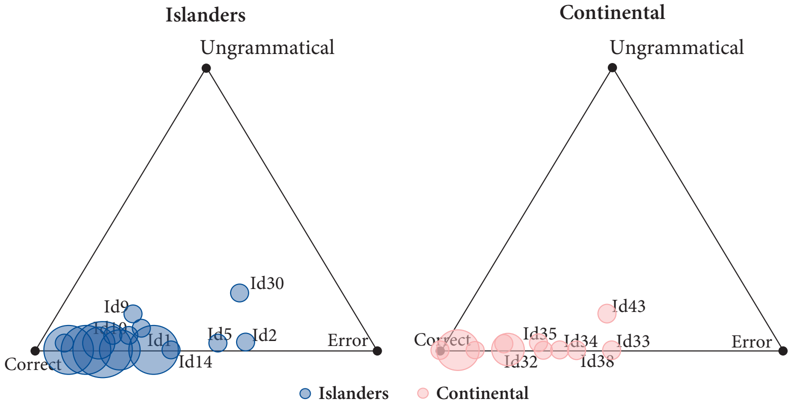
Taking all children together, the results for the nine tasks appear in Table 3. The results for tasks 3 and 9 were further divided into 3a (indefinite D elicitation) and 3b (definite D elicitation), and 9a (subject relative clause elicitation) and 9b (object relative clause elicitation).

Table 3. Percentage correct (Standard Deviation in parentheses)

	Islander	Continental
Test 1: Vocabulary	95.3% (8%)	97.9% (4.3%)
Test 2: Non-word repetition	96.9% (4.9%)	97.5% (4.7%)
Test 3a: Determiner (indefinite)	91.9% (15.4%)	93.6% (7.4%)
Test 3b: Determiner (definite)	73.5% (15.3%)	76.8% (17.5%)
Test 4: Judgment	83.2% (20.5%)	85.8% (15.9%)
Test 5: Nominal agreement	98.8% (3.4%)	98.2% (5.4%)
Test 6: Pluralisation	96.3% (6.9%)	96.4% (5.8%)
Test 7: Sentence repetition	83.8% (15.2%)	79.8% (22.7%)
Test 8: Preposition	97.1% (6.8%)	96.3% (6.3%)
Test 9a: Relatives (subject)	97.5% (5.9%)	95.8% (5.1%)
Test 9b: Relatives (object)	82.5% (20.3%)	78.3% (24.4%)

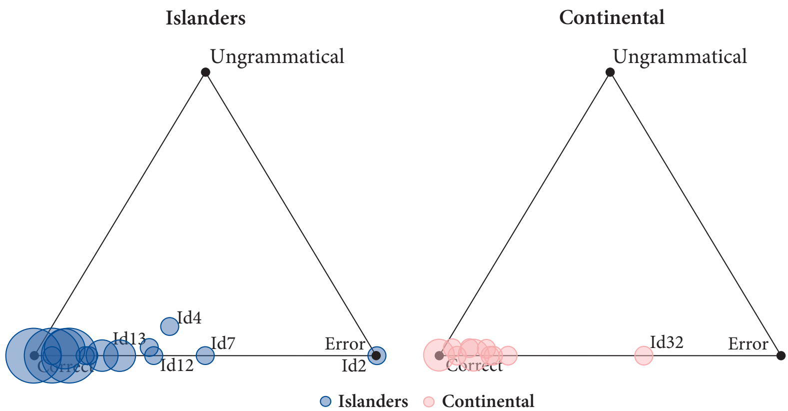
A first observation is that in several tests children are virtually at ceiling, even though individuals as young as 4 took part in the task. Only in determiner use (definite articles), grammaticality judgment, sentence repetition and object relative clause production does the children's performance not reach a 90% correct value. A second observation is that the pattern of responses is the same for islander and continental subjects, in that the tests in which scoring is lower are the same for the two groups. The differences between the groups are very small; continental children outperform islander children in five tests, while islander children outperform continental children in the remaining five (in absolute numbers).

For the four (sub)tests in which performance is lowest, individual results are represented graphically in graphs 1, 2, 3 and 4, where the size of the shaded circles is proportional to the number of individuals revealing each pattern. Graph 1 represents answers for definite determiner elicitation, where 'Error' corresponds to the use of an inappropriate determiner or no determiner at all, while 'Ungrammatical' corresponds to mismatched gender or number determiners).



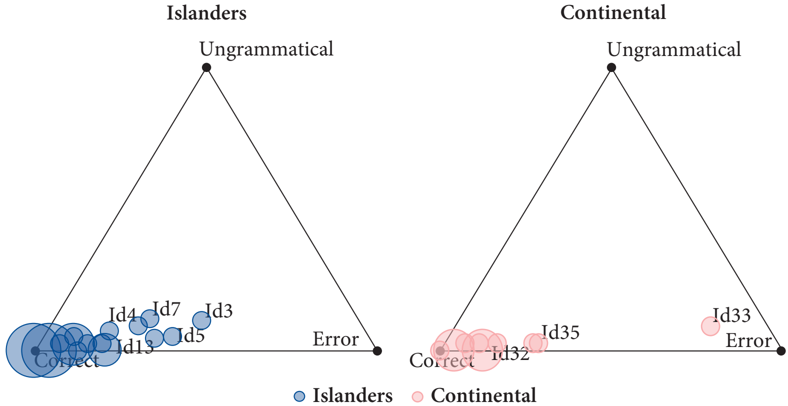
Graph 1. Individual results, (definite) determiner production

Answers for the grammaticality judgment task are represented in Graph 2. 'Error' here refers to misses (i.e., undetected ungrammatical sentences) and 'Ungrammatical' refers to ungrammatical corrections.



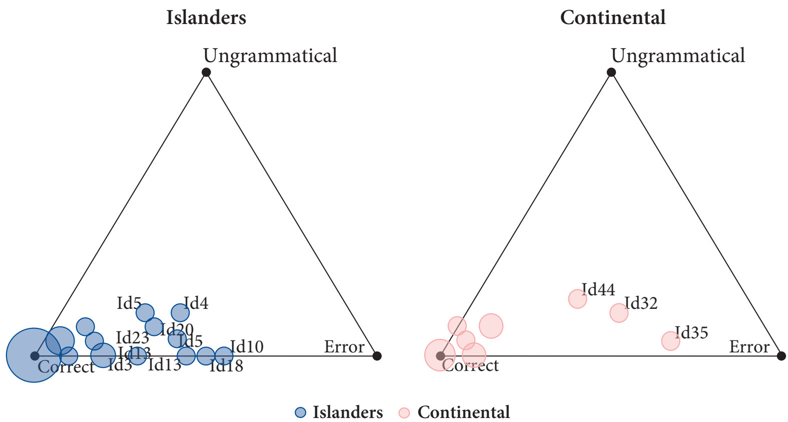
Graph 2. Individual results, grammaticality judgment

Graph 3 represents accuracy in sentence repetition; here 'Error' designates an inexact (but grammatical) repetition, while 'Ungrammatical' designates an answer that is not only inexact, but also ill-formed. (There are many ways to score a repetition task, but many of these methods are unwieldy in practical terms; here we have chosen one that is often used in the work on SLI and for which scoring is straightforward.)



Graph 3. Individual results, sentence repetition

Finally, Graph 4 presents the individual results of object relative clause elicitation. ‘Error’ here designates answers in which non-target grammatical sequences were produced, while ‘Ungrammatical’ designates ill-formed sentences.

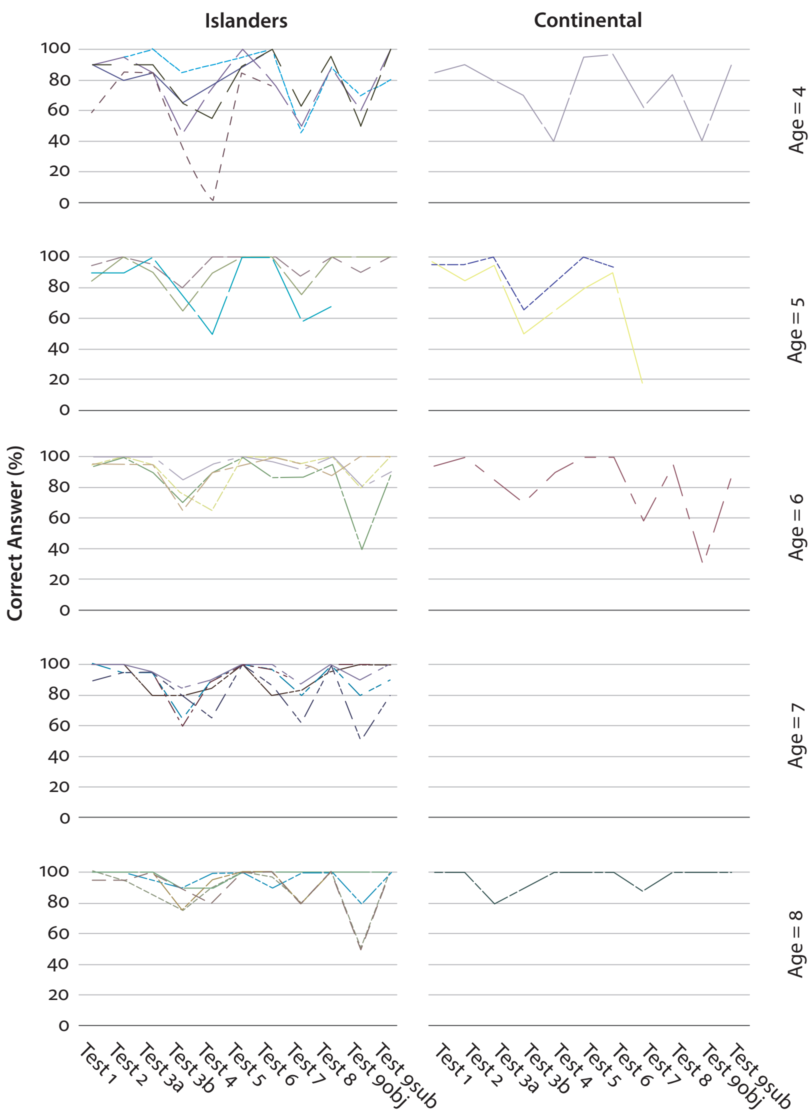


Graph 4. Individual results, object relative clause elicitation

Individual results are not reproduced for all tests, but they resemble those seen above, with little discrepancy between groups.

4.2 Results for 4- to 8-year-olds

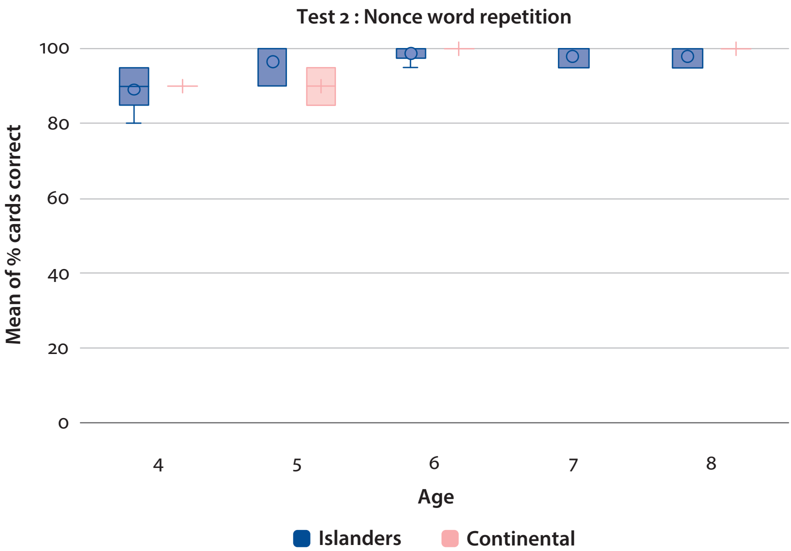
We used a Linear Model (binomial distribution) to examine our results by age for each test (and all children, of islander or continental origin), and we did find statistically significant differences in performance as a function of age for test 1 ($F = 20.64$; $p = 0.0001$), test 2 ($F = 11.73$; $p = 0.0021$), test 3b ($F = 17.61$; $p = 0.0003$), test 4 ($F = 43.69$; $p < 0.0001$), test 5 ($F = 9.77$; $p = 0.00046$), test 7 ($F = 39.18$; $p < 0.0001$), test 8 ($F = 20.14$; $p = 0.0002$), and test 9 ($F = 5.98$; $p = 0.0238$). Therefore, we found no difference as a function of age either for the use of indefinite determiners or for pluralisation, but for the remaining tests there was an improvement in performance between the ages of 4 and 8. This outcome is hardly surprising if we consider that not all grammatical knowledge is in place at age 4.



Graph 5. Individual results of the children, broken down by age group

Having considered the variable of age, let us turn to the central issue here: the behaviour of islander vs. continental children. Individual results for the nine tasks appear, divided by age and origin, in Graph 5.

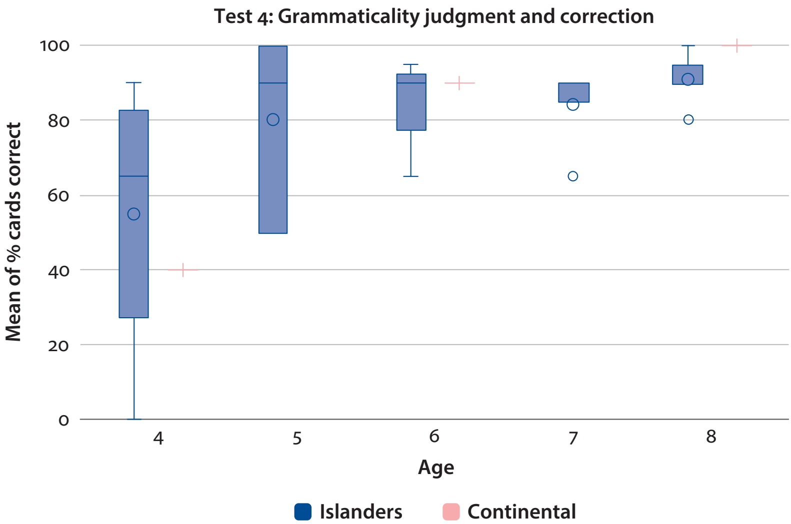
For reasons of space we focus on the results by age for only six of the nine tests performed, those with higher discriminatory power according to the literature. The boxplot in Graph 6 represents the results for the non-word repetition task broken down by origin: blue boxes correspond to islanders, red boxes to continentals. Performance for both groups is near ceiling, and continentals do not outperform islanders. This is in line with Villanueva et al.'s (2015) observation that phonological performance was not impaired.



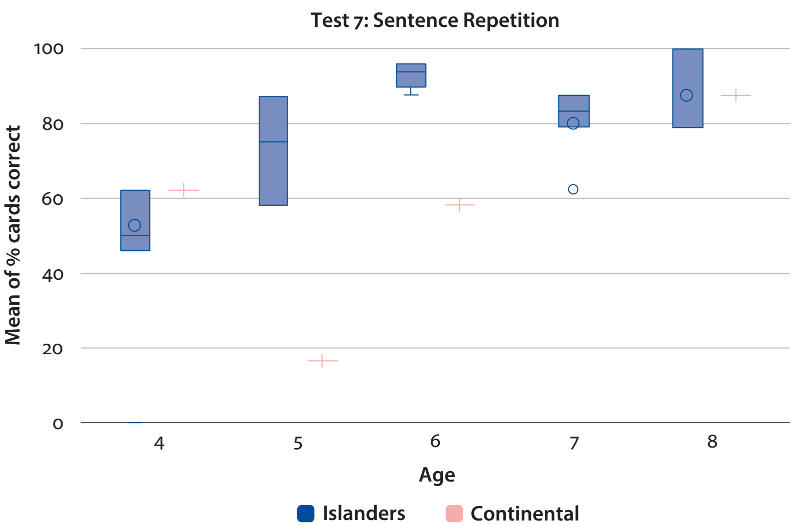
Graph 6. Results for non-word repetition task

Grammaticality judgment and sentence repetition are two tasks standardly used to identify syntactic SLI. The boxplots corresponding to these tasks appear in Graphs 7 and 8 respectively. Both show a developmental curve from ages 4 to 8 and considerable individual variation, but continentals perform either like islanders or worse, not better (in sentence repetition at ages 5 and 6).

The results for the object relative clause elicitation task appear in Graph 9 and show, as has been found for other languages, that this construction is not adult-like until quite late, but there seems to be no correlation between origin and performance.

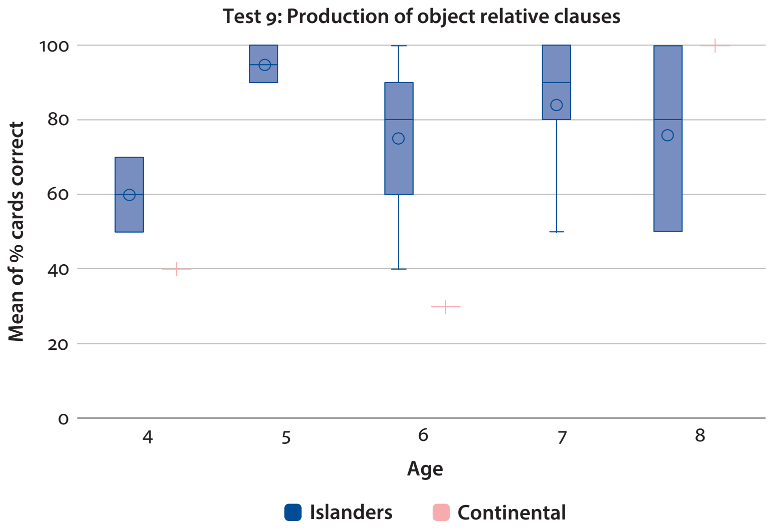


Graph 7. Results for grammaticality judgment and correction task

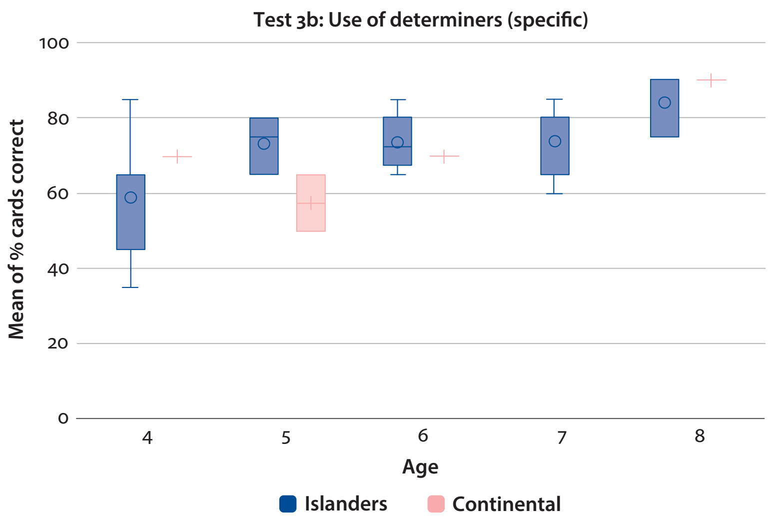


Graph 8. Results for sentence repetition task

Finally, the results for the two tests for which we hypothesised that Spanish-speaking children with SLI might be delayed are reported in Graphs 10 and 11. Children performed better on the first than on the second, but again there appears to be no difference as a function of origin.

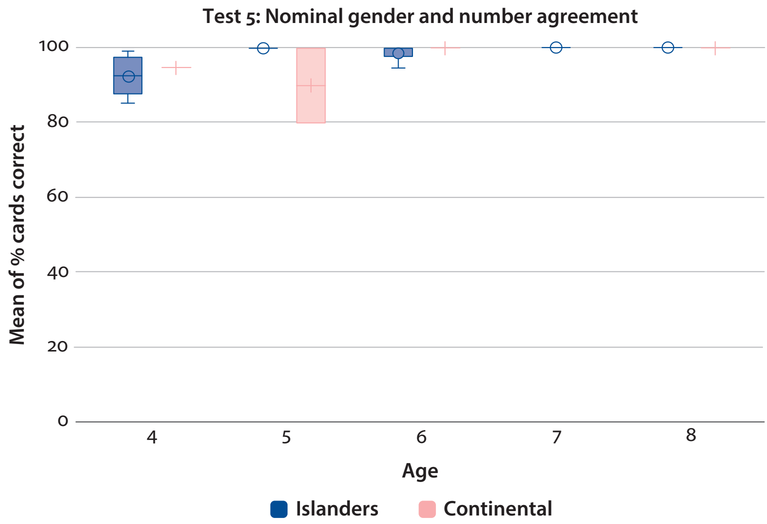


Graph 9. Results for object relative clause production task

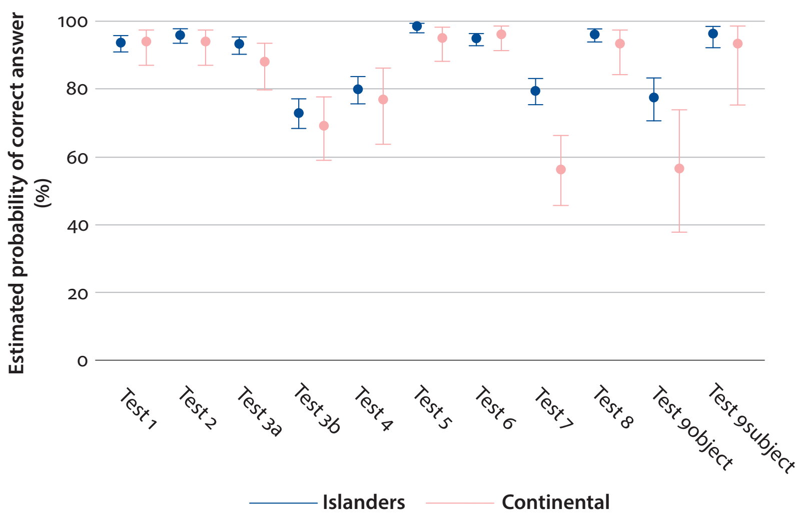


Graph 10. Results for use of definite determiners test

Estimates of the percentage of correct answers broken down by test and origin (islander, continental) in the 4 to 8 age range appear in Graph 12 (here all tasks are reported).



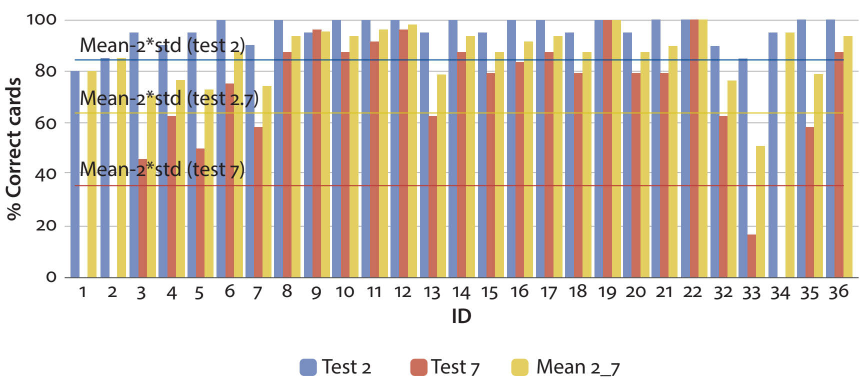
Graph 11. Results for nominal gender and number agreement task



Graph 12. Estimated percentage of correct answers by test between 4 and 8

When we compare the performance of the two groups, islander and continental, we only find statistically significant differences for tests 7 and test 9b, that is, those tasks testing sentence repetition and object relative clause elicitation ($F = 21.83$; $p = 0.0001$ for test 7, $F = 5.57$; $p = 0.0285$ for test 9b). In both cases, the islander group performs better than the continental group. (In tests 3a and 5 the differences between the two groups are also statistically significant at the level of 10%.)

According to Villanueva et al. (2008, 2011), 35% of the islander children are affected by SLI and another 27.5% show language difficulties compounded with other cognitive delays. Only 37.5% 'display normal language skills' (Villanueva et al. 2008: 190). For a population of 22 children (the ones of islander origin for ages 4 to 8 in our sample), this would mean 5.9 children who are acquiring language normally. As summarised in Villanueva et al. (2015), language abilities were assessed on the basis of a phonological competence test and a repetition and comprehension test (as detailed above) and SLI was defined as performance >2SD below expected on either test (assuming normal non-verbal IQ and hearing). Owing to the fact that our tests of non-word repetition and sentence repetition are similar, albeit not identical, to those performed by Villanueva et al., we measured how many children performed >2SD below the mean in our sample. These measurements were carried out for non-word repetition (test 2) and sentence repetition (test 7), and for the combination of both, as shown in Graph 13. (In the following graphs subjects 1 to 22 correspond to islander children and 32 to 36 to continental children.)

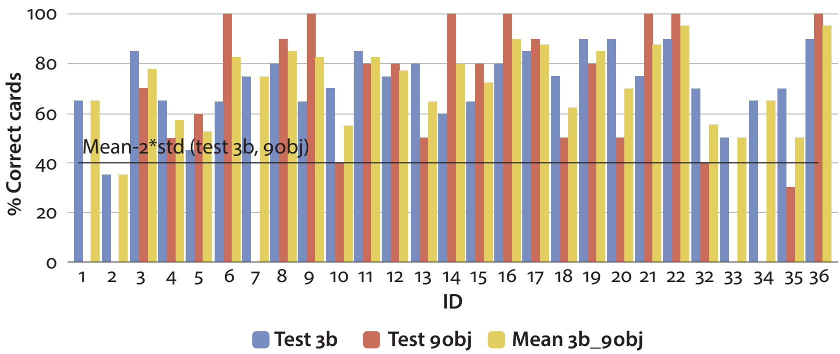


Graph 13. Results for non-word repetition and sentence repetition tasks

As we can see, only one child (1), of islander origin, is >2SD below the mean for test 2, and another child (33), of continental origin, is >2SD below the mean for test 7. Considering the two tests together, this last child (33) is >2SD below the mean. Unlike those used in Villanueva et al. (2008, 2011), our tests are not standardised and therefore our mean is based on our sample only. It would be desirable to obtain results for typically developing children of the same ages to have an independent measure of performance. In spite of this limitation, the picture that emerges is not what we would expect if a large proportion of the population suffered from language impairment and some other linguistic and cognitive deficit:

only two children can be singled out, and we do not find the pattern expected if impairment (exclusively or non-exclusively linguistic) affected around 60% of the children, and 40% were typically-developing.

We also performed measurements for definite determiner use and object relative clause production; Graph 14 shows that by the composite measure of the two tests only one child (2), of islander origin is >2SD below the mean (this child was not tested on object relative clauses, and therefore this result depends on D production only).

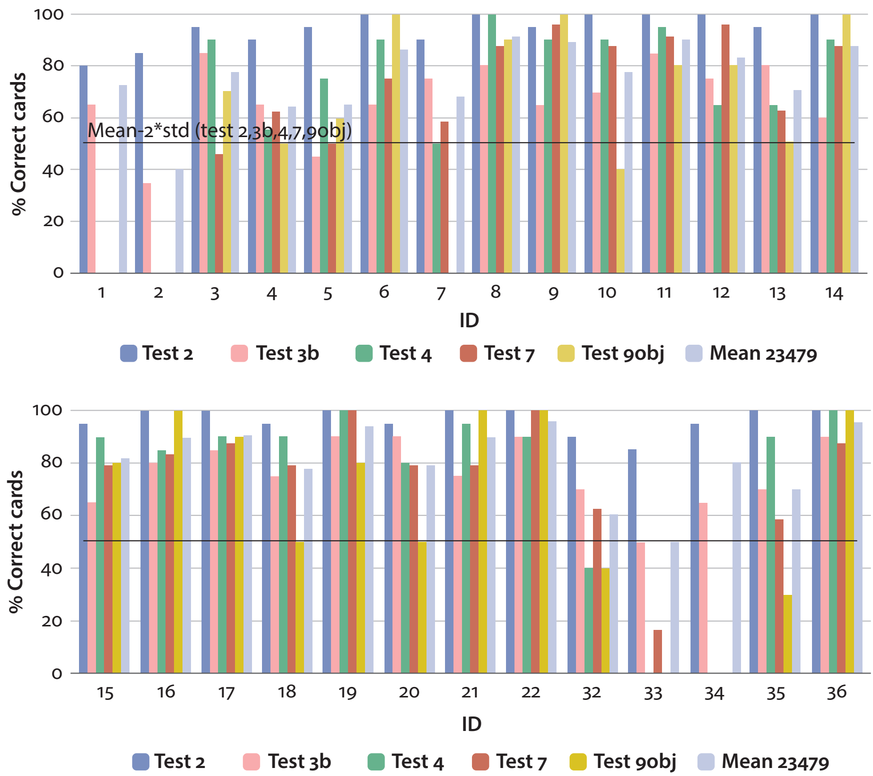


Graph 14. Results for definite D use and object relative clause production task

By putting all the results from Graphs 13 and 14 together, and adding the results from the grammaticality judgment test, we obtain Graph 15. Only one child (2), of islander origin, is >2SD below the mean on the composite of all these tests. One other child (33), of continental origin, is exactly 2SD below the mean.

As pointed out, there are some methodological differences between our study and that of Villanueva et al. We have used a broader but non-standardised battery of tests, and so the comparison between the two sets of results is sketchy. Nonetheless, the fact remains that, on the basis of our experimental results, it seems unlikely that a large part of the population suffers from SLI or is language-delayed.

Is it possible that our sample is skewed? That is certainly a possibility, and it was for this reason we focused on the 4 to 8 age range so that we could include a more representative sample of the island's children in the study. C. Ceccheto (p.c.) has pointed out the possibility that children with language problems were not authorised by their parents to take part in the study. However, for age 4, 75% (6/8) of the school population was tested; for ages 5, 6 and 7, 33% (5/15 for each group) were tested, and for age 8, 85.7% (6/7). Percentages of children who participated for ages 11 to 14 are indeed lower, and we can only speculate that families who had taken part in the earlier study did not wish to let their children participate in a second study.



Graph 15. Results for tests 2, 3b, 4, 7 and 9b

5. Conclusion

We have examined language production and comprehension by means of a battery of tests in a sample of the islander and the continental populations of a South Pacific island allegedly affected by SLI to a much higher degree than the general population. Some years have elapsed since the first tests were conducted by Villanueva et al. (2008), yet the genetic profile of the islanders is not expected to have changed in this period. Genetic studies of the islander population indicate that there is indeed a chromosomal abnormality in the islander population, an instance of the founder effect.

The linguistic performance of the affected individuals is described in little detail in the numerous papers discussing this island population, although the high incidence of SLI is always assumed. At the same time, a very large number of the children who took part in the 2007 study were classified as language-delayed, so it may be assumed that their linguistic performance was likewise abnormal, though compounded with other cognitive deficits (i.e. the linguistic problems are secondary to another deficit). For a reason not clear to us, this deficit was disregarded in later studies, even though its incidence in islander children was reported to be 27.5%. Furthermore, the population examined is not affected in regions of chromosomes 16 or 19, previously associated with SLI, and the deficit of the islanders appears to be of complex inheritance.

Needless to say, we are not in a position to question any of the claims made about the genetic characteristics of this population.[2] Nevertheless, the fact that in the course of the present study we failed to find evidence of a linguistic deficit of the proportions described by Villanueva et al. came as a surprise. It seems highly unlikely that, in a population with 37.5% typically developing children, we would fail to find any difference between islander and continental children. One simple way to resolve this issue would be to test the entire child population of the island. That pending, experimental results for a large sample of typically developing children and further statistical analyses should tell us if our preliminary results are consistent with a high incidence of SLI in the islander group.

References

Anderson, R., Marquez, A. & Grinstead, J. 2009. The article paradigm in Spanish-speaking children with SLI in language contact situations. In *Hispanic Child Languages: Typical and Impaired Development* [Language Acquisition and Language Disorders 50], John Grinstead (ed.), 29–55. Amsterdam: John Benjamins. doi:10.1075/lald.50.03and

Auza, A. & Morgan, G. 2013. The use of prepositions in storytelling: Comparison between Spanish speaking children with and without language impairment. *Infancia y Aprendizaje* 36(1): 35–49. doi:10.1174/021037013804826573

Bedore, L.M. & Leonard, L.B. 2001. Grammatical morphology deficits in Spanish-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research* 44(4): 905–924. doi:10.1044/1092-4388(2001/072)

Bedore, L.M. & Leonard, L.B. 2005. Verb inflections and noun phrase morphology in the spontaneous speech of Spanish-speaking children with specific language impairment. *Applied Psycholinguistics* 26(2): 195–225. doi:10.1017/S0142716405050149

Bishop, D.V.M, North, T. & Donlan, C. 1996. Nonword repetition as a behavioural marker for inherited language impairment: Evidence from a twin study. *Journal of Child Psychology and Psychiatry* 37(4): 391–403. doi:10.1111/j.1469-7610.1996.tb01420.x

Bishop, D.V.M. 2002. The role of genes in the etiology of specific language impairment. *Journal of Communication Disorders* 35(4): 311–328. doi:10.1016/S0021-9924(02)00087-4

2. The situation here is reminiscent of that of the KE family, whose genetic disorder was clear, but whose linguistic deficit was debatable – see Grodzinsky (2002).

Bol, G. & Kuiken, F. 1987. The development of morphosyntax in Dutch children from one to four. *Belgian Journal of Linguistics* 2(1): 93–107. doi:10.1075/bjl.2.06bol

Bortolini, U., Caselli, M.C. & Leonard, L.B. 1997. Grammatical deficits in Italian-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research* 40(4): 809–820. doi:10.1044/jslhr.4004.809

Bottari, P., Cipriani, P., Chilosi, A.M. & Pfanner, L. 1998. The determiner system in a group of Italian children with SLI. *Language Acquisition* 7: 285–315. doi:10.1207/s15327817la0702-4_7

Cantú-Sánchez, M. In preparation. A Study on Spanish SLI. Ph.D. dissertation, Universitat Autònoma de Barcelona.

Chiat, S., Armon-Lotem, S., Marinis, T., Polišenská, K., Roy, P. & Seeff-Gabriel, B. 2013. The potential of sentence imitation tasks for assessment of language abilities in sequential bilingual children. *Issues in the Assessment of Bilinguals*, 56–89.

Clahsen, Harald. 1992. *Linguistic Perspectives on Specific Language Impairment*. Düsseldorf: University of Düsseldorf.

De Houwer, Annick. 1990. *The Acquisition of two Languages from Birth: A Case Study*. Cambridge: CUP. doi:10.1017/CBO9780511519789

Gavarró, Anna. 2012. Third person clitic production and omission in Romance SLI. In *Pronouns and Clitics in Early Language,* Pedro Guijarro-Fuentes & Pilar Larrañaga (eds), 79–104. Berlin: De Gruyter Mouton.

Gavarró, Anna, Espinosa, A., Khouja, M., Marcet, H., Oliver, O. & Redondo, V. 2012. Tasca de repetició per a l'avaluació de la maduresa gramatical: Català. Research report GGT–12–02. ⟨http://filcat.uab.cat/clt/publicacions/reports/pdf/GGT-12-02.pdf⟩

Gavarró, A., Torrens, V. & Wexler, K. 2010. Object clitic omission: Two language types. *Language Acquisition* 17(4): 192–219. doi:10.1080/10489223.2010.509262

Girbau, D. & Schwartz, R.G. 2007. Relative clauses comprehension in Spanish children with and without Specific Language Impairment. In *Proceedings of the 2007 American Speech-Language-Hearing Association (ASHA) Annual Convention*.

Grinstead, J., Cantú-Sánchez, M. & Flores, B. 2008. Canonical and epenthetic plural marking in Spanish-speaking children with Specific Language Impairment. *Language Acquisition* 15: 329–349.

Grodzinsky, Y. 2002. Neurolinguistics and neuroimaging: Forward to the future, or is it back? *Psychological Science* 13(4): 388–393. doi:10.1111/j.0956-7976.2002.00470.x

Jakubowicz, C., Nash, L., Rigaut, C. & Gérard, C.-L. 1998. Determiners and clitic pronouns in French-speaking children with SLI. *Language Acquisition* 7: 113–160. doi:10.1207/s15327817la0702-4_3

Hagstrom, P. 2002. Implications of child errors for the syntax of negation in Korean. *Journal of East Asian Linguistics* 11(3): 211–242. doi:10.1023/A:1016035006888

Hansson, K., Nettelbladt, U. & Leonard, L.B. 2003. Indefinite articles and definite forms in Swedish children with specific language impairment. *First Language* 23(3): 343–362. doi:10.1177/01427237030233005

Leonard, L.B., Caselli, M.C., Bortolini, U., McGregor, K.K. & Sabbadini, L. 1992. Morphological deficits in children with specific language impairment: The status of features in the underlying grammar. *Language Acquisition* 2(2): 151–179. doi:10.1207/s15327817la0202_2

Mills, A.E. 1986. *The Acquisition of Gender: A Study of English and German*. Berlin: Springer. doi:10.1007/978-3-642-71362-0

Newbury, D.F., Bishop, D.V.M. & Monaco, A.P. 2005. Genetic influences on language impairment and phonological short-term memory. *Trends in Cognitive Sciences* 9(11): 528–534. doi:10.1016/j.tics.2005.09.002

Novogrodsky, R. & Friedman, N. 2006. The production of relative clauses in syntactic SLI: A window to the nature of the impairment. *International Journal of Speech-Language Pathology* 8(4): 364–375. doi:10.1080/14417040600919496

Orgassa, A. 2009. *Specific Language Impairment in a Bilingual Context: The Acquisition of Dutch Inflection by Turkish-Dutch Learners*. Utrecht: LOT.

Picallo, M.C. 2008. Gender and number in Romance. *Lingue e Linguaggio* VII: 47–66.

Picallo, M.C. 2012. Structure of the noun phrase. In *The Handbook of Hispanic Linguistics*, J.I. Hualde, A. Olarrea & E. O'Rourke (eds), 263–283. Oxford: Blackwell. doi:10.1002/9781118228098.ch14

Polišenská, D. 2005. Dutch children's acquisition of inflection. Paper presented at IASCL 2005. Berlin.

Restrepo, M.A. & Gutiérrez-Clellen, V.F. 2001. Article use in Spanish-speaking children with specific language impairment. *Journal of Child Language* 28(2): 433–452. doi:10.1017/S0305000901004706

Rice, M.L., Wexler, K. & Cleave P.L. 1995. Specific Language Impairment as a period of extended optional infinitive. *Journal of Speech, Language, and Hearing Research* 38: 850–863. doi:10.1044/jshr.3804.850

SLI Consortium. 2002. A genomewide scan identifies two novel loci involved in specific language impairment. *The American Journal of Human Genetics* 70(2): 384–398. doi:10.1086/338649

SLI Consortium. 2004. Highly significant linkage to the SLI1 locus in an expanded sample of individuals affected by specific language impairment. *The American Journal of Human Genetics* 74(6): 1225–1238. doi:10.1086/421529

Stromswold, K. 2001. The heritability of language: A review and metaanalysis of twin, adoption, and linkage studies. *Language* 77(4): 647–723. doi:10.1353/lan.2001.0247

Villanueva, P., De Barbieri, Z., Palomino, H.M. & Palomino, H. 2008. High prevalence of specific language impairment in Robinson Crusoe Island. A possible founder effect. *Revista Médica de Chile* 136: 186–192. doi:10.4067/S0034-98872008000200007

Villanueva, P., Jara, L. & Palomino, H. 2010. Association of D16S515 microsatellite with specific language impairment on Robinson Crusoe Island, an isolated Chilean population: A possible key to understanding language development. *Human Biology* 82(4): 395–408. doi:10.3378/027.082.0404

Villanueva, P., Newbury, D., Jara, L., De Barbieri, Z., Ghazala, M., Palomino, H.M., Fernández, M.A., Cazier, J.-B., Monaco, A.P. & Palomino, H. 2011. Genome-wide analysis of genetic susceptibility to language impairment in an isolated Chilean population. *European Journal of Human Genetics* 19: 687–695. doi:10.1038/ejhg.2010.251

Villanueva, P., Fernández, M.A., De Barbieri, Z. & Palomino, H. 2014. Consanguinity on Robinson Crusoe Island, an Isolated Chilean Population. *Journal of Biosocial Science* 46(4): 546–555. doi:10.1017/S0021932013000436

Villanueva, P., Nudel, R., Hoischen, A., Fernández, M.A., Simpson, N.H., Gilissen, C., Reader, L.J., Echeverry, M.M., Francks, C., Baird, G., Conti-Ramsden, G., O'Hare, A., Bolton, P.F., Hennessy, E.R., the SLI Consortium, Palomino, H., Carvajal-Carmona, L., Veltman, J.A., Cazier, J.-B., De Barbieri, Z., Fisher, S.E. & Newbury, D.F. 2015. Exome sequencing in an admixed isolated population indicates NFXL1 variants confer a risk for Specific Language Impairment. *PLOS Genetics* 11.

Wexler, K. 1998. Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage. *Lingua* 106(1): 23–79. doi:10.1016/S0024-3841(98)00029-1

Wexler, K. 2002. The Unique Checking Constraint as the explanation of clitic omission in SLI and normal development. In *Essays on Syntax, Morphology and Phonology in SLI*, C. Jakubowicz, L. Nash & K. Wexler (eds). Cambridge MA: The MIT Press.

Appendix 1: Experimental materials used by Villanueva et al. (2008)

Phonological Language Test: *Test para evaluar los procesos fonológicos de simplificación TEPROSIF*

A 15-minute test designed to detect phonological simplification (substitution, assimilation or syllable structure) in child Spanish. It consists of 36 items, of one syllable (#1), two syllables (#16), three syllables (#12), four syllables (#5) or five syllables (#3). The child is invited to see a figure and listens to a sentence describing the scene. He is then asked to complete a sentence about a related figure which obligatorily requires the use of the word elicited. Every simplified syllable is detected and given a score; therefore, the higher the score, the poorer the performance.

Language Test: *Test exploratorio de gramática española de A. Toronto. Aplicación en Chile*

A 20-minute test originally designed to evaluate the language of children from 3;00 to 6;11 years. It is divided into two sub-tests, one for language comprehension and another for language production. The subtest of comprehension consists of 23 elicitations (including declarative sentences, prepositions, pronouns in subject and object position, third person singular verb forms and various other tense forms, indefinite and demonstrative pronouns and verbal passive) and one example. Every elicitation is about four figures (two of them distractors). The child is invited to listen to a sentence and select the corresponding picture. The subtest of production makes use of a repetition task, which also includes 23 items (including wh- questions, various tenses, pronominal clitics, prepositions, passives, etc.) and one example. The child is invited to observe a page with two pictures (there are no distractors) and then listens to a sentence. Then the investigator points to one picture and the child repeats what was said about that picture.

Appendix 2: Experimental items

a. Test 1: Vocabulary retrieval, 20 items
Qué hay aquí? 'What do we have here?' [showing the picture of an object, e.g., a ball]
b. Test 2: Non-word repetition, 20 items (of which 4 monosyllabic, 4 bisyllabic, 4 trisyllabic, and 4 tetrasyllabic)
c. Test 3: Use of determiners, 40 items (of which 10 definite and 30 indefinite)
Mira estos dibujos. ¿Qué hay aquí? Una puerta, una lámpara y una planta. ¿Cuál ha desaparecido? La lámpara. ['Look at these drawings. What do we have here? A door, a lamp and a plant. Which one has disappeared here? The lamp.']
d. Test 4: Grammaticality judgment and correction, 20 items
Había un niño que a veces hablaba bien, a veces hablaba mal. Un día dijo: A los niñas les gustan mucho las muñecas. ¿Está bien? ¿Cómo se dice? [There was a boy who sometimes spoke well sometimes didn't. One day he said, 'The(masc.) girls(fem) like dolls. Is that alright?' How do we say it?]

e. Test 5: Nominal gender and number agreement, 20 items
Aquí hay una flor blanca. Y aquí? Una (flor) roja. ['Here there is a white flower. And here? A red flower.']

f. Test 6: Nominal plural marking, 30 items
*Aquí hay un niño/autobús, y aquí? Dos zapato***s***/autobus***es***.* ['Here there is a boy/bus, and what about here? Two boy**s**/bus**es**.']

g. Test 7: Sentence repetition, 24 items, including various tenses, interrogatives, etc. (adapted from the Catalan repetition task by Gavarró et al. 2012)
Vendremos otra vez a la tienda? [Will we come to the shop again?']

h. Test 8: Use of prepositions, 25 items
Completion of *Las tijeras las usamos… para cortar*. ['We use scissors … to cut.']

i. Test 9: Production of relative clauses, 20 items, of which 10 subject relatives and 10 object relatives.
E.g. *Un niño bebe leche y un niño bebe zumo; ¿qué niño te gustaría ser? Me gustaría ser el niño que bebe leche.* 'A boy drinks milk and a boy drinks juice. Which child would you rather be? I would like to be the child who drinks milk.'

Syntax and its interfaces at the low and high ends of the autism spectrum

Arhonto Terzi[1], Theodoros Marinis[2] & Kostantinos Francis[3,4]
[1]Technological Educational Institute of W. Greece, Patras /
[2]University of Reading / [3]University of Athens / [4]Kuwait Centre for Mental Health, Shuwaikh, Kuwait

Studies on the language abilities in autism spectrum disorders (ASD) have tended to include individuals across the spectrum, with the consequence that the ensuing picture is rarely clear. Most recent studies setting apart individuals at the lower end of the autism spectrum have discovered severe problems in certain areas of grammar. Investigation of grammatical abilities at the higher end of the spectrum has not identified severe problems so far, in an interesting contrast with the lower end. Here we report on current research on pronominal object clitics and their counterpart DPs, which demonstrates that, in some syntactic environments, high-functioning children with ASD fall behind typically developing children. We claim that this behavior does not reflect problems with syntax proper, but is a consequence of pragmatic shortcomings with consequences for the syntax-pragmatics interface. Errors of substitution of clitics with their corresponding DPs are likely to be caused by difficulties in detecting prominence in the discourse. Difficulties with Focused DPs are likely to be caused by problems in distinguishing old from new information and its mapping to prosody. Future research needs to investigate pragmatics, syntax and prosody independently, in order to reach solid conclusions regarding their interaction with respect to specific phenomena in autism, which, in turn, provides an ideal condition to test the contribution of each domain to these phenomena.

1. Introduction

Research on the language of individuals with autism spectrum disorders (ASD) has addressed whether there are particular properties that characterize their language abilities, but has focused primarily on pragmatics and prosody, domains that were traditionally known to be associated with problems in autism (see Diehl et al. 2009; Landa 2000; Surian et al. 1996; Tager-Flusberg et al. 2005, and references therein). In contrast, studies addressing the morphosyntax of individuals with ASD are still relatively scarce. This is much more the case for studies

DOI 10.1075/la.235.09ter

that investigate the interface of morphosyntax with pragmatics and/or prosody, with the consequence that it is unclear to a large extent how the latter impact on the former in individuals with ASD. Finally, studies on the language abilities of individuals with ASD have been primarily concerned with issues pertaining to English-speaking populations and the English grammar.

The relative scarcity of studies of the grammatical abilities in ASD is complicated by two addition factors. First, ASD is a spectrum, and, as a consequence, there is large variability in the profile of individuals. Second, some individuals with ASD may also be comorbid with Specific Language Impairment (SLI). A number of studies have in fact been preoccupied with how the grammatical abilities in ASD differ from those in SLI (Roberts et al. 2004 among others).

This paper addresses aspects of the morphosyntax of high-functioning children with ASD, namely, children with ASD who score like typical populations in general language and cognitive tasks. In Section 2 it presents evidence from previous studies and discusses the role of the high vs. low ends of the spectrum in the language profile of the children. Section 3 focuses on the acquisition of binding of pronouns, reviewing previous research. Binding involves syntax proper, but, depending on the task used and the pronouns tested, it may also involve pragmatics. Section 4 focuses on our own studies of high-functioning children with ASD, and discusses their performance on phenomena that involve syntax proper compared to phenomena at the interface of syntax with pragmatics and prosody.

2. Effects of high- vs. low-functioning on morphosyntactic abilities

A first complete and well-informed study of morphosyntax in autism is the one conducted by Roberts et al. (2004). The authors divided the participants of their study into three groups, based on their performance on the Peabody Picture Vocabulary Test III (PPVT: Dunn & Dunn 1997), a test that measures the comprehension of single-word vocabulary. Group I had PPVT scores within the normal range, that is, 85 and higher, Group II had PPVT scores between 1 and 2 standard deviations from the mean, that is, between 70 and 84, and Group III had PPVT scores below 2 standard deviations. All children of Group I had non-verbal IQ within the normal range, while this was the case for less than half of the children of Group II and only 4 out of the 19 children of Group III. The study investigated the use of third person singular *-s* and regular past tense *-ed* in English, the former being well known to constitute a clinical marker for SLI. They found that the scores of Group 3 were worse than those of children with SLI of the same language (verbal IQ) range. However, the children with SLI were within norms in terms of non-verbal IQ, whereas the majority of the children with ASD had non-verbal IQ below the normal range. These results indicated that low-functioning children with ASD have deficits in morphosyntax and perform less well than children with SLI whose language is characterized by deficits in grammar. Moreover, it highlights the importance of matching groups in terms of non-verbal abilities, even when the groups are matched for their verbal abilities.

A similar outcome emerges from two recent studies of another domain of English grammar, the comprehension of pronouns (Perovic et al. 2013a, b). Perovic et al. (2013a) studied Binding Principles A and B of children with ASD. The participants with ASD of their study had low language and non-verbal abilities and were matched with two groups of TD children, one on language abilities and the other one on non-verbal IQ. Individuals with ASD were found to perform more or less like the control groups on binding of personal pronouns, but significantly lower on binding of reflexive pronouns, an area that is not known to present problems in early language. This finding was important precisely because it had the potential of identifying an area of grammar that is not expected to be impaired, since we do not have instances of either earlier grammar, or some other pathology in which children fall behind on assigning the appropriate antecedent to a reflexive pronoun (with the exception of Down syndrome, see below). Hence, the specific finding had the potential of qualifying as a fundamental characteristic of the linguistic phenotype of individuals with ASD.

In a follow up study, Perovic et al. (2013b) found that things were a bit more complex. The participants of this study were divided into two groups: those with ASD and language impairment (ALI) and those with ASD and normal language (ALN), as assessed by standardized measures of vocabulary and grammar. The result was, again, that performance on binding of reflexive pronouns was low, but only for the ALI group. Interestingly, the majority of the children with low language abilities in this study also had low non-verbal abilities. The authors claim that low non-verbal abilities alone cannot be responsible for the poor performance on binding of reflexives for two reasons: first, because, although reflexive pronouns are impaired in individuals with Down's syndrome, a syndrome which is characterized by extensive language delay and low non-verbal IQ (Perovic 2006), a group of children with Williams syndrome with equally low non-verbal IQ as the ALI children of the Perovic et al. (2013b) study did not demonstrate a similar weakness on reflexives; second, because the TD controls that were matched to the ALI group on non-verbal reasoning did not have low performance on reflexives either. Therefore, despite the fact that it has been pointed out that children with ASD and low non-verbal IQ show a more delayed language than those who are high-functioning (Boucher 2009), low-functioning alone is not in a position to explain why there is a deficit in specific domains of grammar. Moreover, it is difficult to estimate the contribution of non-verbal abilities to deficits on reflexives in some precise manner. Nevertheless, it is clearly the case that Perovic et al. (2013a, b) identified an impaired domain of grammar associated with the lower end of the autism spectrum, regardless of whether the reasons for this association are well understood.[1]

If detecting weaknesses in the (morpho)syntax of individuals who are in lower range of the autism spectrum is valuable, it is equally important to investigate the characteristics of (morpho)syntax in children within the higher end of the spectrum. This will enable us to identify specific areas of grammar that present challenges for this group of individuals with ASD.[2] We already reported that English speaking ALI children differ from ALN children on reflexives, with the latter demonstrating the behavior of the TD controls. One wonders, however, whether other aspects of morphosyntax are affected in high-functioning children with ASD and how high-functioning children with ASD compare to TD children in terms of grammatical development. If high-functioning children with ASD have deficits in specific domains of grammar, these would also be candidates for deficits associated with ASD and their source should be investigated. In our published and ongoing research, we tackle precisely these issues.

3. Binding of pronouns: Syntax proper and its interface with pragmatics and prosody

3.1 Reflexive pronouns

The finding of Perovic et al. (2013a) that children with ASD demonstrate a weakness on the binding of reflexive pronouns in English was the initial source of our motivation to investigate how Greek-speaking children with ASD perform on binding of reflexive pronouns (Terzi et al. 2014). There were several reasons for being particularly motivated to undertake the study. First, because Greek reflexive pronouns have strikingly different properties from the reflexive pronouns of English, as discussed in much detail by Anagnostopoulou and Everaert (1999), and can probably be inferred even after a superficial look at

1. However, one cannot disregard that although the group of the ALI children with ASD and the group of the children with Williams syndrome of the study were matched on age and non-verbal intelligence, the overall language abilities of the ALI children in terms of vocabulary and grammar were much lower than those of the children with Williams syndrome.

2. This is actually the aim of the study of Janke and Perovic (2015) who did not detect weaknesses specific to the high-functioning children with autism in control structures.

their form, (1a). Furthermore, besides employing reflexive pronouns, reflexivity in Greek can also be expressed by means of non-active morphology on the verb, (2b).

(1) a. John loves himself.

b. O Yianis agapa ton eafto tu.
the John loves the self his
'John loves himself.'

(2) a. John is shaving himself.

b. O Yianis ksirizete
the John shaves-non-active
'John is shaving himself.'

The participants in the study of Terzi et al. (2014) were 20 high-functioning children with ASD, individually matched with TD children of similar age on a vocabulary task modelled after the PPVT. Ages of both groups ranged between 5 and 8 years old, with mean age 6;08 and 6;09 for ASD and TD respectively. We decided to start by focusing on a narrow age range in order to avoid confounds due to different developmental trends in the two groups. Children of both groups had average or above average PPVT and Raven's scores (mean Raven's and vocabulary scores for ASD: 103.5 and 102.3 respectively, mean Raven's and vocabulary for TD: 98.0 and 102.7 respectively). The children were tested on binding of reflexive pronouns, but also on binding of object personal pronouns and of object clitic pronouns. The task employed was a picture selection task that used three pictures for each of the sentences assessed.

We found that children with ASD performed well on reflexives. This was a surprise at the time, and several reasons for this discrepancy were considered since it was not until sometime later that the Perovic et al. (2013b) study came out and clarified that, even among English-speaking children with ASD, only the low-functioning have trouble with binding of reflexives. The children in our study were high-functioning with typical overall language abilities, as assessed by the vocabulary task on the basis of which they were matched and a morphosyntax task (DVIQ; Stavrakaki & Tsimpli 2000). However, three children who took part in the study could not be included in the sample of the 20 high-functioning children, because their Raven's score was low and they did not meet the selection criteria of high functioning children with ASD. Precisely these three children performed much worse on binding of reflexives than the high-functioning children included in the study of Terzi et al. (2014), to which we return in detail immediately below. The sample is too small to allow us to draw firm conclusions, but given the findings in Perovic et al. (2013b), it is worth reporting and definitely worth confirming in a future study with a larger sample.

3.2 Personal pronouns

As already mentioned, the study of Terzi et al. (2014) also assessed the reference of personal pronouns, both strong forms, (3a), and clitics, (3b), that is, the knowledge of Principle B of Binding Theory, (3).[3]

(3) a. I Maria zografizi aftin.
the Mary paints her-full pronoun

b. I Maria tin zografizi.
the Mary her-clitic pronoun paints
'Mary is painting her.'

The only domain in which children with autism fell behind their TD controls in this study was on binding of clitic pronouns, an area of grammar that is known to be mastered early by TD Greek-speaking children (Varlokosta 2000). Since this is the domain on which this paper will primarily focus, we present in Table 1 below the actual results.

Table 1. Accuracy on binding (comprehension) of pronouns (Terzi et al. 2014)

	Reflexive pronouns	Strong pronouns	Clitic pronouns
ASD	97.5%	94.9%	88.3%
TD	99.2%	93.3%	99.2%

Table 1 shows that, although children with ASD performed significantly worse than the TD controls on clitic pronouns, their performance was not very low. This raises some first doubts over whether the problem high-functioning children with ASD have with binding of object clitic pronouns is strictly a syntactic one.

In a follow up study, we assessed production of clitics of the same children and their typical TD controls, using the elicitation task of Chondrogianni et al. (2015). In this task, two characters are introduced in one picture, (4a), and, in a subsequent picture, participants are asked to respond on what one of the characters did to the other, (4b). The target answer to such a question is a VP containing the object, since the verb is transitive. Because the object was mentioned in the eliciting question, the felicitous answer should contain a clitic rather the corresponding DP, (5).

3. The study also investigated comprehension of passive sentences, which turned out to be low (around 70% correct responses), but for both groups of children. Perovic et al. (2013b) report, from Perovic et al. (2007), that English-speaking children with autism performed low on passives, but do not clarify at which part of the spectrum these children were.

(4) a. Edo exume enan liko ki enan elefanda. Object clitic
here we-have a wolf and an elephant

b. Ti kani o likos ston elefanda? Eliciting question
what does the wolf to the elephant

(5) *Ton* filai. Target answer
him-clitic kisses
'(he) kisses him.'

Sixteen out of the 20 children of the initial study, along with their matched controls, participated and the results showed that the children with ASD fell behind on the production of clitics, although, again, not by far behind the TD controls.

Table 2. Accuracy on production of clitics (Terzi et al. 2014)

	Clitics	DPs	Omissions
ASD	87.39%	5.27%	7.34%
TD	97.74%	2.26%	0%

Before discussing the breakdown of the production errors, we will call attention to the comprehension errors, since they were the ones that motivated the study to be discussed in much of what follows. The predominant error type in the comprehension task (10 out of 14 errors), Table 1, was that children interpreted sentences such as (3b), as one in which *Mary* was the patient, rather than the agent. The hypothesis we entertained in order to explain this behavior, hence the weakness on the comprehension/binding of object clitics as well, was that the children with ASD interpreted sentences such as (3b), as Clitic Left Dislocation structures (CLLD), (6).

(6) Ti Maria ti zografizi.
the Mary, her-clitic pronoun paints
'As for Mary, (she/he) paints her.'

4. Object clitics and their counterpart DPs in high-functioning autism

A consequence of the previous findings was that they motivated a new study, which investigated how high-functioning children with ASD interpret sentences such as (6) above, and how this compares to their interpretation of sentences with simple clitics, such as in (3b). In order to do so, we did not only assess comprehension and production of simple clitics, but also comprehension and production of clitics in CLLD structures, along with a number of other structures that forbid the use of a clitic pronoun (Terzi et al. 2016). The use of clitic pronouns, by contrast to their corresponding DPs, is determined on the basis of specific pragmatic grounds, which are rather well described in the relevant literature – see Mavrogiorgos (2010) for a recent review, and the discussion later in the paper. Such a study, therefore, would provide the opportunity to investigate whether morphosyntax of children with ASD is indeed affected by deficits in pragmatics and how, a finding of much interest given that we are dealing with a population widely held to fall behind in pragmatics.

The study of Terzi et al. (2016) focused on a new group of 20 high-functioning children of a very similar age group as the one in Terzi et al. (2014). The mean age of the ASD group was 6;11 and that of their TD controls was 6;07. The latter were matched individually with the children with autism on the PPVT vocabulary test (adaptation for Greek: Simos et al. 2011), and children of both groups had to score above 80 on the Raven's test in order to be included in the study. Both groups were tested on comprehension (binding) of pronominal clitics, and production of clitics. Moreover, they were also tested on comprehension and production of CLLD structures, (7). Comprehension and production of clitics was assessed as in the previous study. Comprehension of CLLD was assessed just as comprehension of (simple) clitics, that is, by using a picture pointing task via which children had to select from a set of three pictures each time. Production of CLLD was tested via a sentence completion task with the use of two pictures. The first picture showed three animal characters who were identified for the children, (7a). The experimenter subsequently asked a question pertaining to the action of one of the three animals to another and started answering the question himself by using a DP. The child had to complete the answer, and, crucially, the felicitous answer had to include a clitic, (8), hence, end up in a CLLD structure:

(7) a. Edo exume mia gata, enan liko ke mia katsika. — CLLD
here we-have a cat, a wolf and a goat.

b. Pios filai ti gata? Ti gata … — Eliciting question
who kisses the goat? The goat …
'Who kisses the goat? As for the goat …

(8) … *ti* filai o likos. — Target answer
her-clitic kisses the wolf
the wolf kisses her.'

In addition to CLLD, we investigated another structure, which looks similar to it at the surface, in the sense that it also starts with an object DP displaced in sentence initial position. This was a Focus structure, in which the object of the target sentence is Focused, therefore, no clitic is allowed to double it (Cinque 1997, a.o.).

An additional difference between CLLD structures and Focus structures is that the object DP that starts the sentence in the Focus structure bears a particular Focus accent, indicated with upper case letters. The two structures also differ in that the Focus structure refers to new information, while the CLLD to old information, hence the use of the clitic pronoun, that is, of an element that needs to refer to something that has been mentioned in the discourse in order to be felicitous (Anagnostopoulou 1997; Cinque 1997; Rizzi 1997). The Focus task was a sentence completion task that employed two pictures as well. The experimenter presented the animals in the first picture, (9a), and then asked a question which he started to answer with a DP with Focus accent, (9b). The participants had to continue the answer with a sentence such as in (10), crucially not using a clitic.

(9) a. Edo exume ena liondari, mia arkuda ki enan elefanda. — Focus
here we-have a lion, a bear and an elephant.

b. Pion filai i arkuda? TON ELEFANDA … — Eliciting question
who kisses the bear? THE ELEPHANT
'Who does the bear kiss? It is the elephant …

(10) … filai i arkuda. — Target answer
kisses the bear
that the bear kisses.'

Finally, we also elicited answers to questions that do not allow for the use of a (simple) clitic, but require the corresponding DP, (12). These DPs were elicited via two conditions, condition DP1 and condition DP2. In both conditions, the same question was asked, (11c), but the sentence that introduced the characters in the pictures was different, cf. (11a) and (11b). Just like when eliciting clitics, the answer to the eliciting question requests the use of a VP. However, because the object DP is not mentioned in the eliciting question, hence, it is not prominent in the immediately preceding discourse, the felicitous response does not allow for the use of a clitic, but requires the DP, (12).

(11) a. Edo exume ena liondari ki ena elafi. — DP1
here we-have a lion and a deer

b. Des edo! — DP2
Look here!

c. Ti kani to liondari? — Eliciting question (DP1, DP2)
what does the lion
'What does the lion do?'

(12) Dagoni to elafi. — Target answer
bites the deer
'(he) bites the deer.'

Thus, by comparing (11a) and (11b), we can see that in condition DP1 the characters of the picture, i.e., *the lion* and *the deer*, were introduced to the participants, while in condition DP2 they were not. Instead, in condition DP2 the participants were just asked to look at the characters in the picture. We report below the results from all experiments as well as the error analyses for the conditions that need to be further discussed. The columns with the stars are the only ones in which there was a significant difference between the two groups.

Table 3. Accuracy on binding (comprehension)

	Clitics*	**CLLD**
ASD	94.2%	86.3%
TD	100%	91.7%

Table 4. Accuracy on production

	Clitics*	**CLLD**	**Focus***	**DP1**	**DP2**
ASD	82%	85.7%	71.5%	52.3%	91.5%
TD	97.5%	95.3%	88.9%	35.4%	89.8%

Table 5. Error analysis in the production of clitics

	Clitics	**DPs**	**Omissions**
ASD	82%	12%	6%
TD	97.5%	2,5%	0%

Table 6. Error analysis in the production of Focus structure

	Production of clitics	**No sensitivity to context**	**Other**
ASD	15	10	3
TD	4	2	3

Table 7. Error analysis in the production of DP1

	Production of clitics	**Omission of DP**	**Other**
ASD	50	4	2
TD	75	1	0

Table 8. Error analysis in the production of DP2

	Production of clitics	Omission of DP	Other
ASD	3	4	3
TD	8	3	0

The two groups differed significantly from each other only on the comprehension and production of clitics and on the production of Focus structures, that is, on the cells of Tables 3 and 4 that are marked with a star. Let us start by noting that in both studies, namely, the current one and the one by Terzi et al. (2014), Greek-speaking high-functioning children with ASD differed from TD children on both comprehension and production of simple clitics, moreover, they differed in a very similar manner quantitatively. This shows that the findings are replicable and indicates that we are dealing with an area of morphosyntax, in which high-functioning ASD children indeed fall behind TD children, although not by far as comparison of the actual results confirms.

Does the difficulty that children with ASD have in comprehending and producing object clitics relate to deficits in syntax proper? Let us start with production: the most common error among children with ASD in the production of clitics task of the current study was to use a DP instead of a clitic, see Table 5. We believe they commit this error because they are not entirely in compliance with the condition that allows for the use of a clitic. As claimed by Anagnostopoulou (1999) and Mavrogiorgos (2010), among others, a clitic refers to an entity that has been mentioned in the immediately preceding discourse, hence, has become not only familiar, but also prominent. In other words, in their use of object clitic pronouns, people make use of the *Prominence Condition* of Heim (1982), according to which a pronoun refers to a prominent element in the discourse. If Greek-speaking children with ASD do not produce clitics, it means, either that they do not know the Prominence Condition and the fact that it regulates the use of clitics, or that they know it but cannot always tell what is the prominent element in the discourse. Do we have independent evidence to this effect? Not really from the children of our study. It is known, however, that individuals with autism do not have good awareness of salience in their environment (Landa 2000). If this property carries over to language, it can be considered to correspond to a pragmatic condition that does not allow children to attain full mastery of the use of clitics as a consequence of not being able to distinguish the salient element in the discourse. We are led to conclude that the children with ASD, at least the high-functioning children of our study, fail to distinguish the prominent element in the discourse, rather than ignore the Prominence Condition altogether, because their error rate on the production of promominal object clitics is higher than that of TD children but it is not extremely high. This pragmatic factor can presumably also account for the mild weakness attested in Terzi et al. (2014), Table 2, according to which about half of the errors in the production of clitics consisted of replacing the clitic with the full DP.

How about the conditions that elicited full DPs? As mentioned earlier, two conditions elicited object DPs (and did not allow for the use of the corresponding object clitic). The two conditions differed from each other with respect to the part that introduced the characters in the pictures that were used, right before asking the question that aimed at eliciting a DP. In condition DP1 the characters were introduced upon showing the picture that contained them, (11a). In condition DP2 the characters were not introduced; instead, the picture with the characters was shown to the participants asking them to just look at it, (11b). The two groups, ASD and TD, did not differ significantly from each other on either condition. However, there are two important observations: First, both groups did extremely low on condition DP1, by contrast to condition P2. The overwhelming majority of errors for both groups involved use of a clitic, rather than the (felicitous) DPs. Second, the children with ASD did much better than the TD children on condition DP1, although this difference did not reach statistical significance. We believe that the much worse performance of both groups on DP1, which essentially consisted in using clitics rather than the corresponding DPs, was due to the fact that the characters of the story had been introduced, by sentence (11a), hence, the children were already familiar with them and were able to refer to them via a clitic, ignoring that they actually had to respond to a specific question, (11c), which did not include any of the characters, hence, did not allow for the use of clitics. We believe that the children with ASD did slightly better than the TD children on this task precisely because they were able to follow instructions better, that is, to focus on what the particular sentence was asking them to do, that is, consider question (11c) as the relevant discourse for the use of the DP. All in all however, the contrast between condition DP1 and DP2 shows that the high-functioning children with ASD have a fairly good knowledge of the rules, according to which you cannot refer with a clitic to something not mentioned in the discourse, and this accounts for their good performance on DP2. This offers further support to our earlier claim about the production of simple clitics, namely, that children with ASD cannot always tell the prominent element in the discourse, rather than not being of the *Prominence Condition* and that it regulates the distribution of clitics.

Let us now proceed to the results on CLLD. This condition showed that the two groups did not differ significantly from each other and they also did not differ significantly from the simple clitics production task either. Regardless of how exactly a CLLD structure, (6), differs from a structure with a simple clitic, (3b), it is definitely the case that the former is syntactically more complex than the latter: for one thing, CLLD involves a chain that connects the DP in sentence initial position and the clitic. This is a *predicate variable chain* according to Anagnostopoulou (1997), and it is reasonable to assume that it results in a syntactically more complex structure when compared to a structure that contains just a clitic. Since the two groups of children do not differ, and neither group differs significantly from the simple clitics task, we believe we have a clear indication that syntactic complexity per se does not affect the high-functioning children with ASD disproportionally. This amounts to saying that we have not found so far a problem with syntax proper in the high-functioning group of children we tested. By contrast, the problems detected so far are most likely associated with the syntax-pragmatics interface. Such was the case with the production of clitics, and we believe it also holds for what is to be discussed immediately below.

The last structure that remains to be discussed is (production of) Focus, the other structure on which ASD children were found to perform at a significantly lower rate than their TD controls, see Tables 4 and 6. The structure is similar to CLLD in the sense that it also contains a DP that is displaced to the beginning of the sentence. On the other hand, as already mentioned, it differs in three important ways from CLLD: (a) no clitic is or may be employed to double the DP at the beginning of the sentence, (b) the DP at the beginning of the sentence refers to new information, and (c) the DP at the beginning of the sentence bears Focus accent (Keller & Alexopoulou 2001). The majority of errors of children with ASD on this condition involved the use of a clitic, which as we have repeated, is ungrammatical in Focus structures. One may be tempted to think that the children with ASD do not perceive the different intonation associated with a Focused DP, and, as a consequence, they disregard the rest of the properties of the structure associated with it.

Evidence from other studies indicates that this may not be the case for two reasons: first, the recent study of Diehl et al. (2015) has offered convincing evidence, that, although prosody is a domain of language that is impaired even in high-verbal children with autism, these children do not have difficulties using prosody in order to determine the syntactic structure of a linguistic expression. Second, the authors report that although prosody definitely distinguishes ASD children from TD children on (non-linguistic) pragmatic domains, such as detecting emotions, there is no evidence that it impacts on syntax, although, admittedly there are not very many studies on the topic.

We believe, therefore, that it is most likely not problems with Focus accent/intonation per se that lead the high-functioning children with ASD of our study to perform less well than the TD children on the Focus structure we tested. Instead, we believe that they do perceive that the DP has a distinct intonation, but they are not able to tell, or know, that this particular intonation is associated with a specific interpretation, that is, with new information, which, in turn, precludes the use of a clitic.

To summarize, we believe that the ASD children of our study did not do well on the Focus structure not because this is a structure associated with a particular prosody, although prosody is a domain that even high-functioning children have trouble with. Instead, their problem lies in the fact that, although they are able to detect a distinct prosody in Focus structures, they cannot associate it with a distinct interpretation, namely, with new information. This behavior may be related to problems children with ASD have in distinguishing between new and old information. We do not have independent evidence that the children of our study had trouble in establishing this contrast. Nevertheless, problems in distinguishing old from new information are well documented in the literature, even for high-functioning children with autism (Diehl et al. 2006; Tager-Flusberg 2000).

Moreover, the children of the study in Terzi et al. (2014), who were of practically the same age and had almost the same profile as the ones of the current study, had difficulties in establishing another type of contrast. Assessment of the pragmatic abilities of the aforementioned group of children via a Greek adaptation of the Diagnostic Evaluation of Language Variation (DELV) (Seymour et al. 2005) showed that they had difficulties contrasting characters that they had to describe and present in a story (Marinis et al. 2013), despite the fact that they performed fine on mental state and false beliefs, areas that are considered particularly problematic in autism (Surian et al. 1996). A question that arises at this point is the following: if the children of the current study have difficulties distinguishing old from new information, which, in turn, cannot map the latter to a Focus accented DP appropriately, why didn't they have similar difficulties with CLLD, which stands for old information? We believe that the issue of distinguishing old from new information does not arise for CLLD for the simple reason that the sentence initial object DP offers the property that is required for the use of a clitic by simply being there, namely, by providing the prominent element in the discourse. In the Focus structure, however, this piece of information has to be inferred via the particular Focus accent, which children with ASD cannot map accordingly.

A last observation is that, although children erroneously produced a clitic when asked to complete a Focus structure, hence, in effect they produced erroneously a CLLD structure, they never failed to employ the verb-subject order in the response sentence, see (8), which is the only grammatical order for the verb and the subject in this syntactic environment. This constitutes another piece of evidence in favor of a non-impaired syntax proper.[4]

4. Table 6 indicates that the second larger type of error ASD children commit is what we have called 'no sensitivity to context'. In this error type the children to ASD answered question (9b) without taking into account that they had to complete the answer of the experimenter. The children made the same error type also in the CLLD condition, but we did not report the breakdown of the error types of this condition because there was no difference between the two groups.

5. Conclusions and further directions

The pattern shown in the previous section indicates that the high-functioning Greek-speaking children we have assessed via two studies already do not seem to have problems in syntax proper. This follows from their performance on binding of reflexive pronouns (Terzi et al. 2014), but also from their performance on CLLD when compared to performance on simple clitics (Terzi et al. 2016). The recent study by Janke and Perovic (2015), which also studied high-functioning children, did not find problems on subject and object control either. This contrasts with the studies of Perovic et al. (2013a, b), who investigated children on the lower end of the spectrum, and discovered serious difficulties with (binding of) reflexives as well as the study of Roberts et al. (2004) on the English Tense inflection. Moreover, a careful reading of the literature on the language abilities in autism reveals that whenever the individuals who are assessed appear to have problems, it is either that the high vs. low end of the spectrum has not been taken into consideration, or that the studies are not clear about where in the spectrum their participants belong. Therefore, it is safe to conclude that when individuals with ASD demonstrate impaired performance on morphosyntax, they are not high-functioning.

Yet, as we demonstrated, mild problems do exist in the morphosyntax of high-functioning Greek-speaking children in structures that involve clitic pronouns. We claim that these problems do not reflect impaired morphosyntax. Instead, they reflect weaknesses in pragmatics, possibly along with its mapping to prosody that have consequences for the interfaces with syntax. Admittedly, there has been a caveat in our argumentation: although we resorted to a pragmatic shortcoming in order to explain the mild problems in syntax, we did so on the basis of what we knew from other studies, either on the notion of prominence or on new vs. old information in autism. In order to enhance the validity of such claims it is necessary to run independent experiments on these very factors with the same individuals whose morphosyntax is found mildly impaired. The same goes for prosody and Focus accent.

Until this happens, the conclusion from the studies reported here, including our own, is that problems with morphosyntax which can be attributed to syntax proper have been discovered only among low-functioning individuals with autism. The shortcomings of the grammar of the individuals on the high end of the spectrum are mild to non-existent and are, most probably, a consequence of impairments in pragmatics and the syntax-pragmatics interface, in ways that deserve further investigation. Given that some of these domains may be found impaired in autism on the basis of independent evidence, one can tell apart their contribution to the study of phenomena associated with clitics, and not only, rendering the study of language in autism even more interesting for this reason.

Acknowledgments

The research has been co-financed by the European Union (European Social Fund—ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF). Research Funding Program: ARCHIMEDES III, Grant MIS 383592, "The structure of (a)typical language: linguistic theory and intervention". PI: Arhonto Terzi. We thank the children, parents and personnel of the clinics in Athens and Patras, and the children, parents and teachers of the 6th and the 19th Public Schools and the 42nd Public kindergarten in Patras.

References

Anagnostopoulou, E. 1997. Clitic Left Dislocation and Contrastive Left Dislocation. In *Materials on Left Dislocation* [Linguistik Aktuell/Linguistics Today 14], E. Anagnostopoulou, H. van Riemsdijk & F. Zwarts (eds),151–192. Amsterdam: John Benjamins. doi:10.1075/la.14.11ana

Anagnostopoulou, E. 1999. Conditions on clitic doubling in Greek. In *Clitics in the Languages of Europe*, H. van Riemsdijk (ed.), 761–798. Berlin: Mouton de Gruyter.

Anagnostopoulou, E. & Everaert, M. 1999. Toward a more complete typology of anaphoric expressions. *Linguistic Inquiry* 30: 97–119. doi:10.1162/002438999553977

Boucher, J. 2009. *The Autistic Spectrum: Characteristics, Causes and Practical Issues*. Thousand Oaks CA: Sage.

Chondrogianni, V., Marinis, T., Edwards, S. & Blom, E. 2015. Production and on-line comprehension of definite articles and clitic pronouns by Greek sequential bilingual children and monolingual children with Specific Language Impairment. *Applied Psycholinguistics* 36: 1155–1191. doi:10.1017/S0142716414000101

Cinque, G. 1997. 'Topic' constructions in some European languages and 'connectedness'. In *Materials on Left Dislocation* [Linguistik Aktuell/Linguistics Today 14], E. Anagnostopoulou, H. van Riemsdijk & F. Zwarts (eds), 93–118. Amsterdam: John Benjamins. doi:10.1075/la.14.08cin

Diehl, J.J., Bennetto, L. & Young, E.C. 2006. Narrative coherence of high-functioning children with autism spectrum disorders. *Journal of Abnormal Child Psychology* 34: 87–102. doi:10.1007/s10802-005-9003-x

Diehl, J.J., Watson, D., Bennetto, L., McDonough, J. & Gunlogson, C. 2009. An acoustic analysis of prosody in high-functioning autism. *Applied Psycholinguistics* 30: 385–404. doi:10.1017/S0142716409090201

Diehl, J.J., Friedberg, C., Paul, R., & Snedeker, J. 2015. The use of prosody during syntactic processing in children and adolescents with autism spectrum disorders. *Development and Psychopathology* 27(3): 867–884.

Dunn, L.M. & Dunn, D.M. 1997. *Peabody Picture Vocabulary Test,* 3rd edn. Circle Pines MN: American Guidance Service.

Heim, I. 1982. The Semantics of Definite and Indefinite Noun Phrases. Ph.D. dissertation, MIT.

Janke, V. & Perovic, A. 2015. Intact grammar in HFA? Evidence from control and binding. *Lingua* 164: 68–86. doi:10.1016/j.lingua.2015.06.009

Keller, F. & Alexopoulou, D. 2001. Phonology competes with syntax: Experimental evidence for the interaction of word order and accent placement in the realization of information structure. *Cognition* 79: 301–372. doi:10.1016/S0010-0277(00)00131-1

Landa, R. 2000. Social language use in Asperger syndrome and high-functioning autism. In *Asperger Syndrome*, A. Klim, F. Volkmar & S. Sparrow (eds), 125–155. New York NY: Guilford Press.

Marinis, T., Terzi, A., Kotsopoulou, A. & Francis, K. 2013. Pragmatic abilities of high-functioning Greek-speaking children with autism. *Psychology* 20: 321–337.

Mavrogiorgos, M. 2010. *Clitics in Greek. A Minimalist Account of Proclisis and Enclisis* [Linguistik Aktuell/Linguistics Today 160]. Amsterdam: John Benjamins. doi:10.1075/la.160

Perovic, A. 2006. Syntactic deficit in Down syndrome: More evidence for the modular organization of language. *Lingua* 116: 1616–1630. doi:10.1016/j.lingua.2005.05.011

Perovic A., Modyanova N., Wexler, K. 2007. Knowledge of c-command and A-movement in children and adolescents with autism and with Asperger syndrome. Paper presented at Generative Approaches to Language Acquisition (GALA). Barcelona, Spain.

Perovic, A., Modyanova, N. & Wexler, K. 2013a. Comprehension of reflexive and personal pronouns in children with autism: A syntactic or pragmatic deficit? *Applied Psycholinguistics* 34: 813–835. doi:10.1017/S0142716412000033

Perovic, A., Modyanova, N. & Wexler, K. 2013b. Comparison of grammar in neurodevelopmental disorders: The case of binding in Williams syndrome and autism with and without language impairment. *Language Acquisition* 20: 133–154. doi:10.1080/10489223.2013.766742

Rizzi, L. 1997. The fine structure of the left periphery. In *Elements of Grammar*, L. Haegeman (ed.), 281–337. Dordrecht: Kluwer. doi:10.1007/978-94-011-5420-8_7

Roberts, J.A., Rice, M.L. & Tager-Flusberg, H. 2004. Tense marking in children with autism. *Applied Psycholinguistics* 25: 429–448. doi:10.1017/S0142716404001201

Seymour, H., Roeper, T., de Villiers, J., & de Villiers, P. 2005. *Diagnostic Evaluation of Language Variation (DELVTM) – Norm Referenced*. San Antonio: Harcourt Assessment.

Simos, P.G., Sideridis, G.D., Protopapas, A. & Mouzaki, A. 2011. Psychometric evaluation of a receptive vocabulary test for Greek elementary students. *Assessment for Effective Intervention* 37: 34–49. doi:10.1177/1534508411413254

Stavrakaki, S. & Tsimpli, I.M. 2000. Diagnostic Verbal IQ Test for Greek preschool and school age children: standardization, statistical analysis, psychometric properties. In *Proceedings of the 8th Symposium of the Panhellenic Association of Logopedists*, 95–106. Athens: Ellinika Grammata.

Surian, L., Baron-Cohen, S. & van der Lely, H. K. J. 1996. Are children with autism deaf to Gricean maxims? *Cognitive Neuropsychiatry* 1: 55–71. doi:10.1080/135468096396703

Tager-Flusberg, H., Paul, R. & Lord, C. 2005. Language and communication in autism. In *Handbook of Autism and Developmental Disorders: Diagnosis, Development, Neurobiology, and Behaviour,* 3rd edn, F.R. Volkmar, R. Paul, A. Klin & D.J. Cohen (eds), 335–364. Hoboken NJ: John Wiley & Sons.

Tager-Flusberg, H. 2000. Language and understanding minds: connections in autism. In *Understanding Other Minds: Perspectives from Developmental Cognitive Neuroscience,* S. Baron-Cohen, H. Tager-Flusberg & D. Cohen (eds), 124–149. Oxford: OUP.

Terzi, A., Marinis, T. & Francis, K. 2016. The interface of syntax with pragmatics and prosody in children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders* 46: 2692–2706. doi:10.1007/s10803-016-2811-8

Terzi, A., Marinis, T., Francis, K. & Kotsopoulou, A. 2014. Grammatical abilities of Greek-speaking children with autism. *Language Acquisition* 21: 4–44. doi:10.1080/10489223.2013.855216

Varlokosta, S. 2000. Lack of clitic pronoun distinctions in the acquisition of principle B in child Greek. In *Proceedings of the 24th Boston University Conference on LanguageDevelopment [BUCLD 24]*, 738–748. Somerville MA: Cascadilla Press.

Communication in schizophrenia, between pragmatics, cognition, and social cognition

Marta Bosia[1,2], Giorgio Arcara,[3] Mariachiara Buonocore,[1] Margherita Bechi,[1] Andrea Moro,[4] Roberto Cavallaro[1] & Valentina Bambini[4]

[1]Department of Clinical Neurosciences, IRCCS San Raffaele Scientific Institute, Milan, Italy / [2]Vita Salute San Raffaele University, Milano, Italy / [3]IRCCS Fondazione Ospedale San Camillo, Venice, Italy / [4]Center for Neurocognition and Theoretical Syntax (NeTS), Scuola Universitaria Superiore IUSS Pavia, Pavia, Italy

We previously reported communication disruption in schizophrenia at the pragmatic level, i.e., in the ability to match language and context. Pragmatic abilities interact with a number of cognitive functions, from Theory of Mind to executive control, which in turn are known to be compromised in schizophrenia. This study aims to explore the relationship between communication-related skills, assessed through a newly developed pragmatic protocol, and neuropsychological measures, including Theory of Mind, in a sample of 39 patients with schizophrenia. Among all neuropsychological domains assessed, verbal short term memory and executive functions seem to especially correlate with the comprehension of the pragmatic aspects of language. Other cognitive and socio-cognitive domains seem to correlate in a task-specific fashion, i.e., depending on the pragmatic task under investigation. Our findings suggest that, while there is a cognitive platform for pragmatic abilities, communicative behavior is at least partially independent of the global cognitive profile. Also, the effect of Theory of Mind is likely to be mediated by more basic cognitive functions.

1. Introduction

Schizophrenia is a severe and disabling chronic mental illness affecting an estimated 0.3–0.7% of the world's population, according to the last edition of Diagnostic and Statistical Manual of Mental Disorders (DSM-5). The disease course is frequently associated to poor functional outcome and quality of life, and the main determinant of such disability is represented by cognitive impairment, which in the past decades has been recognized as a core feature of schizophrenia (Kahn & Keefe 2013; Green et al. 2000). Cognitive functioning is moderately to severely

doi 10.1075/la.235.10bos

impaired in almost every patient with schizophrenia. Although descriptions of the profile of cognitive deficit in schizophrenia vary across literature reviews, the most important domains that are usually impaired in schizophrenia are: working memory, attention/vigilance, verbal learning and memory, visual learning and memory, executive functions (reasoning, problem solving, and speed of processing) (Green et al. 2004). Recently, also social cognition, referring to an array of abilities that involves cognitive capability applied to social situations (Brothers 1990), including emotion perception and recognition, attributional styles, cognitive biases, social knowledge and Theory of Mind, has been deeply investigated in schizophrenia. Consensus is growing among researchers on the key role of social cognition in mediating the relationship between cognitive deficit and functional impairment in patients with schizophrenia (Barbato et al. 2013). Although social cognition may include several different capacities, the general focus of the literature in schizophrenia is on Theory of Mind (ToM) skills. ToM, i.e. the ability to reflect upon one's own and other persons' mental states, is particularly relevant as it is classified as a key predictor of interpersonal functioning impairment and it is thought to influence real-world behaviors more directly than psychopathology and cognition (Barbato et al. 2013). Currently, these aspects are well characterized at the neuropsychological level and represent the main target of rehabilitation programs aimed at improving the patient's functional outcome (Bechi et al. 2015; Bosia et al. 2014).

Communicative abilities are also impaired in schizophrenia, as reported since early clinical descriptions of the illness, often with vivid examples of the patients' speech, such as the following, from a 1911 book by Bleuler: *I always liked geography. My last teacher in that subject was Professor August A. He was a man with black eyes. I also like black eyes. There are also blue eyes and gray eyes and other sorts, too. I have heard it said that snakes have green eyes. All people have eyes* (from Noonan 2014). In this example, we can notice that the speaker, while trying to pursue some meaning, loses focus and slides off topic, showing what in clinical terms is referred as formal though disorder or conceptual disorganization. Traditionally, the study of language in schizophrenia has attempted to characterize speech disturbances as epiphenomena of the psychopathological dimension, attributing discourse tangentiality and incoherence to positive symptoms, and poverty of speech to negative symptoms. Only in the past decades, modern multidisciplinary approaches, thank to advancements in linguistics and neuroscience of language, have paved the way to more principled characterization of linguistic disruption in schizophrenia (Covington et al. 2005). Although with some conflicting evidence, partially depending also on the heterogeneity of the tasks used, the deficit exhibited by patients with schizophrenia seems to encompass both comprehension and production, as well as syntax and semantics (DeLisi 2001; Kuperberg 2010).

Beyond the identification of specific components of the linguistic structure that are impaired, a global failure in the use of language in social interaction and in producing and comprehending contextually appropriate meanings clearly stands out, highlighting the role of pragmatic abilities. There is indeed abundant evidence that patients with schizophrenia fail in tasks that typically involve the domain of so-called "pragmatics", i.e. how contextual factors interact with linguistic meaning in the interpretation of utterances, including inferring the speaker's intended meaning, especially in non-literal language use, and providing the appropriate amount of information in discourse (Sperber & Wilson 2005). In schizophrenia, figurative language processing deficits have been reported since at least 100 years and have been traditionally attributed to the inability of abstract thinking, clinically defined as "concretism" (Harrow et al. 1974). In recent years, the interest on this topic has grown and several studies on patients with schizophrenia showed impairments in proverb interpretation, comprehension of idioms, metaphor and irony (Langdon et al. 2002; Kiang et al. 2007; Schettino et al. 2010; Rapp et al. 2013; Pesciarelli et al. 2014; Mossaheb et al. 2014). However, this evidence is rarely described in pragmatic terms and only few studies include a broad assessment of pragmatic abilities (Perlini et al. 2012; Colle et al. 2013), while most investigations focus on single aspects of the pragmatic competence. In this view, we recently analyzed pragmatic abilities in schizophrenia as compared to healthy controls (Bosia et al. 2015), by means of the Assessment of Pragmatic Abilities and Cognitive Substrates (APACS), a comprehensive protocol combining the most standard pragmatic tasks, from discourse production to non-literal language comprehension (Arcara & Bambini 2016). Our results confirmed that pragmatic abilities are widely compromised in schizophrenia, as patients performed significantly worse than controls in all tasks, with the main differences standing out in comprehension. Moreover, we also investigated the role of psychopathology, suggesting that the impairment of pragmatic abilities in schizophrenia is not directly related to any symptoms dimension, neither positive or negative, but rather is intertwined with specific psychopathological manifestations, that capture speech disturbances and verbal comprehension at the clinical level (Bosia et al. 2015). Specifically, we observed no correlation between pragmatic tasks and symptoms scales, but we found significant negative correlations between the items of the PANSS scale evaluating conceptual disorganization and difficulty in abstract thinking on the one hand, and several pragmatic comprehension tasks on the other hand.

As known from research in neuropragmatics, pragmatic behavior is also affected by the interplay of several cognitive functions, especially executive functions and ToM (Bambini et al. 2011; Bambini & Bara 2012; Hagoort & Levinson 2014), that are typically impaired in patients with schizophrenia (Bosia et al. 2010, 2011, 2012). For this reason, investigations on pragmatics in schizophrenia need to include assessment of cognition and social cognition. Up to now, cognition was sparsely investigated in the literature: executive functions and working memory were found to predict the comprehension of idiomatic expressions in patients with schizophrenia (Schettino et al. 2010), and similar results were observed for the interpretation of proverbs (Sponheim et al. 2003; Kiang et al. 2007; Thoma et al. 2009). Among social cognition domains, ToM was specifically associated with understanding of irony (Langdon et al. 2002) and other non-literal language uses (Brüne & Bodenstein 2005; Champagne-Lavau & Stip 2010). Interestingly, the few studies that combined the analysis of cognition and ToM suggested that the latter is a better predictor than the former for pragmatic abilities (Brüne & Bodenstein 2005; Champagne-Lavau & Stip 2010).

Overall, this evidence does not allow to derive strong conclusions on the neurocognitive underpinnings of pragmatics, as most of the studies consider a single pragmatic phenomenon, and they either focus on cognitive profile or social cognition. Moreover, it is important to highlight that the debate over the role of cognitive decline in language in general has spanned throughout the literature on schizophrenia. As noted by Kuperberg and Caplan (2003), there are several caveats to the interpretation of most of the studies. First, functions such as working memory and attention have been defined very broadly. Second, even in healthy population, the precise relationships and interactions between general cognitive processes such as working memory and different types of language processing are not fully understood.

In this scenario, schizophrenia represents a perfect test ground to explore language in terms of specific impairments of the different linguistic components and in terms of interplay with other cognitive processes affected by the disease. This study was designed to investigate the interplay between pragmatic abilities in schizophrenia, assessed through an extensive protocol that includes the most standard pragmatic tasks in order to provide a global pragmatic profile, and both cognitive and socio-cognitive domains that are typically impaired in patients. To this purpose, we will combine correlation analysis and Regression Tree Models, suited to explore the effect of several predictors in small samples.

2. Materials and methods

2.1 Subjects

For this protocol, we included the same patients that participated to a previous study (Bosia et al., 2015). For clarity, we still report the description. Thirty-nine subjects diagnosed with schizophrenia, according to the DSM-IV-TR (American Psychiatric Association, 2000) were enrolled from the Department of Clinical

Neurosciences, San Raffaele Scientific Institute, Milan. After a complete description of the study, informed consent to participation was obtained. The protocol followed the principles of the Declaration of Helsinki and was approved by the local Ethical Committee.

To be included, patients had to satisfy the following conditions: 1. DSM-IV-TR diagnosis of schizophrenia (all subtypes), made by staff psychiatrists through clinical interviews; 2. Treatment with a stable dose of the same antipsychotic therapy for at least 3 months, with a good response (30% or more reduction of Positive and Negative Syndrome Scale-PANSS Total score); 3. No evidence of substance dependence or abuse, comorbid diagnoses on Axis I or II, epilepsy, or any other major neurological illness or perinatal trauma, or mental retardation; 4. Italian native language.

2.2 Psychopathological assessment

All patients were assessed with the Positive and Negative Syndrome Scale for Schizophrenia (PANSS), administered by a trained psychiatrist. The PANSS (Kay et al. 1987) is a standardized measurement for typological and dimensional symptoms assessment. It includes three subscales (Positive, Negative, General), assessing positive symptoms, negative symptoms and general psychopathology, respectively.

2.3 Neuropsychological assessment

Cognitive performance was evaluated by means of the Italian version of Brief Assessment of Cognition in Schizophrenia (BACS) (Keefe et al. 2004; for the Italian version, Anselmetti et al. 2008), a battery assessing the main cognitive functions that are usually impaired in patients with schizophrenia. The BACS consists of 6 subtests, evaluating the following domains:

– *Verbal Memory*: patients are presented with 15 words and are asked to remind as many of these words as possible, then they are asked to recall them in whatever order. The whole procedure is repeated 5 times. Measures: number of recalled words at the 5th trial. Max score: 75.

– *Working Memory*, evaluated with a sequence of numbers task. Patients are read groups of numbers (i.e. 9, 3, 6) of increasing length at the time of 1 per second. Then, they are asked to repeat to the tester the numbers starting from the lowest value to the highest. The test is composed of 28 groups of numbers going from 2-figure as minimum to the maximum of 8-figure numbers. Measures: number of correct answer. Max score: 28.

– *Psychomotor Speed and Coordination*, evaluated with a token motor task. Patients are given 100 plastic token scattered in the way of not being overlapped, and they are asked to place them in a container as quickly as possible in a 60 seconds time, taking only 1 per hand and not making them slide to the table edge. Measure: number of tokens placed in the container during the first 30 seconds and the final 30 seconds. Max score: 100.

– *Verbal Fluency*, derived from Semantic Fluency and Letter Fluency. For Semantic Fluency, patients are given 60 seconds to name as many words as possible within a given category (i.e "supermarket object"). Measure: number of words generated. For Letter Fluency, in two separate trials, patients are given 60 seconds to generate as many words as possible, starting with a specific letter (F and R in the version A, T and M in the version B). Measure: number of words generated.

– *Processing Speed*, evaluated with a symbol coding task. Patients receive a key explaining how unique symbols correspond to the individual numerals 1–9. They are asked to fill in the corresponding number beneath a series of symbols as quickly as possible. There is a 90 second time limit. Measure: number of correct items. Max score: 100.

– *Planning (Executive Functions)*, evaluated with the Tower of London. Patients are presented with two pictures simultaneously. Each picture shows three different colored balls arranged on three pegs, but the balls will be in a unique arrangement in each picture. The patient has to give the total number of times the balls in one picture would have to be moved in order to make the arrangement of balls identical to that of the other, opposing picture, not helping himself tracing passages with fingers and having 20 sec for each picture. Measure: number of correct responses. Max score: 22.

Theory of Mind (ToM) was assessed using the ToM Picture Sequencing Task (PST; Brüne, 2003a), consisting of six cartoon picture stories of four cards each, depicting (1) two scenarios where two characters cooperated, (2) two scenarios where one character deceived a second character and (3) two scenarios showing two characters cooperating to deceive a third. The cards were presented face-down in mixed order; the participants were asked to turn the cards over and to order them in a logical sequence of events. Sequencing represents a measure of non-verbal and abstractive processes involved in ToM (Brüne 2003b). In addition, a ToM questionnaire with 23 questions was given to subjects to test their ability to appreciate the mental states of the characters involved in the cartoon stories, in order to evaluate verbal cognitive ToM. The questions referred to the mental states of the characters according to different levels of complexity and included first to third false beliefs questions, intentional attribution questions, questions involving the understanding of cheating detection and 2 reality questions, included to rule out major attentional problems. If subjects failed to sequence the story correctly, pictures were brought into the correct order by assessors before administering the ToM questionnaire. Rating was divided in 2 parts: the first (PST Sequencing Score) was made by giving two points for the first and last correctly sequenced cards, and one point each for correct sequencing of the two middle cards (thus, 6 pts. maximum per picture story, 36 pts. maximum sum score); the second (PST Questionnaire Score) resulted from the sum of each questionnaire (maximum sum score 23 pts.). Finally, a global measure of ToM abilities (PST Total Score) was derived as the sum of Sequencing and Questionnaire Scores (59 pts. maximum).

2.4 Pragmatic assessment

To assess pragmatic abilities we employed a novel test (APACS, Assessment of Pragmatic Abilities and Cognitive Substrates) that combines different pragmatic tasks widely used in the literature, with refined materials in Italian (Arcara & Bambini 2016). The test includes 6 tasks, assessing both production and comprehension and focusing on two main pragmatic domains in the Gricean and post Gricean tradition, as well as in the clinical literature on pragmatics, i.e. discourse and non-literal meaning. These domains involve context-based uses of language, and scoring was focused on the pragmatic aspects of each task.

Task 1 (Interview) measures the ability of engaging in conversation through a semi-structured interview, organized around four autobiographical topics widely employed in the aphasiology literature to enhance speech: family, home, work, organization of the day. Elaborating on previous approaches (Marini et al. 2011), four dimensions of discourse are rated for the presence of communication difficulties at the contextual-pragmatic level: speech (e.g. repetition, incomplete utterances, echolalia), informativeness (e.g. over- or under-informativeness, loss of verbal initiative), information flow (e.g. missing referents, wrong order of the discourse elements, abrupt topic shift), and the paralinguistic dimension (e.g. loss of eye-contact, fixed facial expression). Scores (0/1/2) refer to the frequency of each communication difficulty (always/sometimes/never). Maximal score: 44.

Task 2 (Description) measures the ability of producing informative descriptions of everyday life situations through a classic picture description task, here considered in a pragmatic perspective. The subject is asked to describe ten photographs that depict scenes of everyday life (e.g. a woman waiting at the bus station) in relation to the main elements that characterize the scene (the location, i.e., the so-called "scene setting topic", the agent and the action performed). Scores (0/1/2) refer to missed identification, partially correct identification, correct identification of each salient element. Maximal score: 48.

Task 3 (Narratives) measures the ability to comprehend the main aspects of a narrative text. The subject is presented with 6 stories, inspired by real newspaper and TV news, with increasing length (number of sentences ranging from 4 to 8), and complexity set on a medium difficulty level for subjects with 8 years of schooling based on the Gulpease readability index (Lucisano & Piemontese 1988). Following each story, several question items are administered, assessing the global topic of the story, specific elements of the text, either main or detail, either explicit or implicit, see (Ferstl et al. 2005), and the comprehension of non-literal expressions embedded in the story. Maximal score: 56.

Task 4 (Figurative Language 1) measures the ability to infer non-literal meaning through multiple choice questions. Materials include: 5 highly familiar idioms, extracted from existing norms (Tabossi et al. 2011); 5 novel metaphors, extracted from existing ratings (Bambini et al. 2013); 5 common proverbs extracted from a dictionary of Italian proverbs (Guazzotti & Oddera 2006), all provided with a minimal context. For each sentence, the subject is asked to select the option that correctly expresses the figurative meaning, choosing among three possible interpretations, including one correct (i.e. figurative), one incorrect (i.e. literal), and another one incorrect (i.e. unrelated). For instance, a metaphor like "Ho appena visto una corsa di formula uno. Certe automobili sono frecce", tr. "I have just seen a F1 race. Some cars are arrows", the options were: "Certe automobili sono veloci", tr. "Some cars are fast" (correct); "Certe automobili sono appuntite", tr. "Some cars are pointy" (incorrect, literal); and "Certe automobili sono lussuose", tr. "Some cars are luxurious" (incorrect, unrelated). Each item is scored either 1 or 0 according to the accuracy. Maximal score: 15.

Task 5 (Humor) measures the ability to comprehend verbal humor through multiple choice questions, inspired by the Joke and Story Completion Test (Brownell et al. 1983). The materials consist of 7 items, each presenting a brief story. For each story, the subject is asked to select the ending that best functions as the punchline of the story, choosing among three possible endings, one correct (i.e. funny, based either on processing polysemous meaning or requiring to derive unexpected scenarios), one incorrect (i.e. straightforward non-funny), and another one incorrect (i.e. unrelated non-sequitur). Each item is scored either 1 or 0 according to the accuracy. Maximal score: 7.

Task 6 (Figurative Language 2) measures the ability to infer non-literal meanings through verbal explanation, similar to previous tests (Papagno et al. 1995; Amanzio et al. 2008). Materials include: 5 highly familiar idioms, 5 novel metaphors, and 5 common proverbs, with the same psycholinguistic characteristic of materials in Figurative Language 1. Good descriptions of the meaning of the figurative expression are scored 2, incomplete explanations (i.e. concrete examples missing a general meaning) score 1, paraphrases and literal interpretation score 0. Maximal score: 30.

The neuropsychological and pragmatic assessments were performed by different trained psychologists, blind to each other's ratings, in separate sessions within a 2 weeks time frame.

2.5 Data analysis

The association between pragmatic abilities and both cognitive and socio-cognitive performance was examined using non-parametric correlations (Spearman ρ). In details, correlations were analyzed between scores on each APACS pragmatic task (Interview, Description, Narratives, Figurative Language 1, Humor, Figurative Language 2) and each BACS subtest (Verbal Memory, Working Memory, Motor Speed and Coordination, Verbal Fluency, Processing Speed, Planning) and ToM Picture Sequencing Task (PST Sequencing, Questionnaire and Total Scores), respectively. The statistical significance level was set at $p < 0.05$, then adjusted according to Bonferroni correction when required. All statistical analyses were performed with R, release 3.1.0 (R Core Team, 2014).

To further evaluate the effect of cognitive and socio-cognitive performance on pragmatics, also taking into account psychopathological features, we used Regression Tree Models (Breiman et al. 1984; Baayen 2008). This is a non-parametric and non-linear method used to analyze continuous outcome, indicated to explore the effect of several predictors on one predicted variable, in small samples. In Regression Trees, the number of explanatory variables (predictors) is not restricted, as only the best splitter takes at each step of the tree, therefore there is no mandatory minimal sample size and missing data are also well managed. Moreover, multicollinearity in explanatory variables can also be handled, by selecting the best splitter. The Trees look for the variable that best is able to split the data in two, minimizing the mean squared error (MSE, that is the error in prediction). Once a first split is made, the Regression Trees find another split, and so on, until satisfying splits are found (a split is "satisfied" if the MSE is consistently reduced and if there are enough observations in each branch of the split data). In this way, each generated tree presents with one or more nodes and at least two branches. The numbers at the end of the branches (bottom of the plot) indicate the predicted values of the dependent variables (in our case the predicted scores of APACS tasks). The numbers that appear at the node (beside a logical test, e.g. Test A <12) are the selected splitting values of the predictors. If the logical test is true (e.g. Test A score is <12), you go left in the branch, while if the test is false (e.g. Test A score is >12), you go right.

In this study, the algorithm was run separately for each APACS task (namely Interview, Description, Narratives, Figurative Language 1, Humor, Figurative

Language 2), including psychopathological features (measured by PANSS Positive, Negative and General subscales), cognitive performance (all BACS subtests) and social cognition abilities (as evaluated by PST Sequencing and Questionnaire scores) as explanatory variables, generating Regression Trees with one or two terminal nodes.

3. Results

3.1 Sample Description

As reported in Bosia et al. (2015), the sample was composed of 39 patients with schizophrenia (21 males and 18 females), diagnosed with the following subtypes of schizophrenia: paranoid (n = 25), undifferentiated (n = 13) and disorganized (n = 1). The mean age was 40.87 years (±10.30), the mean years of education were 11.89 (±2.68) and mean age at onset was 24.97 (±6.99). Mean scores of the PANSS were 17.97 (±3.90) for Positive, 20.38 (±4.42) for Negative, 38.55 (±6.39) for General Subscale, and 76.72 (±11.48) for Total Score. The antipsychotic treatment was distributed as follows: 13 patients were treated with clozapine (mean daily dose 300.96 mg), 7 with paliperidone (mean daily dose 8.14 mg), 6 with haloperidol (mean daily dose 6.12 mg), 6 with risperidone (mean daily dose 3.79 mg), 3 with olanzapine (mean daily dose 20 mg), and 1 with zuclopentixole (mean daily dose 10 mg).

Mean scores of pragmatic and neuropsychological evaluation are reported in Table 1.

Table 1. Neuropsychological and pragmatic data on individuals with schizophrenia

Test	Subtest	Mean (S.D.)
Brief Assessment of Cognition in Schizophrenia (BACS; Anselmetti et al. 2008)	*Verbal Memory*	42.18 (11.16)
	Working Memory	17.28 (4.35)
	Psychomotor Speed and Coordination	64.25 (16.96)
	Verbal Fluency	37.87 (12.06)
	Processing Speed	37.66 (12.47)
	Planning	14.21 (4.04)
Theory of Mind Picture Sequencing Task (ToM PST; Brüne 2003a)	*PST Sequencing*	26.46 (8.82)
	PST Questionnaire	16.47 (4.80)
	PST Total	42.84 (12.80)

(*continued*)

Table 1. (Continued)

Test	Subtest	Mean (S.D.)
Assessment of Pragmatic Abilities and Cognitive Substrates (APACS; Bosia et al. 2015)	*Interview*	39.82 (3.01)
	Description	47.12 (1.73)
	Narratives	45.20 (6.44)
	Fig. Lang. 1	13.10 (2.61)
	Humor	4.49 (1.76)
	Fig. Lang. 2	20.94 (4.63)

3.2 Association between pragmatic tasks and neuropsychological measures

3.2.1 *Correlations*

Significant correlations (Bonferroni corrected) were observed between pragmatic tasks performance and different domains of cognition, assessed by BACS subtests. In details, as shown in Table 2, Verbal Memory significantly correlated with Narratives, Figurative Language 2, and Humor; Verbal Fluency with Narratives and Humor, whereas Processing Speed correlated only with Humor. No significant correlations were observed between APACS tasks and Working Memory, Psychomotor Speed and Coordination, nor Planning.

Table 2. Correlations between cognitive measures as assessed in the BACS and performance in the pragmatic tasks of the APACS test.

	Verbal Memory	Working Memory	Psychomotor Speed and Coordination	Verbal Fluency	Processing Speed	Planning
Interview	$\rho = 0.3$ $p = 1$	$\rho = 0.04$ $p = 1$	$\rho = -0.03$ $p = 1$	$\rho = 0.12$ $p = 1$	$\rho = 0.24$ $p = 1$	$\rho = 0.35$ $p = 1$
Description	$\rho = 0.49$ $p = 0.06$	$\rho = 0.09$ $p = 1$	$\rho = 0.3$ $p = 1$	$\rho = 0.13$ $p = 1$	$\rho = 0.28$ $p = 1$	$\rho = 0.18$ $p = 1$
Narratives	$\rho = 0.6$ $p < 0.001$*	$\rho = 0.3$ $p = 1$	$\rho = 0.29$ $p = 1$	$\rho = 0.54$ $p = 0.02$*	$\rho = 0.31$ $p = 1$	$\rho = 0.5$ $p = 0.06$
Fig. Lang. 1	$\rho = 0.47$ $p = 0.09$	$\rho = 0.42$ $p = 0.3$	$\rho = 0.23$ $p = 1$	$\rho = 0.41$ $p = 0.35$	$\rho = 0.34$ $p = 1$	$\rho = 0.33$ $p = 1$
Humor	$\rho = 0.72$ $p < 0.001$*	$\rho = 0.44$ $p = 0.19$	$\rho = 0.39$ $p = 0.61$	$\rho = 0.53$ $p = 0.02$*	$\rho = 0.54$ $p = 0.02$*	$\rho = 0.32$ $p = 1$
Fig. Lang. 2	$\rho = 0.51$ $p = 0.03$*	$\rho = 0.36$ $p = 0.86$	$\rho = 0.08$ $p = 1$	$\rho = 0.41$ $p = 0.35$	$\rho = 0.18$ $p = 1$	$\rho = 0.25$ $p = 1$

*Significant p values, adjusted for multiple comparison according to Bonferroni correction.

The analysis on social cognition revealed significant correlations between Figurative Language 1 and both PST Sequencing Score, a measure of non-verbal ToM processing, and PST Total Score. Table 3 summarizes correlations between ToM abilities and performance in the pragmatic tasks of the APACS test.

Table 3. Correlations between Theory of Mind abilities as assessed in the PST and performance in the pragmatic tasks of the APACS test.

	PST Sequencing	PST Questionnaire	PST Total
Interview	$\rho = -0.06$ $p = 1$	$\rho = -0.14$ $p = 1$	$\rho = -0.08$ $p = 1$
Description	$\rho = 0.28$ $p = 1$	$\rho = 0.1$ $p = 1$	$\rho = 0.23$ $p = 1$
Narratives	$\rho = 0.4$ $p = 0.45$	$\rho = 0.35$ $p = 0.94$	$\rho = 0.42$ $p = 0.29$
Fig. Lang. 1	$\rho = 0.6$ $p < 0.001$*	$\rho = 0.48$ $p = 0.09$	$\rho = 0.62$ $p < 0.001$*
Humor	$\rho = 0.5$ $p = 0.06$	$\rho = 0.42$ $p = 0.31$	$\rho = 0.49$ $p = 0.09$
Fig. Lang. 2	$\rho = 0.43$ $p = 0.23$	$\rho = 0.46$ $p = 0.15$	$\rho = 0.49$ $p = 0.08$

*Significant p values, adjusted for multiple comparison according to Bonferroni correction.

3.2.2 *Regression Trees*

Separate trees were derived for each APACS task, as shown in Figure 1.

For Interview, Tree 1 indicates that the best prediction is made when BACS Verbal Memory and PST Sequencing Score are taken into account. The first logical test identifies a splitting value of 37 for BACS Verbal Memory. If the Verbal Memory score is <37, the best prediction for Interview is made by Verbal Memory alone. Otherwise, if the logic test is not true (for higher values of Verbal Memory), ToM performance also becomes a relevant predictor, with a splitting value of 32.5 at the PST Sequencing Score.

Tree 2 shows that Description performance is best predicted only by BACS Verbal Memory, with a splitting value set at 39.5.

Regarding Narratives, the best predictors are BACS Verbal Fluency and Verbal Memory, as illustrated in Tree 3. Verbal Fluency has a direct predictive effect on Narratives performance for scores <27, while for higher scores, also the effect of Verbal Memory should be considered, with a splitting value set at 47.5.

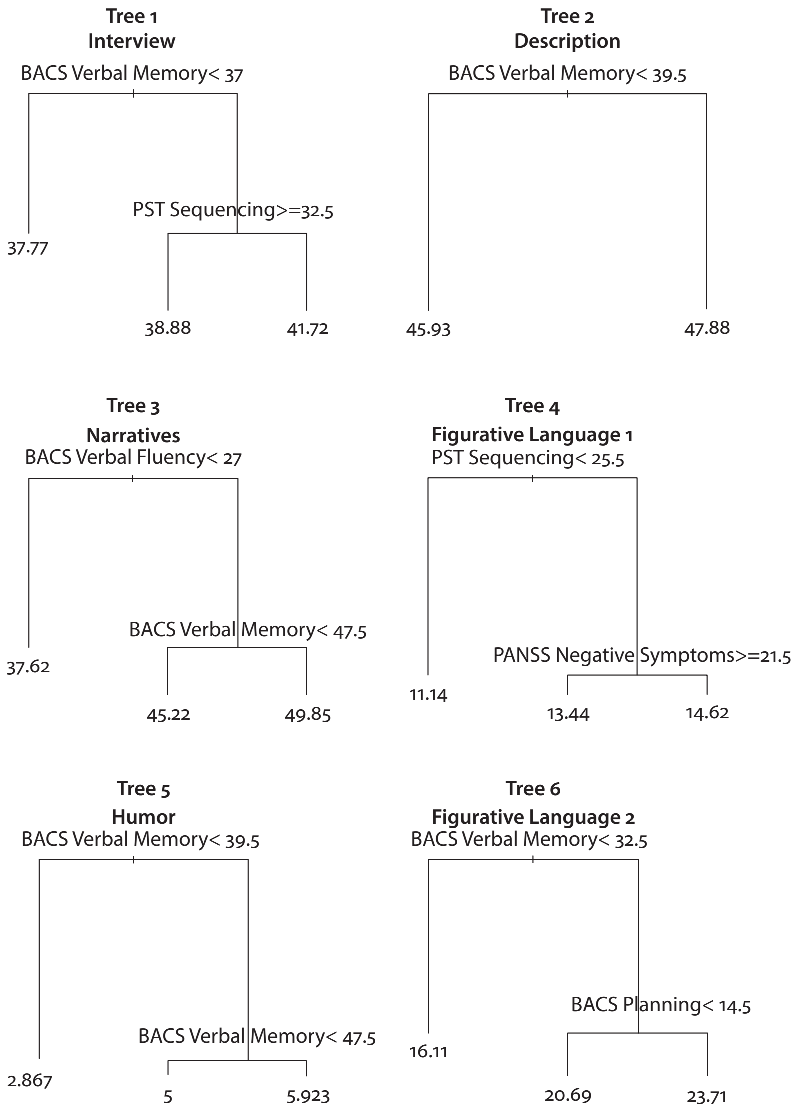


Figure 1. Regression Trees derived for each APACS task

Trees show relevant predictors for each pragmatic task, considering 11 possible variables, including psychopathological features (measured by PANSS Positive, Negative and General subscales), cognitive performance (all BACS subtests) and social cognition abilities (as evaluated through the Brüne PST Sequencing and Questionnaire scores). Each node shows a logical test and indicates the selected splitting values of the predictor. If the logical test is true (e.g. Test A score is <12), you go left in the branch, while if the test is false (e.g. Test A score is >12), you go right. The numbers at the end of the branches (bottom of the plot) indicate the predicted scores of the APACS tasks.

Tree 4 shows that Figurative Language 1 score is best predicted by PST Sequencing Score and PANSS Negative subscale. In details, from the plot, we see that if the PST Sequencing Score is <25.5 (first logical test question), we obtain a direct prediction of Figurative Language 1 score, while if the PST Sequencing Score is >25.5 we need to take into account also PANSS Negative subscale to best predict Figurative Language 1 score.

Concerning Humor interpretation, Tree 5 reveals a predictive effect of BACS Verbal Memory subtest. The first node identified a splitting value of 39.5 with a direct prediction of APACS Humor task in case of a BACS Verbal Memory score <39.5, while for higher scores a second predicting value still in BACS Verbal Memory is recognized by the Model.

Finally, for Figurative Language 2, Tree 6 suggests that the best prediction is made when considering BACS Verbal Memory and Planning subtests. The first node of tree identifies the splitting value of 32.5 for Verbal Memory. If the logical test is not true, i.e. for Verbal Memory scores >32.5, also Planning needs to be taken into account to best predict Figurative Language 2 performance.

4. Discussion

This study aimed to analyze the interplay between pragmatic abilities and both the cognitive and socio-cognitive profile in schizophrenia. We selected a sample of clinically stabilized patients with a good response to antipsychotic treatment and thus more homogeneous in terms of psychopathology, in order to limit the influence of acute phase symptomatology. Pragmatic abilities were evaluated by means of APACS (Arcara & Bambini 2016), a novel test that incorporates classic pragmatic tasks, from discourse production to the comprehension of non-literal meaning, which proved to be a suitable tool, able to detect specific communicative deficit in patients with schizophrenia compared to healthy controls (Bosia et al. 2015).

In investigating the relationship between pragmatic abilities and cognition, evaluated with the BACS, we found significant correlations between different pragmatic tasks, namely Narratives, Figurative Language 2, and Humor, and the BACS subtests assessing Verbal Memory and Verbal Fluency, and to a lesser extent Processing Speed. In details, Verbal Memory, a measure of verbal short term memory, significantly correlated with Narratives, Humor, and Figurative Language 2, all of which are tasks requiring storage and retrieval of given information. Verbal Fluency, a measure of executive functions interplaying with language, correlated with Narratives and Humor, in line with previous evidence showing that executive functioning largely contributes to a wide range of non-literal language interpretation (Sponheim et al. 2003; Schettino et al. 2010). Finally, the BACS Symbol Coding Task, a measure of Processing Speed that involves the integration of multiple component operations and relies mostly on effective connectivity among distributed brain networks rather than specific subprocesses (Dickinson et al. 2007), correlated with Humor, a complex task requiring the ability to infer non-literal meanings. Unlike previous studies (Schettino et al. 2010; Kiang et al. 2007), we did not find, after Bonferroni correction, any correlation between Working Memory performance and pragmatic abilities, suggesting that the relationship between Working Memory and pragmatics may not be specific, but rather related to global complexity of the task per se and captured by more general abilities such as executive functions. Further evidence comes from studies on the pragmatic phenomenon of scalar implicature in the healthy population, reporting no effect of working memory on pragmatic processing (Janssen et al. 2014; Heyman & Schaeken 2015).

Concerning ToM, regarded as one of the most relevant socio-cognitive domain of impairment in schizophrenia, we observed significant correlations only between Figurative Language 1 and PST Sequencing Score and Total Score. The absence of any significant correlations between pragmatic abilities and the PST Questionnaire Score, a measure of verbal cognitive ToM, suggests that non-verbal ToM, as assessed by the PST Sequencing Task, is more directly involved in pragmatics, especially in figurative language interpretation. Overall, considering both cognitive and socio-cognitive abilities, significant correlations were observed only for pragmatic tasks assessing comprehension, while none of the cognitive measures correlated with pragmatic production. This can be explained by the fact that production tasks capture speech disturbances, such as tangential discourse or alogia, which may be more related to specific positive and negative symptoms, rather than to cognitive domains, and may be more evident in acute patients.

The role of both cognition and social cognition in pragmatic performance was further explored by means of Regression Tree Models, also taking into account the psychopathological dimension. The Regression Trees allowed to identify the best predictors for each pragmatic domain, as assessed by APACS tasks. Results were mainly in line with the correlation analysis, showing significant effects of Verbal Memory, Verbal Fluency and non-verbal ToM, but they also pointed out an influence of Planning, a subcomponent of Executive Functions, and negative psychopathology, measured by the PANSS Negative subscale. In details, the aspects of discourse evaluated through the Interview were best predicted by Verbal Memory and, only for higher Verbal Memory scores, an effect of ToM PST Sequencing Task was also observed, while, for Description, Verbal Memory was the only significant predictor. For Narratives, the best predictor was Verbal Fluency, with also an effect of Verbal Memory for higher scores. Figurative Language 1 was best predicted by

ToM PST Sequencing Task. In the case of Humor, the performance was influenced only by Verbal Memory, with two identified splitting values. Finally, Figurative Language 2 was best predicted by Verbal Memory, with a further effect also of Planning.

Providing new evidence to the debate over the role of cognitive decline that spans throughout the literature on schizophrenia and language in general, our findings indicate that both cognition and social cognition play a role in determining the pragmatic profile. However, cognition and social cognition do not overlap with pragmatic abilities, but rather they are intertwined with specific pragmatic tasks. In other words, these results, although preliminary, do not support the hypothesis of a global effect of cognition nor of social cognition on pragmatic competence, suggesting instead a more specific interplay between single aspects of the communicative abilities and the neuropsychological profile. Among the cognitive functions measured here, only verbal short term memory and executive functions (as assessed by Verbal Memory and Verbal Fluency, respectively) seem to represent an important substrate of pragmatics as a whole, as, when impaired, they significantly limit the performance in different pragmatic tasks, yet they are not sufficient to explain the pragmatic profile. When we consider specific pragmatic tasks, we observe some variation, due to the nature of the linguistic process but also to the way in which the task is implemented: for instance, planning might become important when metalinguistic explanation is required for figurative expressions.

The interplay between pragmatics and social cognition is even more intricate, with a direct correlation visible only in the case of Figurative Language 1 but not for instance in Humor and Narratives tasks. If on the one hand theoretical pragmatics has strongly emphasized the link between pragmatics and ToM in interpreting context and the speaker's meaning (Sperber & Wilson 2002), on the other hand these results are not surprising when we consider that, neuropsychologically, ToM in schizophrenia is likely to be in turn mediated by cognitive factors (Barbato et al. 2013). To this respect, further development of this study should include, in addition to a larger sample of patients, the analysis of the indirect effects of cognition on pragmatic behavior, through a mediation model including ToM, in line with recent approach to functioning in schizophrenia (Barbato et al. 2013).

Taken together, our data open new perspectives to consider the debate over the cognitive substrate of pragmatic abilities. While we confirmed the important role of executive functions, we found no evidence supporting the hypothesis that ToM can explain pragmatic behavior globally and over and above general cognition. Also, from the theoretical point of view, our findings suggest that social cognition and pragmatics should be regarded as separate constructs.

Extending the discussion to other linguistic domains, our data can contribute to the discussion on the relation between language and cognitive functions. While most study showed an effect of cognitive deficit (especially working memory abilities) on the sentence processing (e.g., Condray et al. 1996; Bagner et al. 2003), there is evidence of the independence of syntax, as defined in the formal linguistic tradition (Moro 2013), from working memory and psychopathological features, as showed in a recent study from our group (Moro et al. 2015). Combining evidence on syntax and pragmatics can thus pave the way to a better understanding of the role of cognition in determining the patient's linguistic and communicative profile.

From the clinical point of view, a full consideration of cognitive, socio-cognitive, and communicative abilities might boost research on functional disabilities. Identifying predictors of daily functioning is indeed a focus of research in schizophrenia, and so far the best power has been obtained through models taking into account both cognition and social cognition, with the latter mediating the effect of the former on functional outcome, i.e. functioning in daily living. To increase the predictive power and optimize treatments, additional factors with possible mediator and moderator effects should be considered. In this view, pragmatics seems as a major candidate worth of further investigations. A comprehensive and ecologically valid assessment of pragmatic abilities could have clinical translational relevance, both as a target to develop new rehabilitation programs and as a measure of treatment outcome.

Authors contribution

Designing of the pragmatic assessment test: Valentina Bambini, Giorgio Arcara; Collection of clinical and neuropsychological data: Margherita Bechi, Marta Bosia, Mariachiara Buonocore; Data analysis: Giorgio Arcara; Writing of the manuscript: Marta Bosia, Valentina Bambini; Clinical and linguistic supervision: Roberto Cavallaro, Andrea Moro.

Acknowledgement

Valentina Bambini and Andrea Moro are partially supported by the Italian PRIN project 'I meccanismi neurocognitivi alla base delle interazioni sociali' (MIUR 2010YJ2NYW_001). This work was also partially supported by Regione Toscana under the framework of the project "Assessing Pragmatic Abilities and Cognitive Substrates" (Bando Salute 2009; Grant number: 19), awarded to Valentina Bambini while affiliated to Scuola Normale Superiore of Pisa.

References

Amanzio, M., Geminiani, G., Leotta, D. & Cappa, S. 2008. Metaphor comprehension in Alzheimer's disease: Novelty matters. *Brain and Language* 107: 1–10. doi:10.1016/j.bandl.2007.08.003

Anselmetti, S., Poletti, S., Ermoli, E., Bechi, M., Cappa, S., Venneri, A., Smeraldi, E. & Cavallaro, R. 2008. The brief assessment of cognition in schizophrenia. Normative data for the Italian population. *Neurological Sciences: Official Journal of the Italian Neurological Society and of the Italian Society of Clinical Neurophysiology* 29(2): 85–92. doi:10.1007/s10072-008-0866-9

Arcara G. & Bambini, V. 2016. A test for the Assessment of Pragmatic Abilities and Cognitive Substrates (APACS): Normative data and psychometric properties. Frontiers in Psychology 7:70. doi:10.3389/fpsyg.2016.00070

Baayen, R.H. 2008. *Analyzing Linguistic Data: A Practical Introduction to Statistics Using R*. Cambridge: CUP. doi:10.1017/CBO9780511801686

Bagner, D.M., Melinder, M.R. & Barch, D.M. 2003. Language comprehension and working memory language comprehension and working memory deficits in patients with schizophrenia. *Schizophrenia Research* 60(2–3): 299–309. doi:10.1016/S0920-9964(02)00280-3

Bambini, V., Gentili, C., Ricciardi, E., Bertinetto, P.M. & Pietrini, P. 2011. Decomposing metaphor processing at the neurocognitive and neural level through Functional Magnetic Resonance Imaging. *Brain Research Bulletin* 86: 203–216. doi:10.1016/j.brainresbull.2011.07.015

Bambini, V. & Bara, B.G. 2012. Neuropragmatics. In *Handbook of Pragmatics*, J.-O. Östman & J. Verschueren (eds), 1–22. Amsterdam: John Benjamins. doi:10.1075/hop.16.neu2

Bambini, V., Ghio, M., Moro, A., Schumacher, P.B. 2013. Differentiating among pragmatic uses of words through timed sensicality judgments. *Frontiers in Psychology* 4: 938. doi:10.3389/fpsyg.2013.00938

Barbato, M., Liu, L., Penn, D.L., Keefe, R.S., Perkins, D.O., Woods, S.W.& Addington J. 2013. Social cognition as a mediator between neurocognition and functional outcome in individuals at clinical high risk for psychosis. *Schizophrenia Research* 150(2–3): 542–546. doi:10.1016/j.schres.2013.08.015

Bechi, M., Bosia, M., Spangaro, M., Buonocore, M., Cocchi, F., Pigoni, A., Piantanida, M., Guglielmino, C., Bianchi, L., Smeraldi, E. & Cavallaro, R. 2015. Combined social cognitive and neurocognitive rehabilitation strategies in schizophrenia: Neuropsychological and psychopathological influences on Theory of Mind improvement. *Psychological Medicine* 11: 1–11.

Bosia, M., Anselmetti, S., Pirovano, A., Ermoli, E., Marino, E., Bramanti, P., Smeraldi, E. & Cavallaro, R. 2010. HTTLPR functional polymorphism in schizophrenia: Executive functions vs sustained attention dissociation. *Progress in Neuro-psychopharmacology & Biological Psychiatry* 34: 81–5. doi:10.1016/j.pnpbp.2009.10.001

Bosia, M., Anselmetti, S., Bechi, M., Lorenzi, C., Pirovano, A., Cocchi, F., Buonocore, M., Bramanti, P., Smeraldi, E. & Cavallaro, R. 2011. Effect of 5-HT1A-receptor functional polymorphism on Theory of Mind performances in schizophrenia. *Psychiatry Reseach* 188(2): 187–190. doi:10.1016/j.psychres.2010.11.014

Bosia, M., Riccaboni, R., Poletti, S. 2012. Neurofunctional correlates of Theory of Mind deficits in schizophrenia. *Current Topics In Medicinal Chemistry* 12: 2284–2302. doi:10.2174/156802612805289917

Bosia, M., Zanoletti, A., Spangaro, M., Buonocore, M., Bechi, M., Cocchi, F., Pirovano, A., Lorenzi, C., Bramanti, P., Smeraldi, E. & Cavallaro, R. 2014. Factors affecting cognitive remediation response in schizophrenia: The role of COMT gene and antipsychotic treatment. *Psychiatry Research* 217(1–2): 9–14. doi:10.1016/j.psychres.2014.02.015

Bosia, M., Arcara, G., Moro, A., Cavallaro, R. & Bambini, V. 2015. Pragmatic abilities across symptoms dimensions in schizophrenia. *Studi Italiani di Linguistica Teorica e Applicata* XLIV(3), 473–485.

Breiman, L., Friedman, J.H., Olshen, R.A. & Stone, C.I.1984. *Classification and Regression Trees*. Belmont CA: Wadsworth.

Brothers, L. 1990. The social brain: A project for integrating primate behavior and neurophysiology in a new domain. *Concepts in Neuroscience* 1: 27–51.

Brownell, H.H., Michel, D., Powelson, J. & Gardner, H. 1983. Surprise but not coherence: Sensitivity to verbal humor in right-hemisphere patients. *Brain and Language* 18: 20–27. doi:10.1016/0093-934X(83)90002-0

Brüne, M. 2003a. Social cognition and behavior in schizophrenia. In *The Social Brain. Evolution and Pathology*, M. Brüne, H. Ribbert & W. Schiefenhovel (eds), 277–313. Chichester: Wiley and Sons. doi:10.1002/0470867221.ch13

Brüne, M. 2003b. Theory of Mind and role of IQ in chronic disorganized schizophrenia. *Schizophrenia Research* 60: 57–64. doi:10.1016/S0920-9964(02)00162-7

Brüne, M. & Bodenstein L. 2005. Proverb comprehension reconsidered: 'Theory of Mind' and the pragmatic use of language in schizophrenia. *Schizophr Res*. 75(2–3): 233–9. doi:10.1016/j.schres.2004.11.006

Champagne-Lavau, M. & Stip, E. 2010. Pragmatic and executive dysfunction in schizophrenia. *Journal of Neurolinguistics* 23(3): 285–296. doi:10.1016/j.jneuroling.2009.08.009

Colle, L., Angeleri, R., Vallana, M., Sacco, K., Bara, B.G. & Bosco, F.M. 2013. Understanding the communicative impairments in schizophrenia: A preliminary study. *Journal of Communication Disorders* 46: 294–308. doi:10.1016/j.jcomdis.2013.01.003

Condray, R., Steinhauer, S.R., Van Kammen, D.P. & Kasparek, A. 1996. Working memory capacity predicts language comprehension in schizophrenic patients. *Schizophrenia Research* 20(1–2): 1–13. doi:10.1016/0920-9964(95)00061-5

Covington, M.A., He, C., Brown, C., Naçi, L., McClain, J.T., Fjordbak, B.S., Semple, J. & Brown, J. 2005. Schizophrenia and the structure of language: The linguist's view. *Schizophrenia Research* 77(1): 85–98. doi:10.1016/j.schres.2005.01.016

DeLisi, L.E. 2001. Speech disorder in schizophrenia: Review of the literature and exploration of its relation to the uniquely human capacity for language. *Schizophrenia Bulletin* 27(3): 481–96. doi:10.1093/oxfordjournals.schbul.a006889

Dickinson, D., Ramsey, M.E. & Gold, J.M. 2007. Overlooking the obvious: A meta-analytic comparison of digit symbol coding tasks and other neurocognitive measures in schizophrenia. *Archives of General Psychiatry* 64(5): 532–42. doi:10.1001/archpsyc.64.5.532

Ferstl, E.C., Walther, K., Guthke, T. & Von Cramon, D.Y. 2005. Assessment of story comprehension deficits after brain damage. *Journal Of Clinical and Experimental Neuropsychology* 27: 367–384. doi:10.1080/13803390490515784

Green, M.F., Kern, R.S., Braff, D.L. & Mintz, J. 2000. Neurocognitive deficits and functional outcome in schizophrenia: Are we measuring the 'right stuff'? *Schizophrenia Bulletin* 26: 119–136. doi:10.1093/oxfordjournals.schbul.a033430

Green, M.F., Kern, R.S. & Heaton, R.K. 2004. Longitudinal studies of cognition and functional outcome in schizophrenia: implications for MATRICS. *Schizophrenia Research* 72: 41–51. doi:10.1016/j.schres.2004.09.009

Guazzotti, P. & Oddera, M.F. 2006. *Il grande dizionario dei proverbi Italiani*. Bologna: Zanichelli.

Hagoort, P., Levinson, S.C. 2014. Neuropragmatics. In *The Cognitive Neurosciences*, M.S. Gazzaniga (ed.). Cambridge MA: The MIT Press.

Harrow, M., Adler, D. & Hanf, E. 1974. Abstract and concrete thinking in schizophrenia during the pre-chronic phases. *Archives General Psychiatry* 31(1): 27–33. doi:10.1001/archpsyc.1974.01760130013002

Heyman, T. & Schaeken, W. 2015. Some differences in some: Examining variability in the interpretation of scalars using latent class analysis. *Psychologica Belgica* 55(1): 1–18. doi:10.5334/pb.bc

Janssens, L., Fabry, I. & Schaeken, W. 2014. Some effects of age, task, task content and working memory on scalar implicature processing. *Psychologica Belgica* 54(4): 374–388. doi:10.5334/pb.ax

Kahn, R.S. & Keefe, R.S. 2013. Schizophrenia is a cognitive illness: Time for a change in focus. *JAMA Psychiatry* 70(10): 1107–1112. doi:10.1001/jamapsychiatry.2013.155

Kay, S.R., Fiszbein, A. & Opler, L.A. 1987. The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin* 13(2): 261–276. doi:10.1093/schbul/13.2.261

Keefe, R.S., Goldberg, T.E., Harvey, P.D., Gold, J.M., Poe, M.P. & Coughenour, L. 2004. The brief assessment of cognition in schizophrenia: Reliability, sensitivity, and comparison with a standard neurocognitive battery. *Schizophrenia Research* 68(2–3): 283–297. doi:10.1016/j.schres.2003.09.011

Kiang, M., Light, G.A., Prugh, J., Coulson, S., Braff, D.L. & Kutas, M. 2007. Neurocognitive, neurophysiological, and functional correlates of proverb interpretation abnormalities in schizophrenia. *Journal of the International Neuropsychological Society* 13: 653–63. doi:10.1017/S1355617707070816

Kuperberg, G.R. 2010. Language in schizophrenia Part 1: An Introduction. *Language and Linguistics Compass* 4(8): 576–589. doi:10.1111/j.1749-818X.2010.00216.x

Kuperberg, G. & Caplan, D. 2003. Language dysfunction in schizophrenia. In *Neuropsychiatry*, 2nd edn, R.B. Schiffer, S.M. Rao & B.S. Fogel (eds), 444–466. Philadelphia PA: Lippincott Williams and Wilkins.

Langdon, R., Davies, M. & Coltheart, M. 2002. Understanding minds and understanding communicated meanings in schizophrenia. *Mind and Language* 17: 68–104. doi:10.1111/1468-0017.00190

Lucisano, P. & Piemontese, M.E. 1988. GULPEASE: Una formula per la predizione della difficoltà dei testi in lingua Italiana. *Scuola e Città* 110–124.

Marini, A., Andreetta, S., Del Tin, S. & Carlomagno, S. 2011. A multi-level approach to the analysis of narrative language in aphasia. *Aphasiology* 25: 1372–1392. doi:10.1080/02687038.2011.584690

Moro, A. 2013. *The Equilibrium of Human Syntax: Symmetries in the Brain*. New York NY: Routledge.

Moro, A., Bambini, B., Bosia, M., Anselmetti, S., Riccaboni R., Cappa S., Smeraldi E. & Cavallaro, R. 2015. Detecting syntactic and semantic anomalies in schizophrenia. *Neuropsychologia* 79: 147–157. doi:10.1016/j.neuropsychologia.2015.10.030

Mossaheb, N., Aschauer, H.N., Stoettner, S., Schmoeger, M., Pils, N., Raab, M. & Willinger, U. 2014. Comprehension of metaphors in patients with schizophrenia-spectrum Ddsorders. *Comprehensive Psychiatry* 55: 928–937. doi:10.1016/j.comppsych.2013.12.021

Noonan, D. 2014. Language: Lost in translation. *Nature* 508(7494): S4–5. doi:10.1038/508S4a

Papagno, C., Cappa, S.F., Forelli, A., Laiacona, M., Vallar, G., Garavaglia, G. & Capitani, E. 1995. La comprensione non letterale del linguaggio: Taratura di un test di comprensione di metafore e di espressioni idiomatiche. *Archivio di Psicologia Neurologia e Psichiatria* 56(4): 402–420.

Perlini, C., Marini, A., Garzitto, M., Isola, M., Cerruti, S., Marinelli, V., Rambaldelli, G., Ferro, A., Tomelleri, L., Dusi, N., Bellani, M., Tansella, M., Fabbro, F. & Brambilla, P. 2012. Linguistic production and syntactic comprehension in schizophrenia and bipolar disorder. *Acta Psychiatrica Scandinavica* 126: 363–376. doi:10.1111/j.1600-0447.2012.01864.x

Pesciarelli, F., Gamberoni, T., Ferlazzo, F., Russo, L.L., Pedrazzi, F., Melati, E. & Cacciari, C. 2014. Is the comprehension of idiomatic sentences indeed impaired in paranoid schizophrenia ? A window into semantic processing deficits. *Frontiers in Human Neuroscience* 8: 1–14. doi:10.3389/fnhum.2014.00799

R Core Team. 2014. *R: A Language and Environment for Statistical Computing R Foundation for Statistical Computing*. Vienna: R Core Team.

Rapp, A.M., Langohr, K., Mutschler, D.E., Klingberg, S., Wild, B. & Erb, M. 2013. Isn't it ironic? Neural correlates of irony comprehension in schizophrenia. *PloS One* 8: e74224. doi:10.1371/journal.pone.0074224

Schettino, A., Lauro, L.R., Crippa, F., Anselmetti, S., Cavallaro, R. & Papagno, C. 2010. The comprehension of idiomatic expressions in schizophrenic patients. *Neuropsychologia* 48: 1032–1040. doi:10.1016/j.neuropsychologia.2009.11.030

Sperber, D. & Wilson, D. 2002. Pragmatics, modularity and mind-reading. Mind and Language 17: 3–23. doi:10.1111/1468-0017.00186

Sperber, D. & Wilson, D. 2005. Pragmatics. In *Oxford Handbook of Contemporary Philosophy*, F. Jackson & M. Smith (eds), 468–501. Oxford: OUP.

Sponheim, S.R., Surerus-Johnson, C., Leskela, J. & Dieperink, M.E. 2003. Proverb interpretation in schizophrenia: The significance of symptomatology and cognitive processes. *Schizophr Res*. 65(2–3): 117–23. doi:10.1016/S0920-9964(02)00525-X

Tabossi, P., Arduino, L. & Fanari, R. 2011. Descriptive norms for 245 Italian idiomatic expressions. *Behavior Research Methods* 43: 110–123. doi:10.3758/s13428-010-0018-z

Thoma, P., Hennecke, M., Mandok, T., Wähner, A., Brüne, M., Juckel, G. & Daum, I. 2009. Proverb comprehension impairments in schizophrenia are related to executive dysfunction. *Psychiatry Res*. 170(2–3): 132–139. doi:10.1016/j.psychres.2009.01.026

Author index

Subject index

The papers assembled in this volume aim to contribute to our understanding of the human capacity for language: the generative procedure that relates sounds and meanings via syntax. Different hypotheses about the properties of this generative procedure are under discussion, and their connection with biology is open to important cross-disciplinary work. Advances have been made in human-animal studies to differentiate human language from animal communication. Contributions from neurosciences point to the exclusive properties of the human brain for language. Studies in genetically based language impairments also contribute to the understanding of the properties of the language organ. This volume brings together contributions on theoretical and experimental investigations on the Language Faculty. It will be of interest to scholars and students investigating the properties of the biological basis of language, in terms the modeling of the language faculty, as well as the properties of language variation, language acquisition and language impairments.

ISBN 978 90 272 5718 5

9 789027 257185

John Benjamins Publishing Company