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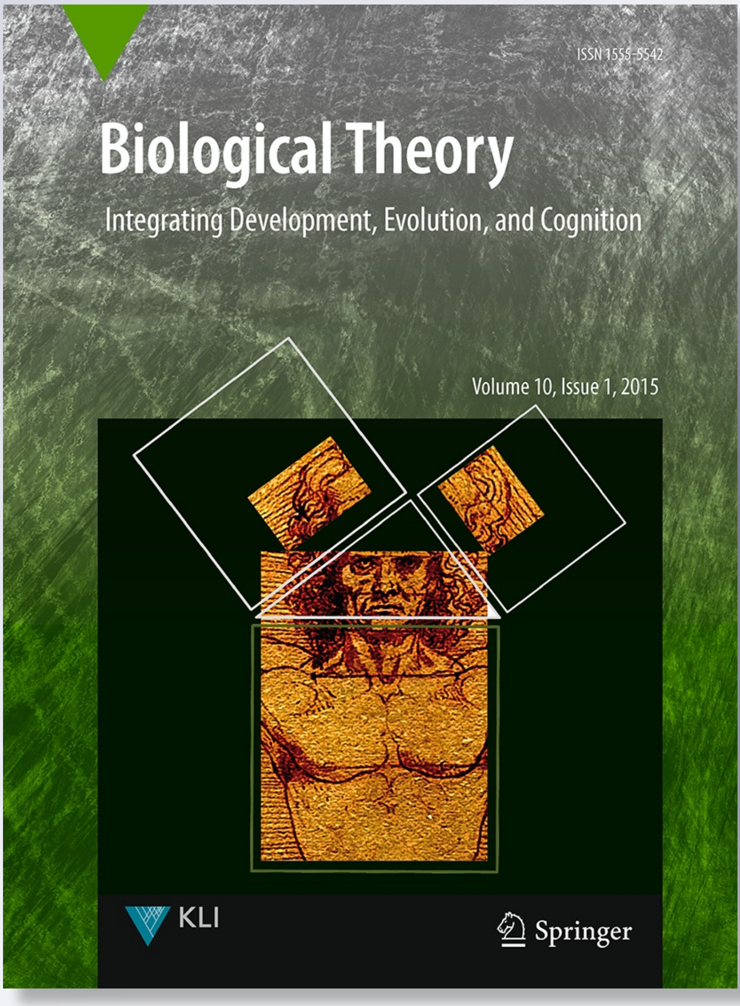

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LONG ARTICLE

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Abstract Recently, there has been a growing interest, both within theoretical biology and the philosophy of biology, in the possibility and desirability of a theory of development. Among the many issues raised within this debate, the questions of the spatial and temporal boundaries of development have received particular attention. In this article, noting that so far the discussion has mostly centered on the processes of morphogenesis and organogenesis, we argue that an important missing element in the equation, namely the development of language and cognition in general, may play an important role in settling the issue of temporal boundaries. After examining the idea that the development of language, cognition, and action are bona fide biological processes, we explore the consequences for a general theory of development of taking them into consideration.

Keywords Boundaries of development · Cognition · Language · Theory of development

Development does not "know" where it is going from the start… There is no set end-state other than the end of life itself.
—Thelen and Smith (1994)

La vie est l'ensemble de fonctions qui résistent à la mort. (Life is the collection of functions that resist death.)
—Bichat (1822)

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In 2011, the journal *Biological Theory* published a thematic issue on the boundaries of development that aimed to seek some preliminary answers to the questions, "What are the temporal boundaries of development?" and "What are its spatial boundaries?" These questions were presented by the guest editors of the issue as critical landmarks in the process of constructing a coherent and robust theory of development given the fact that, while no one can deny that there is a biological theory of evolution, it stands to reason that one can say the same about a biological theory of development (Minelli 2011a, b, 2013; Pradeu et al. 2011). To the extent that clear time boundaries for developmental processes can be determined—which is a debated matter (see Nuño de la Rosa 2010, for an overview of the issues involved)—the first question is aimed at solving the problem of where a developmental process starts and ends. The second question could be recast as what is it that develops when a developmental process is in action. Both issues stem from the dissatisfaction among some biologists and philosophers generated by the traditional idea that development is the process that starts with a fertilized egg and ends when the organism reaches adulthood/sexual maturity. As argued by Minelli (2011b, 2013), there are several reasons to consider this conception of development as highly problematic, a number of which won't concern us here or that we shall touch only in passing, ranging from the notion of "organism" or "biological individual" to the too constrained idea that development always starts with a fertilized egg. It nonetheless appears that for a growing number of biologists and philosophers who have put development at the center of their theorizing, the most vexing one is the explicit assumption that development actually ends at some point in time. For those scholars who, in the wake of Lewontin's (1983, 2000, 2001) original work, have come to see in development a complex array of continuously interacting factors, both internal and external (to use an already outdated dichotomy), developmental processes are more aptly seen as processes of "co-development" or "co-construction" that either end when the organism dies or even could transcend the life cycle of a single organism and span across several generations (Griffiths and Gray 1994, 2001; Oyama 2000a, b; Oyama et al. 2001; Minelli 2003, 2011b, 2013; West-Eberhard 2003; Gilbert and Epel 2009; Gilbert 2011, 2014). This view, which may be seen as the perpetuation of a long tradition dating back to Xavier Bichat or perhaps earlier, and was held, for example, by von Baer (1864; dated 1834),[1] is nonetheless often perceived as problematic when confronted with the task of providing a coherent definition of "organism." Indeed, even if von Baer considered development to be a sufficient—actually, definitional—property for something to be considered an organism,[2] this position may nowadays be qualified as circular or self-contradictory, especially in such radical views as Developmental Systems Theory (DST), where von Baer's "organic bodies" plus their environment are assumed to constitute the whole developing organism. DST has been criticized precisely for maintaining such a promiscuous conception of the organism–environment relationship (see, e.g., Sterelny et al. 1996). Although a number of proposals exist to save the process view from the perils of DST (e.g., Griesemer 2000a), some authors consider that it is better to abandon it altogether in favor of what is often known as the "constitutive view" (Nuño de la Rosa 2010). Very sketchily, the main difference between the process and constitutive views may be located at a point concerning which of the two boundary questions is assumed to be conceptually prior and auxiliary to providing an answer for the other. In the process view, the time boundary of development is assumed to be defined by the whole life cycle, and, accordingly, "organism" is equated to "developmental system." On the constitutive view, however, development is understood as the process of becoming an organism, and, therefore, the point in time where all the potentialities of the process become actual defines the end of development and the beginning of self-maintenance (see again Nuño de la Rosa 2010 for details).

The process view of development has not gone unchallenged, then. A number of articles in the aforementioned issue of *Biological Theory* try to refute on different grounds the idea that development has no temporal boundaries (Laplane 2011; Morange 2011; Nicoglou 2011; Théry 2011; Vervoort 2011), or propose a much more constrained definition of the spatial boundaries of the developing entity (Pradeu 2011). So the debate is open, and in this article we would like to contribute our grain of sand.

A common denominator of the articles just cited, and of many other theoretical reflections on the boundaries of development, is the explicit or implicit exclusion of the development of cognition and action (an expression to which we will attach a specific meaning in the next section) from the definition of development. Our main goal is to argue that cognitive development *is* an integral part of development, and, hence, that it cannot be left out of the equation when the question of the boundaries of development is examined. We will use language acquisition in humans as our main source of examples, although, we contend, our considerations would apply to other skills and to nonhuman animals equally well. In the concluding section we explore what consequences our considerations about language might have for the question of developmental boundaries, and whether these may have any impact on the issue of the process versus the constitutive view.

Cognition and Action: Do They Develop?

We begin this section by explaining what we mean exactly by "cognition and action." We could also have used the less cumbersome expression "behavior," but we'd rather not given the negative connotations it has for us and many other cognitive scientists. For us, "behavior" just refers to the more or less directly observable manifestations of the neurobiological processes that subserve or cause a behavior (Balari and Lorenzo 2013). Therefore, speaking just of "behaviors" for us is tantamount to ignoring the chain of complex internal processes that most of the time resists direct empirical observation. To be sure, many cognitive processes such as understanding the English sentence "she saw a red apple," or the simple fact of actually seeing a red apple, do not necessarily elicit any observable behavior, and would therefore not fall in any possible definition of "behavior," while certainly being bona fide cognitive processes.

That said, we could have used the word "cognition" as well, but this is also a loaded term, as it is traditionally associated with such central processes as problem solving, decision making, memory, language, etc., but not motor

[1] Thus: "Die organischen Körper … zerstören sich selbst. Sie sind nicht nur steter Veränderung unterworfen, sondern ihre ganze Entwickelung ist ein Reifen zum Tode" (Organic bodies… destroy themselves. They are not only subject to a constant process of change, but their whole development is a preparation for death)(von Baer 1864, p. 39). This statement by von Baer presents some clear parallelisms with the above Bichat quote. Other eminent defenders of the process view were Joseph Woodger and Conrad Waddington (Nuño de la Rosa 2010).

[2] "Die organischen Körper sind nicht nur veränderlich, sondern die einzigen, die sich selbst verändern" (Organic bodies are not only mutable, but the only ones that change themselves) (von Baer 1864, p. 39).

control or perception, which in our opinion should also be included in any developmental account. Thus, while we are not alone in considering these processes as part of cognition (Newell 1990), we follow Thelen and Smith (1994) in using "cognition and action" to make clear that motor control and motor behavior must be part of the equation. Actually, our perspective is even broader: while "action" is traditionally assumed to be intentional (Juarrero 1999), we do not see any principled basis for excluding non-intentional acts from a developmental account of cognition and action.

Coming back to the question whether cognition and action do develop, the obvious answer appears to be "yes," unless one is ready to accept that almost a century of research in developmental psychology along the lines of Piaget and Vygotsky have been a waste of time, or that its practitioners chose the wrong rubric. Alternatively, one could maintain a less radical position but still assert that biological development is one thing and psychological development another, and that therefore there is no room for a unified theory of development encompassing both kinds of processes. Vygotsky (1986), for one, appears to have assumed something like this with his sharp distinction between cultural development and ontogeny, although even he accepted that "natural functions" formed the innermost layer of culturally developed functions. Similarly, Piaget (1962) signaled the "formal operational stage" as the endpoint of cognitive development proper, and thought of further (lifelong) "intellectual development" as a form of knowledge accumulation, rooted in the biological bases of intelligence but different from them. Be that as it may, to reiterate, it is conceivable that biological development and psychological development are two different, perhaps continuous or overlapping, processes, but nonetheless the subject matter of different theories.

We find this a rather bleak perspective, mostly because it runs the risk of divorcing (again) cognition and action from their biological underpinnings, and throwing cognitive science into the arms of methodological if not ontological dualism (Michel and Moore 1995; Oyama 2000b). So we propose to reframe the question above in order to ask: Do cognition and action develop? Is this developmental process a properly biological one? And does such a process have a meaningful impact on our understanding of what development is? The bulk of this article is devoted to arguing that the answer to these questions can only be an emphatic "yes."

The Development of Cognition and Action is Biological Development

Our main focus will be on language. Language is interesting because it poses a number of challenging questions. Thus, few people would deny that, for example, learning to walk is a properly biological developmental process in which a number of organic and environmental factors conspire to eventually consolidate the typical bipedal gait of humans (Thelen and Smith 1994). Similarly with vision, at least since the celebrated experiments with kittens performed by David Hubel and Torsten Wiesel in the mid-1960s (Hubel and Wiesel 1963; Wiesel and Hubel 1963a, b; Wiesel 1982). But the development of language is arguably different because, although it clearly involves an organic component associated with the development of the nervous system, it also involves the cultural transmission of what could be termed "grammatical traditions" in the form of word order patterns, case and agreement systems, and so forth (Balari and Lorenzo 2013). It is this dual nature,[3] with the critical element of acquiring a grammatical system, that makes language a potentially borderline case between what is properly biological and what belongs perhaps to another domain—say, psychological or cultural development.

Traditionally, the mainstream assumption within linguistics has been that language acquisition is a properly biological process, although this assumption has rarely been made explicit beyond the limits of the most naive genetic determinism. A number of authors, however, have seen in EvoDevo the ideal framework for delivering acquisition theory from its biological incoherence by opening the black box of development in order to account for the easiness, speed, and uniformity with which children acquire language (Longa and Lorenzo 2008, 2012; Lorenzo and Longa 2009). Note that these universal and recurrent features of language acquisition set it apart from other putatively similar skills such as writing or playing the trumpet, and suggest an inquiry more from the perspective of developmental biology than from that of cultural anthropology (see Dupré 2013 for some considerations along these lines). Since language acquisition is a central piece of the overall biolinguistic project (Boeckx et al. 2012; Boeckx and Grohmann 2013), we deem it crucial to explore the actual status of language development within a unified theory of biological development.

[3] An anonymous reviewer notes that we appear to assume that this dual nature is exclusive of language, while this property is also observed in other phenomena like color vision, for example. We believe, however, that a strong case could be made in favor of the idea that most, if not all, developmental phenomena showing this dual nature are strongly parasitic on language development. Thus, to the extent that there are no universal perceptual categories (a debated issue), the process of constructing them is intimately connected to the act of actually naming them; in other words, the cultural aspect of language provides the necessary feedback to definitely ground perceptual categorization. For the case of color vision, see Steels and Belpaeme (2005), the references cited therein, and the open peer commentary for an overview of the issues involved.

Let's take three definitions of development from the aforementioned issue of *Biological Theory*, and see how acquisition theory would fare according to them:

> Development is the ability to produce (and not just to maintain) a full functional organ.… Development ends with the loss of pluripotent stem cells. (Laplane 2011, p. 57)

> Development ends when the limits of these basic physical and molecular constraints are reached, when emergent properties decrease in the face of simple causal properties of morphological process, leading to the end of the morphological process and to the beginning of physiological process. (Nicoglou 2011, p. 45)

> Indeed, as long as sequential and irreversible changes in gene expression take place in the entire organism, development can be considered to be still ongoing. When such changes occur only locally (in some parts of the organism only), adulthood is reached. (Théry 2011, p. 21)

These three definitions, as different as they are, share a common element: they all refer to "internal" mechanisms or processes. These are, respectively, the presence/absence of stem cells (Laplane); physical and molecular processes during morphogenesis (Nicoglou); and global, as opposed to local, regulatory gene expression (Théry). Two of them (Laplane and Nicoglou) moreover put a special emphasis on organogenesis or morphogenesis.

None of these definitions appears to be able to incorporate language acquisition and other similar phenomena as legitimate developmental processes. The only exception is perhaps Laplane's, but if it does, then only to the extent that neural stem cells exist and participate in processes of this kind (Zhang et al. 2008). Nicoglou explicitly excludes from her definition "the formation of behavioral and physiological traits" (2011, p. 37), and we therefore must conclude that it would also exclude anything having to do with the development of cognition and action, since underlying her treatment is the implicit assumption that such processes can be decoupled from morphogenesis proper. Théry's definition also excludes cognition and action, given the locality constraint she imposes on regulatory gene expression, which is assumed to be global during development but only restricted to certain organs or organ systems during adulthood. The latter is arguably the case of cognitive development, on the (not necessarily well-grounded) assumption that it just concerns the nervous system.

We would like to contest these three definitions of development, first because of their failure to account for the development of cognition and action, and second because in our opinion they foster an adult-centric view of development and the idea, rather widespread among non-biologists, that developmental biology (or EvoDevo) is only concerned with the generation of form and is therefore helpless to shed some light on such hard problems as the evolution and acquisition of language (e.g., Bickerton 2014).

In retrospect, it is not at all surprising that these authors have neglected, or even explicitly excluded, the development of cognition and action from their definitions. There is a long tradition in biology and psychology of seeing the cognitive abilities of animals (humans included) as either the product of instinct or the result of some learning process. We already mentioned the case of acquisition theory in linguistics, which has mostly been driven by the assumption that humans possess a rich innate linguistic component that simply "unfolds" as the child receives the appropriate linguistic stimuli—a naive interactionism of the sort criticized by, for example, Oyama (2000a). But this idea has its roots, and has been influenced by, the ethological tradition of Konrad Lorenz and Niko Tinbergen (see Chomsky 2009, p. 16; and Chomsky and McGilvray 2012, p. 21, for some self-acknowledging comments), which strongly relied on said dichotomy. This dichotomy is deeply entrenched in behavioral sciences such as behavioral ecology, sociobiology, and evolutionary psychology (see Laland and Brown 2011 for an overview of these disciplines), and has fostered the conviction that development of such skills is not relevant (Brown 2008), or that it is but only to the extent that it is "a gene's chosen route to perpetuity" (Surbey 2008). The net effect is that the analysis of development reduces to the mere determination of how much is "genetic" and how much "learned" in some specific cognitive or behavioral ability, again a form of naive interactionism that reduces the equation to just two terms: gene expression (development proper) and acquisition of information from the environment (learning). Such a view, however, had already been severely contested in the 1920s by Kuo (1921, 1922, 1924, 1967 for a synthesis), who argued that development is one single process, and that developmental pathways eventually leading to the emergence of some behavioral pattern were indistinguishable from the processes of morphogenesis and organogenesis. Kuo's ideas were later picked up and refined by some of his collaborators, in particular Schneirla (1956, 1966) and Lehrman (1953, 1956, 1970), to develop a framework that would eventually come to be known as developmental psychobiology (Michel and Moore 1995). As pointed out by Moore (2003), the adoption of this perspective in developmental psychology brought a radical shift in focus from the traditional "development toward" to the "development from" kind of analysis. Thus the emphasis has shifted to processes rather than outcomes, which in turn have come to be seen not as goals in themselves but as mere stages, the products of the interaction of several earlier developmental resources and constraints, capable of acting themselves as constraints for the kinds of future developmental transformations that can occur.

Now the existing parallelisms between this conception of the development of cognition and action and the kind of non-finalistic and non-adult-centric view of biological development advocated for by, for example, Minelli (2003, 2011a, b, 2013, 2014) are striking.

More importantly, the shift to an analysis of cognitive development with an emphasis on "development from" has only confirmed what Kuo in a long series of papers generically entitled "Ontogeny of Embryonic Behavior in Aves" (especially Kuo 1932a, b) defended, viz., that it is virtually impossible to tell apart those processes traditionally labeled as "morphogenesis" and "organogenesis" from those that eventually give rise to some behavioral pattern. In other words, as soon as one does not focus on a specific outcome (often the adult model), certain developmental events and products that a finalistic view would never classify as precursors of the goal pursued, suddenly are seen as "ontogenetic adaptations" (Oppenheim 1981, 1982, 1984) or "scaffolds" (Robinson and Smotherman 1992; Caporael et al. 2014) capable of facilitating or constraining successive reorganizations of the organism at any level of organization.

Let us recapitulate. Taking the case of language as a paradigm, as has been common from the inception of cognitive science, it is no surprise that the study of cognition and action from an ontogenetic perspective has been less than helpful in regard to the task of clarifying what development is, and where its limits are. Very sketchily, our diagnosis is this: Primarily, the distinction between a purely operative or organic base of linguistic activity,[4] on one hand, and an intentional layer of grammatical conventions known by speakers of different communities,[5] on the other (see Bickerton 2014, for a similar distinction and examples), is not always meticulously respected by theories of language. And what is worse, when it is, it seems to be conceived of as confronting two opposing ways of conceptualizing the language faculty, instead as two complementary sides of it (to wit, see the recent upshots of Chomskyan linguistics; Hornstein et al. (2005) give an overview; also Devitt (2006)). Moreover, no particular insights concerning matters of acquisition are derived as associated to this crucial issue (Longa and Lorenzo 2008; Lorenzo 2013). The "consensus view" (Hornstein et al. 2005) within Chomskyan linguistics continues to claim that substantial parts of what speakers "know about" how particular languages are, and to what extent they can differ from each other, correspond to an inborn cognitive endowment, both species- and language-specific. Only a minority approach (Balari and Lorenzo 2013; Bickerton 2014) departs from this view in suggesting that while growth processes equivalent to morphogenesis offer the right model for the organic component of the language faculty, all that in language entails "knowledge" also entails one or another form of learning from experience. Yet some of these approaches do not offer any particular clue as to how the organic and the intentional components of language interact (if at all), so they are not particularly useful in clarifying the position (if any) of cognition and action in a general theory of development. As a consequence, the state of the art in theoretical linguistics continues to feed the idea that the accomplishment of a full state of linguistic competence is a process that can be divorced from the organic and/or inborn cognitive bases that underlie the process, thus reinforcing the Vigotskyan/Piagetian view that conceptualizes it as a form of accumulation of knowledge of a social sort ("acculturation"), instead of bona fide "biological development." We believe that this is a wrong picture of what language is and how it develops—for reasons not different from those previously raised under rubrics like Michel and Moore's (1995) "psychology/culture dualism" or Oyama's (2000b) "dualism of development"–as well as the main hindrance for any intent of clarifying both how the idea of development applies to language, and how the case of language may help to elucidate the issue of the limits of development.

So let us briefly expand on an alternative position along the lines previously suggested in Balari and Lorenzo (2013), and how it may inform the debate of concern here.

The key of our whole reasoning is that while the distinction between an organic (or operative) and a cognitive (or intentional) layer of linguistic organization is a clear and correct one from a strictly analytical point of view, such a distinction becomes blurred when adopting another perspective, the perspective of the ongoing emergence of the corresponding capabilities. When doing so, a well-supported conclusion is that both facets of language are inextricably intertwined in ways that make them crucial causal factors in each other's development. Let's see how.

What we specifically have in mind when referring to the organic/operative basis of the language faculty is a set of elementary computational operations, roughly corresponding to Pylyshyn's (1980) level of "functional architecture," directly fixed by the biological substrate of the

[4] By which we mean a set of basic universal operations underlying structure building at different levels of linguistic analysis: for example, word building from morpheme merging (*like* + *s* → *likes*), phrase building from word merging (*likes* + *he* → *he likes*), phrase fronting from previously merged phrases (*he likes that girl* → *that girl, he likes*), co-indexing control of agreement (*he*$_i$ *likes*$_i$) or antecedence relations (*that girl*$_i$*, he likes e*$_i$; *e* is the position left behind by the fronted phrase), and so on.

[5] That is, sets of language-specific implementations of the universal operations provided by the language capacity. In English, for example, subjects are canonically head initial (*he likes*, but not *likes he*), verbs agree with subjects only in particular "person, number" combinations (*he likes*, but not *they likes*), fronted phrases cannot antecede the empty copy they left behind at certain distances (*that girl*$_i$*, he likes e*$_i$, but not *that girl*$_i$*, he likes the idea of dating e*$_i$), and so on.

mind and fully automatized ("cognitively impenetrable"), which endows cognition with its essential powers, while simultaneously constraining its scope. It is so basic a set that a reasonable assumption is that it underlies not just a single ability (language) in a particular species (humans). So we rather think of it as capturing aspects of the bare essentials of cognition viewed as an organic activity. Recent findings regarding the structure and functioning of the mind at the physical level may be read as continuous with Pylyshyn's and other cognitive scientists' views at a functional level of description. For example, the idea that the brain implements serial, digital processes fully compatible with those of classic computational approaches to cognition and language is supported by evidence coming from the fields of neural computation (Sarpeshkar 2009), neurobiology (Alle and Geiger 2006; Shu et al. 2006), and neuropsychology (Zylberberg et al. 2011). Besides, the complementary idea that central aspects of the functioning of cognition and language segregate into a computational engine (or sequencer) and (an) associated system(s) of working (or procedural) memory has also received strong support at a physical level in recent years (Ullman 2004; Aboitiz et al. 2006; Makuuchi et al. 2009, among others), as we make clear below.[6]

The first and most basic piece of such a cognitive kit is a "sequencing" operation, which puts symbols together in an elementary "beads-in-a-string" fashion—as in (1), where each x stands for a different mental symbol (ellipses represent here and hereafter an indeterminate number of repetitions of the operation of concern):

$$x\,x\,x\,x\,x\,x \ldots \qquad (1)$$

Next in complexity we have a "grouping" operation, which opens the possibility of keeping track of substrings as component parts of higher level strings until full completion of a sequence with a nested pattern of growth—as in (2), where each group of different characters stands for a different substring:

$$x\,x\,x_1 y\,y_2 z\,z_3 \ldots z_3 z\,y_2 y\,x_1 x\,x \qquad (2)$$

The crucial point here is that while the pattern of growth in (1) is strictly linear, in (2) it is possible to break apart a string into two substrings in order to nest some additional material while still keeping the growth of the two broken substrings simultaneous and continuous; the subscripts in (2) stand for a distinct long-distance connection of this sort.

Outstripping the previous operations in complexity, we finally have a "connecting" operation that tracks dependences among symbols allowing crossed patterns of growth, as in (3):

$$x_1 x\,y_2 y\,z_3 z \ldots x_1 x\,y_2 y\,z_3 z \qquad (3)$$

Technically this would be equivalent to breaking apart a string into three substrings instead of two and keeping their growth simultaneous and continuous.

As for the suggested complexity hierarchy, suffice it to note that sequences like (2) and (3) above entail a working memory device that is not required in the case of patterns like (1), whereas (3) requires a more sophisticated use of such a resource than (2)—something like partitioning it into various memory subunits. This, by the way, leaves sufficient space for interspecific variation along the cognitive dimension; species may have differently enhanced versions of such a device—or not have it at all (Balari and Lorenzo 2013, Chap. 7). Going back now to our concern with particular grammars (the intentional layer of the faculty of language as instantiated in different speaking communities), our main concern here is to observe that the whole array of grammatical rules belonging to one or another language—as copious, diversified, and exotic as it is—seems to exhaustively fit within the limits imposed by the basic operations described above: rules of grammar impose ordering restrictions (1), constrain the formation of patterns of self-containing sentences and phrases (2), or filter the conditions under which long-distance connections (agreement, concord, case, coreference, and so on) not following the nested pattern become legitimate (3). For us, this is a particularly nice illustration of how functional architecture endows/constrains the powers of human cognition.

With all this in mind, we believe that it is not particularly problematic to envision the organic substrate of language as undergoing "normal" developmental processes (i.e., morphogenesis or organogenesis), the outcome of which serves as the underlying means for identifying and learning language-particular rules corresponding to the different complexity strata that we have singled out.[7] We cannot enter into much detail here, but two well-established facts in the field of language acquisition are that regularities having to do with ordering restrictions are the

[6] These findings leave enough elbow room to revitalize old debates concerning how mind and brain ultimately relate. They definitely do not refute functionalism, for minds arguably may be multiply realized. But such discoveries may also inspire new insights to the recent revival of mind-brain identity theory. We cannot go further into this question here; see Polger (2004) for a good exposition of the state of the art.

[7] Deciding whether the cognitive apparatus we have specified above is language-specific (as in Hauser et al. 2002) or not (as in Balari and Lorenzo 2013) is not imperative to our reasoning. If it happens to be generalizable to other cognitive capacities, the only consequence will be that it underlies the growth of them all, at the same time that the ongoing acquisition of the corresponding abilities serves to sustain its own development. Were such a scenario correct—and we think it is—capacities other than language could serve to also illustrate our point, without weakening the value that we attach to language.

ones that children capture earlier, while those having to do with long-distance dependencies are acquired later, following slower paths, and also being the most vulnerable to delays and more or less disruptive conditions (Clahsen 1999; Guasti 2002).

But things cannot stop here lest we be resigned to accept something along the lines of the Vigotskyan/Piagetian story—that knowledge of grammars is something superimposed but different from the biological/developmental bases of cognition, simply adding to the latter as soon as a maturational schedule starts to allow for it. In that case, the never-ending character of the acquisition of language-related skills would be uninformative with regard to the question of the limits of development. We have reasons to think that things are more complex and interesting than that. Particularly persuading, in our opinion, is the fact that while capturing and fixing rules of grammar is a main task to which cognitive architectural operations are put into use, there exist reasons to conclude that these very same rules may also be critical in enhancing and fine-tuning such an underlying cognitive support. So they inextricably compound a developmental unit of sorts (a developmental "hybrid," in Griesemer's 2014a, b conceptualization), not different from other forms of interaction that make possible and ultimately define the realm of development. This point asks for an illustration.

We have in mind, for example, how children construct transient verb-subject agreement systems in richly inflected languages that very reasonably serve as facilitating mechanisms for further aspects of their early cognitive and linguistic developmental progress. We will specifically refer here to the case of German, for which there exists a good record of relevant data (Clahsen 1986; Clahsen and Penke 1992). It is typical of German children at around age 2;0 (2 years, 0 months) to use an idiosyncratic system of agreement endings that they elaborate from scraps of the adult input. This system is different from the fully accomplished system of verb-agreement morphology in many respects: (a) it is highly "degenerate" and "redundant" (in the technical sense of, e.g., Edelman and Gally 2001); and (b) it is mostly alien to the procedure of "feature matching" on which adult agreement systems are commonly based (see Corbett 2006 for an overview). As for (a), on the one hand, children alternate different endings for identical targets (for example, *–en*, *–e*, and *–Ø*, for "first person, singular") and, on the other hand, they use the same ending for different targets (for example, *–en* for both "first person, singular," and "third person, plural"). In contrast, in adult German *–e* is the only affix that remains for the "first person, singular," with *–en* specializing as a "plural" marker (except for the "second person"). At this point one could reasonably raise the question that this may simply be an accidental outcome of children's auditory limitations at this age.[8] We think, however, that this is very unlikely, for children's capacities of phonological discrimination are very powerful almost at birth and perfectly fine-tuned with the maternal stimulus early in the first year of life (Gervain and Mehler 2010). In any event, we think that even if children happen to converge on this system accidentally in the suggested way, this fact does not prevent them from exploiting it as we specifically defend. As for (b), it is easy to conclude from the examples above that children are not particularly picky about the criteria they respect in their version of agreement matches, a feature of their linguistic behavior that proves more telling when observing that they sometimes favor criteria like the "agent/non-agent" distinction over the customary "subject/non-subject" one. So the system may be described as generally connecting verbs to one "prominent" or "external" argument, but in a not completely rigid or unswerving way.

While the previous observations may be interpreted as showing children's failure to deal with the adult system at this stage, we think that they deserve a radically different reading. To begin with, it is significant that children do not behave randomly in this area of their linguistic development, but follow well-defined regularities (see Clahsen 1986 for some inter-individual comparisons). Moreover, the infantile agreement system corresponding to the described stage exhibits properties—viz., those specified in (a) above—that are common to robust or deeply canalized systems of development (see Bateson and Gluckman 2011 for a synthesis). Our interpretation is that children at this stage basically manage by themselves to construct a grammatical device that they can use in training their incipient capacity to connect discontinuous symbols in sequential representations, a claim that we base on the fact that such a device emerges concurrently to the first productions of children where the external or prominent argument appears one or more constituents apart from the verb (Clahsen 1986, pp. 84–85). A further natural conclusion is that in doing so, children are ultimately strengthening the operative or working memory resources required to deal with the higher complexity strata of computational activity as depicted in (2) and (3) above, paving the way for the introduction of particularly difficult new patterns in their linguistic behavior. As a matter of fact, the stage we are describing immediately precedes, for example, the first incipient versions of relative clauses at around age 2;6 (2 years, 6 months) (Mills 1985, p. 203ff), which entail complex applications of both grouping and connecting operations. It is also a particularly strong piece of support for our interpretation that children incapable of dealing with agreement phenomena and failing to accomplish the

[8] This objection was brought up by an anonymous reviewer.

adult patterns of agreement—a pathological condition referred to in the literature as "Grammatical Agreement Deficit" (Clahsen 1986; Clahsen et al. 1997; Clahsen and Hansen 1997)—also accumulate delays and more or less permanent disruptions in other grammatical domains. Significantly, Clahsen and Hansen (1997) report that most affected subjects show spontaneous recovery in those areas after intensive training exclusively focused on the agreement impairment.

Summarizing our point of view, grammars develop with the aid of a basic organic support (see above), which in turn attains its higher degrees of complexification with the aid of the grammatical devices on the way, in what we envision as a mutually facilitating and supportive endeavor. The grammatical devices of concern—agreement systems being, we conjecture, just one particular example—thus have primarily a developmental role (Minelli 2003), in the sense that they arise prior to further putative adult functions, but also in the sense that this developmental role better explains why the corresponding devices exist at all than any possible alternative. Somehow paradoxically, there is strong disagreement among specialists regarding the functional interpretation of agreement systems. The most prevalent views relate them with tasks like fixing discourse referents or attenuating the effects of noise in the communicative uses of language, which, however, do not exhaust the list (see Barlow and Ferguson 1988). It is even possible that they serve to fulfill all such tasks altogether. On the face of it, we think that it is a good idea to relate them primarily to their role in development, from which further unrelated functionalities may unproblematically follow. Involved as it is (both as cause and as consequence) in developmental processes of an ultimately organic or morphological sort—i.e., the development of the brain as the site of sequencing and memory capacities that probably extend beyond the realm of language behavior and humans–we see no cogent reason to exclude the grammatical layer of the faculty of language as a normal domain of application of the concept of "development."

Of course, our particular suggestions concerning the early emergence and primary developmental role of (proto-)agreement systems are open to empirical refutation, as is the extent to which the idea applies to other aspects of grammars (but see Bever 1975, 1981 for some early suggestions that it may extend to grammar at large). Challenging as this is, we think, however, that it is good news that discussions on the nature and the limits of development are not restricted to just conceptual considerations. Clearly, debates will ultimately confront different positions concerning which facts are or are not within the confines of development. For us, the conclusion seems inescapable that something (e.g., a language-particular agreement system) whose growth facilitates the growth of basic or architectural aspects of brains (e.g., a working memory device) cannot be left out from such confines.

Conclusions

Here we expand our discussion in order to tackle a number of open questions concerning the development of language in particular and developmental processes in general.

We have offered a number of arguments that, in our opinion, clearly demonstrate that the development of linguistic abilities must be considered a properly biological developmental process. We have focused on a tiny window of the process concerning mostly the development of agreement marking in verbs in two-year-olds acquiring German, but we could also have mentioned those developmental events that actually precede and scaffold the emergence of grammatical traits. Thus, for example, what could be generically characterized as vocal and auditory learning is a necessary step for the child to be able to perceive and produce such grammatical units as agreement markers. The development of the vocal and the auditory apparatus is an unequivocally biological process involving organogenesis but also requiring the actual fine-tuning of the organs of speech and hearing through neural development in order to gain cortical control of certain tasks related to the articulation and processing of speech sounds (see Locke 1993 for a detailed presentation). Similarly, we could have focused on other stages in order to show that language development extends well beyond adolescence (Locke 1997, 2009; Locke and Bogin 2006), as an additional illustration that definitions of development centered around notions like "organogenesis," "fully functional organs," or "global versus local gene-expression patterns" are much too constrained to capture the manifold and subtle factors that participate in a developmental event.

Take, for example, the notion of "fully functional organ." At what point in time can one judge an organ to be fully functional? Consider, for instance, the case of articulatory organs in humans. Note, first, that no single organ participating in articulation is actually used only for this purpose. Thus, those organs composing what is usually known as the subglottal system, like the diaphragm and the lungs, participate in such a critical activity like respiration; likewise, in the supralaryngeal vocal tract, we find the tongue, the epiglottis, the teeth, the lips, the uvula, all of which have some role either in respiration or in deglutition and feeding. When is one supposed to assume that these organs are fully functional? The first breath occurs immediately after birth and the deglutition of the first food very soon afterwards; in between, all babies cry and produce their first sounds. Are these unmistakable signs of full functionality? Clearly not for articulation, as it cannot be said to start until the end of the first year of life, when babbling smoothly turns into articulation proper (Locke 1993). Observe that we seem to be forced to assume that organs have primary and secondary functions (a conclusion, by the way, that in the case of language was comfortably accepted in the past by those who viewed it as every inch a cultural phenomenon; see Whitney (1875, Chap. 14) and Sapir (1921, Chap. 1) for two venerable examples. But this is a rather problematic assumption, since primary and secondary functional ascription more often than not rests on subjective factors rooted in the ascriber's system of values rather than on truly objective arguments demonstrating the primacy of some function over others (Balari and Lorenzo 2010). When is a hand fully functional? When its fingers can be wiggled? When it is capable of grasping? Or when it can pull the strings of a guitar in coordinated action with the other hand in order to produce musical sounds?

The trouble with this view, shared with the idea that development is a process to produce fully "formed" instead of fully "functional" organs, is that it has serious problems in dealing with putative "malformations" or "malfunctions." Clearly, the difficulty here lies in the finalistic or teleological flavor of the idea that developmental processes point towards a goal (the fully formed/functional organ), an idea that immediately faces the challenge of dealing with those cases in which the goal has not been reached: either we say that the process was not a developmental one, or we say that the process somehow deviated from some preestablished or predefined "norm." But the appeal to natural norms may easily drive one into an ontological cul-de-sac (Canguilhem 1966; Balari and Lorenzo 2010). This is a long-debated question about which von Baer, for example, produced some quite eloquent reflections (von Baer 1876a, 1876b) around the subtle semantic difference between the German words "*Ziel*" and "*Zweck*" (usually translated into English as "goal" and "purpose," respectively; see Lenoir 1989, for a summary of von Baer's cogitations). For von Baer, "*Ziel*" was to be associated with "teleology," while "*Zweck*" was more a matter of "theology" and therefore not deserving a place in the natural sciences. Some parallelisms exist, then, between von Baer's position and some recent attempts at naturalizing "norms" in order to accommodate the idea that biological processes have "goals" (e.g., Barandiaran and Moreno 2008). Space reasons prevent us from going into the details (but, again, see Balari and Lorenzo (2010) for a more elaborated reflection), but we suspect that the mere settlement of a subtle semantic distinction would do little to prevent the goal-oriented view from falling into the trap of adaptationism, even under the assumption that the badness or goodness of some trait can somehow be objectivized (Barandiaran and Moreno 2008). Take again the case of language and agreement systems. As pointed out in the previous section, discussions abound on the putative usefulness (or goodness) of agreement, often in connection with the optimization of communicative acts (e.g., Bickerton 2014, and references therein). What this perspective on agreement in natural languages has always failed to explain is why, if agreement is so useful, so many languages (like Mandarin or Japanese) lack it entirely, while others (like Turkish or Georgian) have such rich agreement systems. Our brief answer to this question would be that this is so simply because such is the range of variation defined by the human linguistic developmental system and the set of constraints acting over it, and certainly not because these are the possible "goals" of this system, which are equally "good" or "useful" for it. This, moreover, also answers (perhaps only partially) an objection raised by an anonymous reviewer regarding our unfairness with the goal-directed view of development and some of its reformulations in terms of developmental trajectories and more or less probable developmental attractors. In our opinion, this criticism rests on a confusion between the theoretical possibility of defining a finite space of variation for developmental trajectories (something we accept without hesitation) and the act of interpreting the different areas in this space as the (potential) "goals" of these trajectories. This may end up being just another semantic or terminological issue, but, for the time being, we'd rather refrain from collapsing the question of the finiteness of variation into that of the putative goals of development.

We suspect that the considerations we've just expounded may turn out to be a potential obstacle for all those views of development that try to fix temporal boundaries, especially when seeking plausible endpoints to the process. Indeed, we believe that the additional move of identifying such endpoints with the stages at which the (pre-defined?) potentialities of the process have been made actually adds a crypto-preformationist flavor to the constitutive view that we find hard to accept; the more so in the case of language, where the identification of actualized potentialities strikes us as based on rather arbitrary considerations.

But, then, if development as a whole cannot be characterized by identifying specific temporal boundaries, what are its defining features? We would like to suggest two: (1) the existence of sensitive periods for the onset of developmental processes, and (2) an important amount of irreversibility in the products of such processes.

Again, language provides a good example of (1). Penfield and Roberts' (1959) Critical Period Hypothesis was worked out in detail by Lenneberg (1967); today, as pointed out by Meisel (2013), "[t]here can indeed be little doubt that (monolingual) first language acquisition is subject to critical period effects." But many other sensitive periods have been observed in other developmental processes, including those participating in morphogenesis and organogenesis (see Hensch 2004 for an overview). We do not mean, however, that one perfectly circumscribed *absolute time* of onset must therefore be singled out corresponding to different developmental processes, but just that, in a view in which development is a collection of interlocked and interrelated subprocesses (e.g., Moczek 2014; see also Pradeu 2014 and the recursive view proposed by Griesemer (2000b and subsequent work), perturbations affecting the workings of one such subprocess may have a critical impact on another, connected subprocess. Again, this is clear in the case of the language faculty, which we rather conceive of as the outcome of a cluster of such instigative phenomena, contingently and expansively affecting each other (in the spirit, for example, of Seliger 1978 and Locke 1997). Such a view seems to us a most natural alternative once one abandons the idea that there exist points at which given developmental phenomena are somehow preformed as already autonomous entities.

As for irreversibility, our point (2) above, although Minelli (2014) cites a couple of cases that might count as counterexamples, it appears that the products of development, while they may suffer further transformations in later stages, cannot in general be undone: languages cannot go unlearned, limbs are not reabsorbed, many structural changes in nervous systems become permanent beyond a certain age (Hensch 2004). Even neural plasticity has its limits.

This will certainly not be the last word on the topic, but we believe that it opens up a promising line of research. To conclude, then, and only very sketchily, let us point out some of the advantages we see in our preliminary proposal to characterize development.

First, it would not call for a species- (or phylum-) specific definition of development, an avenue explored, for example, by Laplane (2011), and which appears to us as a premature abandonment of the hope for a unified theory. Second, it would perhaps exclude cases of reversible plasticity like those documented, e.g., in Piersma and Lindström (1997), West-Eberhard (2003), and Hoverman and Relyea (2007) that motivated Nicoglou's (2011) extremely constrained definition of development. Lastly, it would naturally accommodate alternative developmental pathways that would otherwise be classified as malformations or malfunctions, especially adult-onset disorders such as, for example, schizophrenia and certain forms of epilepsy (often with great impact on linguistic skills) that are traditionally seen as developmental in nature in the medical literature (Duncan et al. 2006; Brodie et al. 2009; van Os and Kapur 2009), as well as those cases discussed in Gilbert (2011, 2014) and Gilbert and Epel (2009). We suspect that phenomena such as regeneration (Vervoort 2011) and aging (Morange 2011) should eventually be included in the class of proper developmental phenomena as well.

Everything suggests that the temporal boundaries of development would eventually be blurred. Perhaps, paraphrasing the words of Xavier Bichat, development is the ensemble of processes that resist death. That is, life itself.

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