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Interfaces between language components: Bootstrapping in sensitive periods after reaching a critical mass of usage

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Conceiving the architecture of language components as modules requires not only specifying how they interact in terms of units and rules, but also how they change in the learning process. This paper specifically proposes that the progressive interactive bootstrap between language components (in a sensitive period and after a critical mass is attained) is the key factor of the expert learning and use of language. Partial evidence for this consideration are the non-linear learning curves in sequences over time that the different components exhibit. To this end, we present some evidence of changes in the lexicon, grammatical categories and inflection. Finally, we postulate that explicitly well documented learning relationships among components (in time and content) should be a central goal in the future language acquisition research.
Keywords: *Language acquisition, interfaces of language components, bootstrapping, modularity, critical mass, sensitive periods.*

Interficies entre los componentes del lenguaje: “Bootstrapping” (cambio funcional) en “períodos sensibles” después de alcanzar una “masa crítica” en el uso

Considerar como módulos a los componentes del lenguaje requiere especificar, no solo como interactúan entre ellos, según sus reglas y unidades, sino también como van cambiando en los procesos de aprendizaje. Este artículo propone que el factor clave para un aprendizaje y un uso experto del lenguaje es el bootstrapping entre dichos componentes (en un periodo sensible y después de alcanzar un nivel determinado de masa crítica). Los datos (todavía parciales) para fundamentar esta propuesta son las curvas no lineales de aprendizaje que se observan en las secuencias temporales de dichos componentes, y sus posibles relaciones. Finalmente, se postula que un objetivo central en el futuro

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de la investigación en la adquisición del lenguaje debe consistir en documentar (según tiempo y contenido) el aprendizaje teniendo en cuenta las relaciones entre los componentes.

Palabras clave: *adquisición del lenguaje, interficies entre componentes del lenguaje, bootstrapping, modularidad, masa crítica, períodos sensibles.*

1. Consequences of modularizing the language processing

The implicit requirements for a module-like organization of the language system are well known (Fodor 1983, 2000): Innate structures with no specification of their units and rules, and independent functioning with no specified interfaces. These characteristics of modularization, correlate with a scarce interest in learning, development, and individual differences. Jackendoff (2002) presented a proposal that modifies Fodor's and provides a blueprint of a structure that identifies the real need for 'module interfaces'; otherwise, the system is not realistic for natural use and processing. This former sketchy proposal has led to an improvement in the characterization of the necessary units and operations for language learning and processing, but continue without content and cut off the fast flow of diverse and complex material on the route of language processing (Levelt 1999; Cutler, 1999). Moreover, this module-like and interfaced conceptualization has not considered three points:

1. How, as we observe in children, these units and their rules must be simplified in order to be integrated into the initial learning phases of the language systems (Karmiloff &Karmiloff-Smith, 2001).
2. How they change in order to cope with the complex series of operations that the language end state requires (Levelt 1999; Cutler 1999).
3. How the modules (plus the required interfaces) approach and execute the plans or transporting information for comprehension and production into real sentences[1].

The viewpoint that we present here is that the modular approach has not been successful in ruling out the more parsimonious conception of language as a multifaceted developing system. We argue that the strong and innate modular proposal has many drawbacks, (for example, the undefined interfaces), and leads to an extreme simplification in terms of structure and processing (Bates & Goodman, 1999; Tomassello, 2003; McWhinney, 2004; Serra, 2013).

[1] As an indirect effect this modular view has had scientific as well as sociological consequences: research groups (and also practitioners) are concerned only with their own module (or sub-module), ignoring the requirements for their inputs and outputs and their role in the learning and functioning of the language system. The isolation of the modules is not only theoretical but also research-driven, academic and applied. This influence has been longstanding in research and applied work.

2. Models with silent language modules

There are many unanswered questions about modularity: How do the encapsulated modules relate to each other? Do they have straightforward relationships? Do they have a 'lingua franca' code on their own[2]? Do they have 'translators'? Are there different 'degrees' of modularity? Do they change over time and upon learning? Do they need a 'central planner'? None of these questions is generally addressed.

Even the theorists inspired by Fodor, like Pinker (1994; 2002), that consider language as a collection of independent modules, accept structures that share some of their architecture. But they do not specify the particularities for each language component (phonology, etc.). They also add a 'central processor' as an organizer to fulfill the, otherwise, widely criticized 'general purpose' of the system. Jakendoff (2002, pp. 196-200) points out that the language structure comprises a number of independent combinatorial systems, which are aligned with each other by means of a collection of interface systems. Each system is characterized by its own set of primitive and combinatorial principles with the required links and the corresponding constraints. Interfaces implement "partial homologies" (not developed in the proposal) between the different structures operating in the processing.

It is obvious that a well-functioning system has to be free from interferences and work fast and smoothly. The modular claim for 'non-interference' and the reality of 'dissociations' is well-formulated but should be reconsidered and clarified. Nevertheless, these two characteristics can be conceived also as the result of experience rather than of a predetermined initial state. Modularization, in this developmental sense, can be pictured as a result of the well-practiced, overlearned, in an organized expert system (Karmiloff 1998). We can adduce here that in many conditions of learning and use, the data do not fit in with modularity - as we see in language diversity and differences, bilingualism, language difficulties seen in hearing loss, neural diseases or just a disharmonic learning organization, such as in the case of (Specific) Language Impairment (Serra 2002; 2013). Below we will add the concept of non-linear learning curves, as well as data relating to these difficulties. Those conditions ask for new contributions to the learning of language that are not compatible with a modular architecture and requires a specific role in the projected interfaces: Bootstrapping between components.

3. Lexis and syntax related: Data for a starting point in their bootstrapping

A clear example of the lacking characterization of the interfaces is that of the relationship between phonology and phonetics. It is widely accepted that phonology

[2] For example, the 'language of thought' postulated by Fodor (Fodor 2002).

is a cognitive representation of the units and rules that govern the physical categorization and realization of vocal sounds transformed into sentences, words, syllables and phonemes (Serra, 2013). How is this transduction conceived and implemented? An unspecific answer is that the interface 'sees' different parts of the auditory signal (for example, it is 'blind' to the pitch but sensitive to the formant transitions in order to identify phonemes). Conversely, the motor output commands will only deal with certain aspects of signal (not the word boundaries, for instance).

In order to move forward with such a proposal, it is crucial to have data corresponding to the learning patterns of two (or more) components, both in terms of content and how, for instance here, lexis and syntax relate to each other in their time course. In front of related data among components the three following assumptions have to be made:

1. A simultaneous presence of components, considering the possible interactions among them, (as is the case, for example, of early the voluntary acts, in which 'voluntary blowing' produces vocal gestures, or later, when intention and memory relate in order to act with an object either naturally or symbolically).
2. A temporal pattern of successive modifications, that is, when the results of ability A precede and produces a change in ability B[3]. These are changes that shift from a simple overlap, to a progressive control of one component over the other, producing a behavioral change with specific consequences in the interaction itself.
3. And lastly, as a result of the interaction, the learning curve of one (or both) ability changes its pattern: for example, it moves from a slow linear shape to a faster non-monotonous increment.

It is in this change where we must determine whether there is evidence that, after the interaction of two abilities, a novel procedure sets up a new form of producing the old units in a renewed system.

This non-monotonic relationship has a very important role in development. Initially, part of the system learns specific and repetitive activities during a sensitive period, resulting in an implicit specialized learning and use. Then, once a critical mass of knowledge and practice has been attained, a very common and economical procedure is to reorganize those units (using the same form) and rules to include them in a more complex ('expert') system. For example, word-nouns and word-verbs end up behaving in a different way as concepts, arguments and grammatical roles. Here, a 'monotonous' learning (for the lexicon) reaches a threshold beyond which the other system (grammar) carries out new behaviors hitherto unseen[4].

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[3] See the notion of "coevolution" which is very relevant in this context (Deacon 1977).
[4] There is evidence of these non-monotonous changes in other fields. For example, see *The evolutionary game theory* (Ferrer & Solé 2003). These authors show changes in the 'lexicon' following a simple reorganizational adaptation among the interaction of 'complex systems' (talkers). This reorganization would be the best option

It is important to point out that these changes are time/age independent. Changes have their own rhythm for developing interactions between cognitive abilities and language components (systems) (Dixon & Marchmann, 2007). This is especially clear in non-normal language learning where there are different calendars and relationships (bootstraps). For example, between the lexicon and the grammar in deaf, Williams and Down children. The necessary critical mass for a bootstrapped grammatical spurt[5] is specific to every circumstance, specific to the circumscribed area that the language system bounds. In other words, failures can only be behaviorally detected in particular constructions, although the cognitive causes of them can be varied and they arise in different time relations.

4. Conditions (sensitive period and critical mass) and interactions (bootstrapping) in non-linear learning

What is conceptualized here is very simple and common sense. Language is the result of relating many abilities and modes of representation that are organized in the communication process. Naturally, learning responds to the corresponding human-like demands of usages in which the novice children or the adult experts adapt, communicating meanings both in comprehension as well as in production.

It is worth referring again to the examples of voluntary adaptive activities, like the very initial intentional expirations with vocal muscles movements in sound production, and the action selection. Those abilities (intention and selection) are the crucial starting point in human communication and are practiced thousands of times during these 'sensitive period' months. These vocal gestures and selective attention are present at the onset of performative communication (attention seeking, object attainment), and increase their use in different contexts and functions, including representative operations (memory and abstraction when comparing, or solving problems). Therefore, once a critical mass of practice (coached and modeled) in increasing complex demands is reached, and in front of the faster and functionally adapted responses, it is reasonable to hypothesize that the usage is reorganized into a more efficient system (bootstrap). The same form/unit has become an item with new capabilities when commanded by a new super/sub-system. This expert and new re-usage makes complexity out of simplicity.

In developmental terms we can easily track how children learn to control vocal gestures and how they implement them as social sounds, word-songs, word-symbols, and finally words as items of a lexicon inserted in a grammar. This inner development of each component (lexicon here) is also of interest. Those functional

for the system in order to maximize the relevant information to be conveyed and to minimize ambiguity with a lower cost in terms of memory and planning.

[5] Or an inhibition in case of deficit as will be mentioned later on.

changes reveal re-organizations when processing identical 'form units' (same phonological words, for example). A good example of this change is the 'lexical spurt', a phenomenon that many children exhibit, with a clear move to a non-monotonous learning curve of word production after attaining a critical mass of + /- 80 words (Serra *et al.*, 2013)[6].

The challenge for this constructive proposal is to gather enough evidence and prove that those old items become accessible and are controlled by a new functional level of representation and action. But these findings, like the reorganization of sounds bootstrapped into the lexicon, are not sufficient for backing this proposal, and should be investigated among the critical language components, namely morphology and syntax.

Focusing in the reorganization of words integrating grammatical classes and inflection, we found in a longitudinal study that, between the 300 and 400 word types in the lexicon there is a non-monotonous and successive change (Serra & Sanz, 2004). This rate of grammatical vocabulary growth is not monotonous anymore and correlates with (1) a subsequent acquisition of the grammatical inflection and (2) an increase in sentence complexity. These data point to that *after* a significant non-monotonous increment of *usage* of words types (from 250 to 300) there is another change: the number of lexical grammatical words increases from 17 at the vocabulary level of 300 types to a 22.4 at 400[7]. In those data there are important individual differences, however and, significantly, they are not related to the age of the children but to the lexical corpus and usage

This relationship has been found in other studies (not longitudinal as our case, but transversal) and for different languages. These data are just a hint that gives initial support to the outline of relationships (bootstrapping in interfaces) hypothesized in this paper. The transversal data upon which we sustain this interactive hypothesis consist of CDI studies (English[8], Italian, Spanish and Catalan[9]). We are not aware of other longitudinal studies that address induced non-monotonous increments.

[6] 'Lexical spurt' is a learning change from a slow, associative-like strategy (one word one referent; only one word in a simultaneous early bilingual learning) towards symbolic fast (decontextualized in use) and linguistic encompassed production (semantic contrasts and roles and grammatical classes). This change occurs between 50 and 80 words (Serra et al. 2000 / 2013).

[7] Those data correspond to a longitudinal study of nine children from 1 to 4 year olds (Serra et al. 2000) of the Serra – Sole Corpus (see CHILDES), The results presented here need clarification for future research: Token usage and, specially, corpus of types are in need of a clarification: In order to better support the bootstrap and reorganization hypothesis we should group the items for functions (determiners in the nominal group and prepositions in PP or Adjunts) and check their inclusion on the changes over time.

[8] Also worth highlighting is the correlation between the lexicon at 20 months and grammar at 28 and the lack of such correlation in grammar itself at 20 and 28 (Bates & Goodman, 2001).

[9] The Catalan data shown in Serrat, 1997, are also identical to that found in Bates, Dale &Thal, 1995, and Marchmann & Bates, 1994, regarding the grammatical lexical growth and the emergence of verbal inflection (strict criteria) between 400 and 600 words.

The relationships found in these data deserve an empirical validation. They are in line with a causal assumption (Morton & Frith, 2002) of action explanation. Here we do not face a simple correlational relationship (superposition of progress), but non-monotonous changes subsequent to it: first, the lexicon growth up to a critical mass of 300 words, and then an induced ('co-evolved') grammatical change, re-organized for a use with increasing complexity in syntax and inflection.

In order to sustain this constructivist approach we must rule out that the relationship is not a complex maturational effect or a result of different strategies of learning. It is necessary to own data for closely analyzing structures, timing and frequency of usages of the two subcomponents under scrutiny (here the lexicon and grammar). We should also bear in mind that the causal relationship will receive more support if the data is age independent. It will also be very profitable if characterized pathologies, such as Williams or Down syndromes, exhibit different dissociations related to their own profiles of cognitive abilities. In the case of the evasive Language Impairment (Serra, 2002), the lack of this causal relationship is of additional interest. It may reveal an opposite relationship. In this case, instead of a re-organization, an 'inhibition' (deficit) due to the absence of the causal bootstrapping learning proposed in here: An interference in 'natural learning' because the unsuited relationship among the lexicon, phonological and semantic systems, or between other cognitive abilities in development, leading to a disharmonic result, in other words, an impairment (Serra, 2002).

5. Recapitulation and final proposal

The conceptualization that language has a necessary module-like organization, which some people consider innate, contains an important flaw that involves the characterization of the required interfaces among the modules they propose. No clear structural or processing units and rules are established for a fluent 'reading' and 'transformation' of the sound, lexical items and sentence meaning into an end product that is behaviorally observable.

A constructivist perspective assumes that language is a compounded system in which we move from natural, animal-like learning to expert, human-like representation and processing of new elements. In order to explain this novelty and the fast, relatively error free and creative learning that takes place, we point to three empirical notions:

1. The special learning of the 'sensitive periods'.
2. A 'critical mass' expert-like usage (see note 6).
3. A 'bootstrapping' modifying or creating a new organization over time that provides new functions and rules to the former units, facilitating those new ones that any adult talker has.

The data that have been adduced, although scarce and not yet well-defined, fulfils the requirements of a causal modeling (Morton, 2004) and is sufficient to encourage a change in child language research. In addition to the developmental data of each component, we should concentrate also on gathering well-timed and structurally refined data of two components simultaneously in order to identify their relationship and their probable causal implication in the course of normal learning, and also in learning under special circumstances.

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