Plasticity and canalization in the evolution of linguistic communication: An evolutionary developmental approach

Article · January 2010

DOI: 10.1017/CBO9780511817755.010

2 authors:

Daniel Dor
Tel Aviv University

Eva Jablonka
Tel Aviv University

9 Plasticity and canalization in the evolution of linguistic communication: an evolutionary-developmental approach

Daniel Dor and Eva Jablonka

Introduction

In the last decade, the introduction of a developmental framework into the core of evolutionary theory has brought about a radical change in perspective. In the emerging synthesis, known as "evolutionary developmental biology" (or "evo devo"), the development of the phenotype, rather than the genetic variant, assumes a primary theoretical position, and is the point of departure for evolutionary analysis. Changes in development which lead to changed phenotypes are primary and the organism exhibiting an altered phenotype is the target of selection. Genes, as West-Eberhardt (2003) succinctly has put it, "are followers in evolution": changes in gene frequencies follow, rather then precede, phenotypic changes that mainly arise as reactions to environmental changes. The focus of developmentally informed studies of evolution is therefore on processes of development that can generate evolutionary innovation, on the constraints and generic properties of developmental systems, on the architecture of developmental networks, and on the evolution of the ability to develop and learn (Gilbert 2003). It is clear today that in order to explain the evolution of a new trait – be it morphological, physiological, or behavioral – it is necessary to explain the evolution of the developmental processes that contribute to its construction during ontogeny. Therefore, processes leading to developmental flexibility and sensitivity to environmental variations on the one hand, and to the buffering of environmental and genetic "noise" on the other hand, are important subjects of empirical and theoretical research. Moreover, an account of the origins of novelty, new morphological and physiological characteristics that are clearly not variations on an existing theme, as well as the regulatory architecture of the developmental system that imposes constraints and affordances on innovation production, are central to the development-oriented research project (Wagner 2000). This developmental framework can be used to study the evolution of behavior, and we apply it to the evolution of linguistic communication.

In a series of papers (Dor and Jablonka 2000, 2001, 2004), we developed and presented a social-developmental, innovation-based theory of the evolution of language. At the core of the theory lies the understanding that language itself, the socially constructed tool of communication, culturally evolved before its speakers were specifically prepared for it on the genetic level. Language was, from the very beginning, a collective invention. It came into being not because its speakers already had genes specifically selected for language, but because their social world evolved to the point where collective inventions (not just of language, but of other cultural tools too) became possible. As language gradually developed, and as it became a more and more important element in the social lives of its speakers, the speakers found themselves locked in a new evolutionary spiral: they came to be selected on the basis of their linguistic performance. The invention of language, and the cultural process of further development and propagation, thus launched a process of selection in which genetic variants that contributed to linguistic ability were selected. The selection of genes whose effects are made visible because of a change in the environment is known as genetic accommodation, and we suggested that during the evolution of language new types of genetic variability were exposed, and new types of genetically based capacities (for learning, for communicating and so on), were selected.

The evolution of language is particularly difficult to study because one needs to address processes at three levels: at the level of the social and linguistic structures, at the ontogenetic, individual level, and at the genetic population level. In this paper we would like to discuss certain aspects of the relation between the three levels and suggest that an evolutionary developmental perspective can open up new frontiers for the study of the evolution of language. Our point of departure is the behavioral plasticity of humans, which is the basis for the evolution of language.

Developmental-behavioral plasticity

Behavioral flexibility in humans is probably the most dramatic example of behavioral plasticity in the living world, and it is based on the remarkable learning ability of humans. It asserts itself in the foundational fact that children learn different languages, in the fact that language acquisition takes place under variable social and psychological conditions, in the attested variability in the onset and duration of the acquisition process, and in the strategies adopted by different children throughout the process. However, developmental flexibility is not necessarily behavioral and is not specific to humans. It is one of the defining properties of biological organisms, and biologists call it *plasticity*. Plasticity is defined as the ability of a single genotype to generate, in response to different environmental circumstances, variable forms of morphology, physiology, and/or behavior. These phenotypic responses can be reversible or irreversible, adaptive or non-adaptive, active or passive, continuous or discontinuous (West-Eberhard 2003). The repertoire of alternative adaptive plastic responses to new conditions may be limited and predictable, as with seasonal changes in the coloration and patterns of butterflies' wings, or it can be large and relatively open-ended including unpredictable, novel adaptive responses. This is evident when we consider how we learn a new skill (for example, learning a to ride a bike or learning to read and write), or when we consider morphological adjustments in bones and muscles that are the results of changes in mechanical pressures brought about by new mode of movement (for example, when a mammal needs to use its hind legs in an unusual way). These are environmentally induced developmental reorganizations that were never specifically selected for, and that are based on the general potentialities and plasticity mechanisms of the preexisting genotype.

A good example of a novel phenotypic response, based on relatively open-ended plasticity mechanisms is provided by the linguistic capacity that the bonobo Kanzi (Savage-Rumbaugh, Shanker, and Taylor 1998) managed to achieve in the lab. Symbolic communication is not part of the behavioral repertoire of his species, yet Kanzi now efficiently uses the communication system invented by the humans around him. His mind is plastic enough for that. The conditions within which he grew up have reorganized preexisting components of his developmental systems (behavioral and neurological) in a new and adaptive way.

But what are the mechanisms allowing for the open-ended plasticity underlying Kanzi's amazing communicative behavior, and the extraordinary variability of human linguistic behaviors? *Exploration and selective stabilization* mechanisms are the most prominent mechanisms that lead to open-ended plasticity. They may occur at the cellular, physiological, behavioral, and social levels. All are based on a similar principle – the generation of a large set of local variations and interactions, with only a small subset eventually being stabilized and manifested. Which output is realized depends on the initial conditions, the ease with which developmental trajectories can be deflected, and the number of possible points around which development can be stably organized. Following convention, we refer to these points as "attractors," since they are stabilizing end-states towards which the system seems to "strive." Selective stabilization thus involves both the contriaining of certain aspects of the response and extensive plasticity (output variability) *within this range*.

An example of a cellular mechanism of selective stabilization is the mechanism underlying spindle formation during mitosis, where there is "dynamic instability" involving the opposing and random processes of growth and breakdown of microtubules polymers. A growing fiber stabilizes only when it incidentally (yet inevitably) reaches the kinetochore of a chromosome (the attractor) thus forming the spindle fibers. This process leads to a very reliable spindle formation despite many initial conditions and variable developmental paths for reaching the attractor (Gerhart and Kirschner 1997). Another example is provided by the selective stabilization of synaptic connections during development and learning (Changeux, Courrege, and Danchin 1973; Edelman 1987). At the behavioral level, any learning that involves elements of trial-and-error can be described as exploration followed by the stabilization of a selected behavior.

Although *how much* learning is involved in language-acquisition is a controversial issue, exploration and selective stabilization mechanisms are obviously associated with the process. The entire language out there, which is spoken by the adults around the child, is the "attractor," and in order for the child to be able to reach the attractor, the child must explore – at all levels: the child must try different ways of communication, different ways of usage of language, different interpretations for the utterances heard around him/her. Moreover, the child's brain goes through a whole series of explorational and selective stabilization processes, in which neural pathways, allowing for successful comprehension and production, are stabilized.

The other side of the developmental plasticity coin is invariance, stability in the face of perturbations, which biologists refer to as *canalization*. Canalization is defined as "the adjustment of developmental pathways by natural selection so as to bring about a uniform result in spite of genetic and environmental variations" (Jablonka and Lamb 1995: 290). In other words, canalization produces a situation where the output is stable *despite* changes in inputs and/or in developmental trajectories. It leads to robustness and stability in a "noisy" world, in which both the genetic milieu and the external environment are constantly changing. We must note, however, that there may be properties of the developing system that lead to uniform results, which are *not* the result of natural selection for constancy. For example, they may be the inevitable effects of the regulatory structure of the developmental network (Hermisson and Wagner 2004). In such cases, the explanation of the origins of the buffering properties that lead to the system's stability in terms of natural selection is unwarranted, although natural selection may eventually contribute to the *maintenance* of the canalized state.

Some features of language and linguistic communication seem to be stable across languages, and across ontogenies, despite the facts of environmental, developmental, cultural, and genetic variation (for partially converging lists of features see Vouloumanos and Werker 2004; Pinker and Jackendoff 2005). Although there is no consensus, most linguists agree that all speakers of all languages share the ability, which becomes manifest relatively early during development, to attend to, imitate, remember, and generate components and patterns of linguistic structure. Most linguists also agree that all spoken languages have constrained ranges of phonemes that are organized in a combinatorial manner (as in bird songs), and form theoretically unlimited phoneme-strings.

Canalization and plasticity seem to be opposites, and for a particular level of phenotypic description they indeed are – a phenotypic response may be either invariant because of canalization (i.e., it may have a single stable output despite many inputs and developmental contexts), or plastic (i.e., context-sensitive with several outputs). The relationship between canalization and plasticity, however, is much more interesting. Almost every case of canalized development (in the face of genetic and environmental "noise") requires plasticity at underlying or overlying levels of organization. Thus, for example, the increase in the number of red blood cells at high altitudes can be seen as a plastic response if we look at the number of red blood cells (which changes), but it is an illustration of canalization if we look at the concentration of oxygen in the blood (which remains constant). It is the plasticity at the level of adjusting the number of red blood cells that allows the stability at the level of oxygen concentration. Similarly, although all normal children acquire the languages of their communities there is plasticity in that the *particular* routes of linguistic development differ, as does the *specific* output – the individual idiosyncrasies of one's language production. Different children come to the world with different genetic makeups, different learning capacities and different embryological histories, and they are exposed to different sets of linguistic inputs. The very fact that they eventually manage to zoom in on the target language and produce a relatively invariant behavior means that they must manifest great plasticity at the neural level. Looking at the brains of different speakers we therefore expect to find a lot of variability at the brain physiology level, and we expect this to be true even of identical twins who have identical genotypes. In fact, it is the ability to generate neurological variability (which is inevitable given genetic differences, anatomical differences between brains, differences among ontogenies, and differences of processes of linguistic socialization) that allows for the construction of different developmental trajectories that lead to something that everyone recognizes as language.

The open-ended plasticity mechanisms at the behavioral and the neural levels are the point of departure of our account of the evolution of language. As we argue below, the evolution of language is incomprehensible without the assumption of such open-ended behavioral plasticity, which enables individuals to explore communicative possibilities and generate communicative novelties. Innovating organisms are, we argue, genetically prepared for the search for behaviors that break the genetic mold of the regular patterns of their lives. The innovations themselves emerge from the search process, which almost always requires a certain amount of luck.

The cultural evolution of language/s

Our account of the evolution of language begins with the cultural history of linguistic innovation, the gradual process in which exploratory communicative behaviors came to be stabilized and conventionalized as part of the linguistic system. From the first prototype (or prototypes) of language back in the past, until today, individual speakers everywhere have been trying to solve new communicative problems (or found themselves accidently doing so) by means that were not yet part of their linguistic arsenal. Speakers have been inventing words for things that have not yet been named by their language; using existing words for new meanings; arranging their words in new ways to express new relational meanings; producing more complex messages; finding new ways to reduce ambiguity; using language for functions that have not been thought of before, and so on. Some of the inventors, at different points in time, might have been by their cognitive nature already more adapted to language, but this is definitely not necessary: Some of them might have actually been those who found language more difficult to learn and to use, and were thus looking for ways to streamline it and arrange it in ways that were easier for them to learn (we will get back to this topic later). Much more important than the variations in the cognitive capacities of the inventors, however, were the functional and contextual conditions of the inventions: The nature of the communicative problems that required solutions, the developmental state of the language at the time of the invention, and the social and communicative circumstances. Throughout the process, new communicative problems kept emerging, and new functional solutions were required, simply because society, communication, and the realities of life kept changing. Language played a crucial role in directing the process of its own development, for a double reason: first, many of the problems that required a functional solution emerged as systemic consequences of the development of the language. Second, as more and more elements came to be canalized, and the language came to assume a certain architectural logic, the logic gradually imposed system constraints on what the next viable innovation could be.

Throughout the process of cultural evolution, the community gradually sophisticated its common world-view, adding new linguistic categories and allowing more successful linguistic communication. Each time a new invention became part of the language, the "attractor" for language acquisition has changed and developed. In the process of cultural evolution, however, language also developed into a more constrained communication system, a system of rules. This was a type of "cultural canalization" because it led to greater stability of linguistic production and comprehension among speakers, despite increases and changes in lexicon and additions of new grammatical elements. This stability did not lead to reduced variability of linguistic production or comprehension. On the contrary: by being subject to rules, plasticity increased within its bounded domain.

The social and communicative circumstances at the time of the invention were important for several different reasons, mostly because the success of the explorative communicative behavior, and then its stabilization, required other people, apart from the innovative speaker, to understand what the speaker tried to do. Innovative speakers may achieve nothing in the absence of attentive and innovative listeners. The same is true of the entire process of stabilization. For a linguistic innovation to be adopted into the language, it has to propagate throughout the community, and be accepted by many of those who did not (or could not) invent it themselves. This process is highly dependent on the relevant social conditions (including the relations of power and the politics of identity in the community).

Cultural evolution, however, did not just involve the effort to allow for cooperative mutually beneficial communication. Language-related struggles may have also contributed to the process of language evolution. As groups became large, it was inevitable that different subgroups would develop their own communicative interests, which might have included, at some point, the concealment of information from members of other groups. Secrecy, in this case, would be advantageous to the members of the "secretive" group. Access to this secret information would, however, be of value to the excluded group members, so there was a clear conflict of interest: members of the excluded group would engage in an attempt to decipher the secret information, which would lead to a ciphering-deciphering arms-race (Dor and Jablonka 2004). If such conflicts have indeed been important during the evolution of linguistic communication, they could have participated in interesting processes taking place at different levels. They may help explain why languages seem to have a wider vocabulary and a more complex structure than is expected from simple utility considerations; they may also help explain the emergence of stratification within languages, including the phenomena of jargon and slang. Hide-and-seek linguistic games may have also contributed to processes of social differentiation (including the extreme case of castes) and division of labor within groups, since linguistic differentiation is likely to enhance social differentiation.

The evolution of speakers

Everything that has ever happened to humans in their evolution as speakers was driven by the social process of the cultural evolution of language. When the first prototype of language was invented, the new tool opened for its users new horizons of communication. Precisely because the new tool proved so efficient, it also presented the speakers with a new and pressing learning challenge: they had to learn to use language, to use it efficiently and in coordination with the other members of the community. In the exploration process that ensued, different individuals recruited capacities of different kinds, and found different strategies to cope with the challenge. Some of them, at the same time, kept developing the language, finding new ways to enhance its expressive power. Every progressively more complex version of language that came to be adopted as a result of a complex social process of negotiation and struggle, made the learning challenge more difficult and more complex. Every enhancement in the expressive power of language made it more important, and eventually virtually necessary, for everybody to learn to use the language – because it gradually changed the entire social world in which they lived.

Cultural selection for the most effective communicators inevitably involved selection for individuals with cognitive features that assisted the development of the now essential linguistic learning. Natural selection favors these organisms in a population which can respond in an effective functional manner to the new inducing or learning conditions. Those genetic changes that stabilize a functional phenotypic response (i.e., make it more reliable and precise), and/or that ameliorate detrimental side-effects, were selected. West-Eberhard terms such genotypic change *genetic accommodation* (2003: 140, 146). Selection of genes is possible only because alleles become selectively relevant as a result of phenotypic adjustments to new environments. Variation is "unmasked." Genetic accommodation therefore follows phenotypic adjustments: changes in gene frequencies follow rather than lead in the evolutionary process.

A special case of genetic accommodation, which probably was important in the evolution of language, is *genetic assimilation* which occurs when selection at the genetic level leads to a more canalized response. It arises through the replacement by natural selection of a physiological or behavioral response, which was originally dependent on an environmental stimulus or learning, by a response that is fully or partially independent of external induction or learning. A behavioral response that was probably fully assimilated is the fear of the smell of lions shown by hyena cubs before they have ever encountered a lion. A response that depended on an external stimulus has become independent of the external stimulus through natural selection. This case is an example of full and complete assimilation, but this is an extreme case of a more general process. Usually, genetic assimilation is partial, leading to the ability to produce the response with decreased exposure to the stimulus (e.g. a smaller number of learning trials, a shorter induction period, a lower threshold, etc.) (Avital and Jablonka 2000).

Partial genetic assimilation may result not only in a more facile response but may also lead to the sophistication of behavior through a process which Avital and Jablonka (2000) called the *assimilate-stretch* principle. By decreasing the number of trials necessary to learn one aspect of behavior, the individual may be able to learn additional things. In other words, by making some learned acts easier, more things can be learned *with the same cognitive resources*, and the result will be an increase of learned behavioural outputs. Hence, genetic assimilation can lead to the sophistication of behavior and may explain many complex sequences of actions, which are otherwise baffling from an evolutionary point of view. In addition, learning to do one thing readily can be a scaffolding for learning other things. For example, if we learn to communicate about the difference between now and not-now, we may also advance our ability to distinguish more sharply between before-now and after-now, then learn to communicate about this distinction, and so on and so forth.

Partial genetic assimilation also leads to the sophistication of behavior by another route – via the construction of broad categories. While complete assimilation leads to a fixed response that does not require any learning (just a single input-trigger), partial assimilation does require learning and hence is inherently plastic. Partial assimilation of communication categories may thus lead to the ability to think about the world, to further communicate about the world, and to respond to the world in terms of categories (for example one/more-than-one, etc). Probably what happens is that certain connections between different parts of the brain become strengthened, or some parts of the brain become "recruited" for a new function. Developmentally this may come at the expense of other functions, or as a substitute for them, and this may lead to increased dependence on the new connections.

What kinds of cognitive capacities were recruited, and eventually genetically accommodated (or partially assimilated) during the evolution of language? Since the task at hand has always been a learning task, individuals with greater general learning capacities must have been selected over the others: the social evolution of language thus played an important driving role in the long process in which humans developed their unprecedented capacities for general learning. Bigger brains, with bigger areas dedicated to associative learning, better long- and short-term memories, better skills of social engagement and learning, including more sophisticated versions of a theory of mind, better imitation skills – all these were gradually emerging as some of the resulting characteristics of the minds of more advanced humans. In other words, the genetically accommodated minds were, first of all, more plastic. Plasticity, of course, has made the entire process possible from the very beginning: as we noted earlier, the bonobo Kanzi is able to communicate well beyond the ability of non-tutored members of his species. However, it is as important to note that he does not seem to be capable of learning our full-fledged languages. This indicates that we have evolved cognitive linguistic plasticity far beyond Kanzi and the other primates.

Increase in general learning ability, however, could not have been the only genetically accommodated and assimilated trait. Individual members of speaking communities must have also been selected for any and every type of capacity they managed to recruit which helped them cope not just with the general learning task – but with different elements of the task that had to do with the *specific* properties of language itself. Certain individuals, at different points in the evolution of language, and regardless of their general learning achievements, found it easier than the others to produce well-demarcated linguistic sounds (and to do it more quickly), to distinguish linguistic sounds from noise in the course of comprehension and analyze them phonetically and phonologically, to learn and remember more signs, to understand the semantic relations between the signs and their relations to the world, to construct and communicate more complex messages, to understand the speakers' pragmatic intent in comprehension, to apply logical analysis to quantifiers – and so on. Genetic accommodation may have been accelerated through positive assortative mating, in which individuals with better linguistic ability chose similar individuals as mates (Nance and Kearsey 2004).

It is not clear whether conflicts between encipherers and decipherers contributed to the genetic accommodation of linguistic plasticity. Hide-and-seek linguistic conflicts probably led to better linguistic memory and attention to linguistic forms, and enhanced the usage of words as objects of play and deliberate manipulation (i.e., encourage linguistic wit). A lot of evidence from child-language, especially in relation to language games, indicates that exploratory behavior has been extended into the linguistic realm. These effects all seem to reflect increased plasticity at the neural and behavioral levels, and were obviously the consequence of the cultural and genetic evolution of language. Genetic accommodation could lead to features that further allow for the development of the hide-and-seek linguistic games, only if such games characterized human societies for a long time, and made systematic fitness differences. If there was systematic selection of those individuals whose cognitions are more suited for inventing, learning, and using rapidly changing "codes," this would have selected for further increase in linguistic capacity.

The co-evolutionary Spiral

The evolution of speakers did not just follow the evolution of languages – it also reciprocated by influencing the way the languages evolved. As we stressed, the process was driven throughout by the social and communicative dynamics: The communicative problems that had to be solved, the emerging system constraints of language itself, the social fabric of communication – all these were throughout the dominant factors. But the cognitive capacities of individual speakers played a constitutive role in three complementary ways. First, as humanity advanced, technologically and epistemology (partly because of language), human minds kept changing, both in terms of content and process: humans came to know things about the world that they did not know before (and probably forgot certain things too); they came to see the world in spatial and temporal directions that were closed to them in the past; their thoughts, fears and ambitions kept changing; they were capable of doing things in very different ways – and all these required changes in language, for information sharing, cooperation and social communication (and also for deceiving and hiding information). Importantly, changes of this type were introduced into the language, as innovations, by individuals who thought and felt certain things (about the world, about society, about communication) that were not yet communicable by language, and *also felt the need* to communicate them. The ways the minds of these individuals worked thus did have an impact on the evolution of language: to the extent that they managed to stabilize their innovations, they actually dragged language closer to their minds. The other members eventually learned about these things through language. In this sense, then, language was partially directed in its evolution by the specific properties of its innovators as cognitive agents.

Second, some of the innovators probably managed to do what they did because they had some very particular capacities that were not generally shared by the others. The first humans who began to explore the possibility of investing meaning in word order, for example, and were thus among the first to start developing what eventually became syntax, were probably much more sensitive – because of the particularities of their developmental history – to linear order on the one hand, and to the complexities of their (very rudimentary) semantics, on the other. They may have otherwise been very competent with language, but on the other hand, they may have launched the explorations precisely because they were lacking in their pragmatic capacities and thus found much more difficult to cope with ambiguity. This way or the other, languages eventually came to reflect something about the way their minds worked.

Finally, all the innovations, on their way to stabilization, had to be accepted by the others, and in order to be accepted, they had to be *learnable*. There was thus an upper limit on the complexity of innovations: they had to be simple enough, easy enough to learn for the others. To a certain extent, then, the evolution of language itself was constrained by the general learning capacity of the population. The importance of this constraint, however, should not be overestimated for three complementary reasons. First, the fact that the innovation was already out there, as an object for learning, implies that many of those who could not invent it (because they lacked some specific cognitive capacity) could now rely on their general cognitive plasticity, and their social learning capacities, in the course of learning it. Second, for a specific innovation to be accepted and stabilized, it did not have to be learnable by *everybody*. Usage of the tools of language is never evenly distributed across the population. Third, many individuals may have been able to learn some of the innovation, to approximate its usage in a way that enabled them, for example, to understand it when used by others, but not to use it themselves. Linguistic production is always more difficult than comprehension (for the same level of complexity). There may have been linguistic innovators who were too far ahead of their times, so to speak, whose innovations were too complicated for the others to learn. But all in all, the constraint most probably played a positive auxiliary role in the evolution of language, in the sense that it gave an edge (other things being equal) to simpler innovations over complicated ones, and thus contributed to the general streamlining of the entire system.

Conclusions

The general idea that the evolution of language involved a complex interaction between genes and culture was suggested by scholars from different theoretical camps, including Pinker and Bloom (1990), Maynard Smith and Szathmáry (1995), Jablonka and Rechav (1996), Deacon (1997), Kirby (1999), Briscoe (2003), and many others. Pinker and Bloom on the one hand and Deacon on the other seem to represent two extreme views of the co-evolutionary view. Pinker and Bloom suggested that specific linguistic properties – as they are defined in the generative literature – may have appeared as part of the social evolution of language, and then genetic assimilated. Deacon objected: he claimed that languages are simply too varied, too different from each other, for any particular property of any of them to have been universally internalized, in an identical way, by all humans. Deacon thus concluded that only properties of general cognition could be assimilated. Language emerged from the general cognitive capacities that all humans share (including the capacity for symbolic thinking), and evolved together with a gradual rise in these general capacities.

In spite of the differences between their positions, some ideas are shared by both sides to the debate. Chomsky's foundational idea, that our genetic endowment for language is universally spread among all human beings obviously informs Pinker and Bloom, but it is also accepted by Deacon albeit in a different way. Deacon rightly rejects the idea that *languages* are universal, and concludes that genetic assimilation of linguistically specific properties was therefore impossible. Nevertheless, both sides agree that languages are the way they are because our minds are universally the way they are. For Pinker and Bloom, this implied linguistic specificities universally encoded in our genes. For Deacon, it implied linguistic specificities locally shaped (in different ways) by the universal human capacity for symbolic thought. Both sides also agree that the entire process of the evolution of language was essentially driven by human cognition – not by the social activity of innovation. Elements of language were indeed invented, but the elements that survived and were eventually established in language were those which adapted themselves to the structures of our minds and brains.

Our analysis, couched as it is within the evolutionary-developmental framework, offers a different solution, and removes what seems to us like the last serious objection, voiced by Deacon, to the idea of partial genetic assimilation. It bases itself on the understanding that the evolution of language has always been first and foremost a socially driven process. Brain plasticity allowed for phenotypic adjustments through learning, and then for the partial genetic accommodation, of elements of language; our general learning capacities might have ruled out some structures that were too complex, but the structures of our brains and minds were never the primary attractors around which humans had to organize their developmental pathways. The primary attractors have always been the languages of the communities. Language not only adapted to the brains and minds of individual speakers, but the brains and minds of the speakers had to adapt themselves to language. And since human brains and our minds have always been somewhat different from each other, they had to adapt themselves to language in somewhat different ways. Nothing was *fully* internalized on the way: no grammatical rules or meta-rules. Our minds and our brains as modern humans, however, are much more sensitive, much more attuned, to linguistic particularities than the minds and brains of our ancestors. We are much better prepared for language then they were, but we are still, each and every one of us, somewhat differently prepared. Variability, at all levels, is an inevitable driver and outcome of the logic of the evolution of language.