

Peer commentary, for BBS, of the article by Michael Arbib: "From monkey-like action recognition to human language: An evolutionary framework for neurolinguistics"

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The fractionation of miracles

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In this dense paper Michael Arbib lines up a rich set of suggestions toward a naturalistic explanation of the evolutionary emergence of language and of its underlying brain structures. For reasons of space, the present commentary can only outline our main reasons for being dissatisfied with what Arbib has to offer.

One could summarize crudely, but not incorrectly, Arbib's entire project as follows: The kind of mysterious interiorization processes once invoked by Piaget are not mysterious any more, because individual mirror neurons and populations thereof can actually carry them out. In fact, it's important to be reminded of the failure of Piaget's much older project, also aimed at deriving linguistic structures from motor schemata. His grandiose schema was based on processes called grouping, reversibility, thematization, reflexive abstraction, reflected abstraction and so forth. Piaget is not even cited in Arbib's impressive bibliography, much to the reader's loss, we think, because the two projects bear a revealing resemblance. Piaget's project failed because it was irreducibly metaphorical, and because it was centered on what arguably still remains the most mysterious of all cognitive processes: abstraction. Humans, unlike machines, are by nature endowed with awesome abstracting capabilities. Some of us tend to take that cognitive feat just for granted (Piaget would have said "allant de soi" (see, for instance, his contributions in (Piattelli- Palmarini, 1980)). The discovery of mirror neurons, one of the most remarkable discoveries in the neurosciences of recent years, appears to be able to dissolve the mystery of abstraction by "discharging" it onto single nerve cells.

We are going to argue that: (a) in spite of the uncontested empirical concreteness of such neural implementations, the nature of this abstraction, and of abstraction in general, remains quite elusive; (b) Even if it were not so, Arbib's elaborate extensions of the abstracting power of mirror neurons would add a host of additional unsolvable mysteries; (c) The single big puzzle of a genetic discontinuity that brought about recursiveness and

thereby(narrow)syntax is not solved by means of the series of coordinated small mysteries conjectured by Arbib;(e) finally we will show that even if one grants Arbib all of his initial points, his final claim that most of the interesting universals are culturally accumulated, would require him to postulate powerful innate languagespecific mechanisms - exactly the sort of nativist claim that he explicitly wishes to avoid. This will finally lead us to some constructive conclusions.

On innateness and experience

As amply reviewed by Arbib, mirror neurons lie side by side with “canonical neurons”, that is, neurons that are described in the literature as being sensitive, say, just to graspable objects, or just to the action of grasping, or just to the observation of a grasping action, or just to the noise emitted by a certain action, but not to any combination of these. It is not known at present (Vittorio Gallese, personal communication, May 2004) whether mirror neurons are such from birth, as a consequence of a genetic program, or whether some canonical neurons can “turn into” mirror neurons by means of learning and experience. Arbib bets heavily on the non-innateness of the specialization of mirror neurons, for reasons that are congruous with his other conjectures (nay, inescapable, once one espouses them).

“A key point is that the functions of mirror neurons reflect the impact of experience rather than being prewired”. (page 15).

No empirical data on the development and tuning of mirror neurons are available yet in order to win or lose this particular bet. (The notion of “potential mirror neurons”, page 40, is, as of now, proprietary to Arbib). One thing is for sure: Not all neurons in the immediate neighborhood, in the relevant brain areas, become mirror neurons. Maybe that’s a consequence of some genetic programming (as we are inclined to conjecture), or maybe the explanation lies entirely in their post-natally different commerce with experience and with other neurons. Be that as it may, and contrary to a widespread opinion (vigorously endorsed also by Arbib), we have some understanding of how a neuron can be selectively tuned to respond to certain specialized inputs in virtue of the genetic makeup of the species and of the individual’s exposure to environmental inputs (selective stabilization à la Huebel and Wiesel is a standard model), while we do not even begin to understand how it can become tuned as a result of experience alone, plus the generic properties of a given class of neurons qua neurons of that class. If nothing at all is “prewired” how can a mirror neuron do anything at all with the data out there, even determine that it constitutes experience for X? And if we recognize that something is prewired, as we must, then the empirical question is different: what is prewired to determine what constitutes experience and what to do with it, and how much variability is left to experience? Something counts as “experience” only if we presuppose some pre-existing structure, and, without further structure, no tuning is possible.

This is a general problem for neurobiology, made more acute when abstractive capabilities

come to the fore.

On abstraction

Let's, then, ask: What is abstraction, at the level of neurons? It has to be intimately tied to the size of equivalence classes between heterogeneous stimuli. Stimulus A and stimulus B are clearly distinguishable by us in nature, in virtue of their transparently different properties (my action of grasping is transparently a different event from your action of grasping), but they are "the same" for that mirror neuron (perhaps modulo quite subtle differences in the firing pattern). The more dissimilar these equivalent stimuli look to us, qua unprejudiced observers of natural phenomena, the higher is the level of abstraction that we have to attribute to the sensitivity of the neuron.

Suppose, as Arbib suggests, that neurons become mirror neurons solely on the basis of experience. Then one should expect that a mirror neuron may be produced that is sensitive to the macaque's own action of grasping and, say, someone else's action of yawning. If genetic programming has nothing to do with the mirror neurons' specialization, then such haphazard pairings (such odd kinds of abstraction) should be actually observed, just granting a sufficiently long history of contingently repeated haphazard simultaneities. The standard Darwinian evolutionist would rule them out on the basis of an excessive proliferation of specialized neurons and of the unlikely adaptive advantage of a grasping-yawning correlation. Fine, but any such story is a genetically based story. Weird pairings (so those stories go) would have been weeded out in the fullness of time, on a selective genetic basis. Therefore, contra Arbib's claim, the characteristic propensity of mirror neurons to abstract actions of grasping qua grasping, regardless of details and regardless of agent, would be genetically pre-wired, or anyhow genetically facilitated.

This applies, with bells on, to the notion of "variants", so pervasive in Arbib's paper (pages 7, 10, 42, 50) especially those (allegedly) "outside the repertoire".

Empiricism in a new guise and Kant's lesson

In virtue of what is B perceived as a "variant" of A? Obviously, criteria of equivalence, relevance and similarity must apply. Where do these criteria come from? No appeal to variants can be explanatory, unless one provides an explanation for the sources of the criteria themselves. The textbook account of empiricism had a standard, but alas unworkable, suggestion: objective (that is, extensional) similarity of shape, proximity in time and closeness in space (for a recent critique see (Fodor, 2003), for the crucibles of psychological similarity see (Tversky, 1977; Tversky and Gati, 1978), and the special issue of BBS on the work of Roger Shepard (2001, (2)). But, of course, the ancestral and irreversible counter-move is Kant's in the First Critique). Even the empiricists were more sophisticated than that, but let's stick to the textbook story, which is relevant here. These criteria can only be intensional, not extensional. Contingencies in thought do not automatically (spontaneously, by themselves) mimic contingencies in experience. Nothing

can be a variant of something else, unless the organism is antecedently equipped with a capacity to detect it as a variant. The canonical lesson from Kant must not be forgotten: It's inside, in the capacities and the dispositions of the organism, that we must look.

One thing is the similarity between the perception of A and the perception of B, quite another the perception *that* A is similar to B (or, equivalently, that A is a variant of B). In order to do the work that is expected of it, similarity must be inside the scope of the thought (must be a component of the perception itself). Arbib reproduces here the arch-impasse of the empiricists: Nothing grants a transition from the first situation to the second. Only post-Kantian internalism-rationalism can do that.

However, even supposing, for the sake of the argument, that this insurmountable central internalist problem has been solved, we still need to hear from Arbib how to find naturalistic solutions to a series of further miracles (we do not use this word lightly) that are introduced into his story. We will select only a few, the most glaring ones.

The miracles of extension and expansion:

Our two basic questions are always the same here: (1) how can this have happened, within the bounds of known naturalistic mechanisms? In particular: (2) What are the sources of the (necessarily internal) criteria on which these manifold accretions and internalizations have to be based?

These are some characteristic passages in Arbib's paper:

"S5: *Protosign*, a manual-based communication system, breaking through the fixed repertoire of primate vocalizations to yield an open repertoire". (page 7)

"When the monkey observes an action that resembles one in its movement repertoire, a subset of the F5 and PF mirror neurons is activated which also discharges when a similar action is executed by the monkey itself". (page 22)

"mirror neurons are not restricted to recognition of an innate set of actions but can be recruited to recognize and encode an expanding repertoire of novel actions". (page 26, italicized in the original)

Our reaction is the usual one: We will evaluate such suggestions only when the criteria of resemblance and similarity, and their sources, will have been specified. In the absence of a specification of criteria and sources of resemblance and similarity, "breaking through the fixed repertoire", "recruitment" and an "expanding repertoire" are just other names for miracles.

A distinction is made (page 28) between "*stimulus enhancement*" (as in the marmosets) defined by Arbib as "apparent imitation resulting from directing attention to a particular object or part of the body or environment", "*emulation*" "observing and attempting to

reproduce results of another's actions without paying attention to details of the other's behavior" and "*true imitation*" "which involves copying a novel, otherwise improbable action or some act that is outside the imitator's prior repertoire".

One cannot refrain from asking, for instance: On which grounds is the child "not paying attention to the details"? Is it a failure of discrimination, similar to change blindness? But, then, there is nothing the child can build on such a failure. Or is it a bona fide equivalence between discriminable, but irrelevant features? The world does not carry on its sleeve, for the child to see, what should, and what should not, be paid attention to. Only pre-existing internal equivalence criteria can allow the child to do so. But Arbib does not admit pre-existing internal templates, or at any rate wants to vastly transcend them. How? The ensuing evocation, by name, of neuronal loci and of connectionist models with acronyms is unable to dissipate the miraculous nature of these alleged processes.

In pure Piagetian style (though, as we said, Piaget is never cited), we read: (page 25)

"Children explore their environment, and as their initially inept arm and hand movements successfully contact objects, they learn to reproduce the successful grasps reliably, with the repertoire being tuned through further experience. [...] With more or less help from caregivers, infants come to recognize certain novel actions in terms of similarities with and differences from movements already in their repertoires, and on this basis learn to produce some version of these novel actions for themselves".

We shall have to repeat here a classic objection: Until we are offered specific naturalizable candidates for the (alleged) processes of "learning" and "tuning" and "similarities", and are told in some detail what kind of "help" caregivers are supposed to be giving, we will suspend judgment (see the contributions to the Royaumont debate with Piaget by Noam Chomsky and Jerry Fodor in Piattelli-Palmarini, loc cit). Selective activation of internal repertoires à la Huebel and Wiesel, and parametrically-based selective theories of language acquisition are something we begin to understand (Fodor, 2000; Gibson and Wexler, 1994; Yang, 2002), while all the above remains irreducibly metaphorical. At best it presupposes what it claims to be explaining.

Arbib maintains the principle that miracles are not miracles any more, provided they take a long time to happen:

"*Stage S4 hypothesis*: Brain mechanisms supporting a complex imitation system —acquiring (longer) novel sequences of more abstract actions in a single trial, and its necessary grounding in the ability to parsing a complex behavior as a composite of familiar actions — developed in the 5-million-year evolution from the common ancestor of apes and humans along the hominid line that led in particular to *Homo sapiens*". (page 30, see also footnote 18).

Single-trial emergence of novelty by activation is a cornerstone of nativist-selectivist

models (see Janet Fodor 2000 and Yang 2002 for a recent, thorough application to language acquisition), but they remain utterly mysterious in all externalist gradualist models like Arbib's. And 5 million years (or any length of time, for that matter) cannot dissipate the mystery. The same applies to pantomime, and to "extractions", two further miracles in Arbib's list:

"the power of pantomime is that it provides open-ended communication that works without prior instruction or convention". (page 32)

"These linkages extract more or less coherent patterns from the creature's experience of the effects of its own actions as well as the consequences of actions by others. Similarly, execution and observation of a communicative action must be linked to the creature's planning and interpretations of communication with others in relation to the ongoing behaviors that provide the significance of the communicative gestures involved". (page 37)

His appeal to an "expanding spiral" from protosign to protospeech and then to speech, via a supposedly multimodal integration of manual, facial and vocal actions (page 39) is also irretrievably metaphorical.

The cultural collective evolution of language.

Arbib invites us, commentators, to keep this aspect separate, and this is what we will try to do here, but he makes it very hard for us to do so. Indeed, we think that his emphasis on collective linguistic inventions percolates through the paper. See for instance page 41

"I would argue that there was no one distinctive speciation event and that the process whereby communication for most humans became predominantly vocal was not a switch but was "cultural" and "cumulative"".

Moreover, his polemic against the evolutionary discontinuity represented by recursion and narrow syntax in Houser, Chomsky and Fitch 2002 (Hauser, 2001; Hauser, Chomsky & Fitch, 2002) rests precisely on the collective nature of languages (resulting from "inventions" by "geniuses", as conjectured in Section 7):

"It might have taken many, many millennia for people to discover syntax and semantics in the sense of gaining immense expressive power by "going recursive" with a relatively limited set of strategies for compounding and marking utterances. As a language emerged, it would come to include mechanisms to express kinship structures and technologies of the tribes, and these cultural products would themselves be expanded by the increased effectiveness of transmission from generation to generation that the growing power of language made possible". (page 46)

Well, how can a species "go recursive", unless it has the relevant potential to do that from the very start? There is no such thing as a fraction of recursiveness (or a fraction of Noun Phrase or Verb Phrase, for that matter). That's a logical impossibility. For instance, one of

the most remarkable results in the semantics of natural languages concerns generalized quantification, with mathematical proofs that it cannot be explained on the basis of firstorder logic (Barwise and Cooper, 1981; Barwise and Etchemendy, 1988; Keenan and Stavi, 1986). Arbib's appeal to co-evolution, presumably suggesting progressiveness, cannot circumvent this logical impossibility.

“LA2. *Syntax, semantics and recursion*: The matching of syntactic to semantic structures coevolves with the fractionation of utterances, with the nesting of substructures making some form of recursion inevitable”. (page 13)

Either the human species had the full capacity already, but it was dormant, not yet activated, and then his claim is substantially similar to Hauser et al's., or it's another mystery how it could have genuinely acquired such capacity on a collective basis.

If Gorillas make food piles within food piles, and thus exhibit a recursive behavior, it does not explain how recursion is abstracted away from food-piling, nor how it is integrated with language. The explanation of that requires a language-specific hypothesis that describes exactly how recursion works in language. And that hypothesis in turn would become part of what we find that is innate in human cognition that leads to the accumulation of languages that all use recursion in exactly the same way. Recursion is what makes it possible, for instance, for a Noun Phrase to contain another Noun Phrase (my little sister's brown dog), or to contain a full sentence (the spy who came in from the cold). It allows a cyclic matching of syntactic structures to logical forms, from the inside out, and it's very hard to see how it could have evolved from gorillas handling heaps of leaves.

In another passage he comes closer to the canonical meaning of recursion, but he seems to want to explain it as the inevitable consequence of something else, probably communicative needs finding an outlet in semantics and, derivatively, in syntax (if so, we would have another revealing parallelism with Piaget). Once more, a long slow unfolding of a miracle does not take away the miraculous nature of the process.

“Such developments and inventions may have occurred very slowly over the course of many (perhaps even thousands) of generations during which expansion of the proto-vocabulary was piecemeal; it may then have been a major turning point in human history when it was realized that symbols could be created ad libitum and this realization was passed on to future generations”. (footnote 22)

The parallel with the development of mathematics (footnote 24) is so extravagant that it hardly needs a rebuttal. Unlike the intricacies of syntax and lexical semantics, it is not (emphatically not) the case that every 5 years old can now master infinitesimal calculus. Moreover, how geniuses of the caliber of Newton and Leibniz managed to invent/discover infinitesimal calculus is a total mystery. Explaining syntax, semantics and lexical semantics, about which we otherwise begin to know a great deal, by means of a total

mystery can hardly be considered progress for cognitive science.

Arbib's peculiar linguistic theory

Michael Arbib nourishes a deep-seated and long-standing dissatisfaction (to put it mildly) with generative grammar and with almost everything it stands for. So be it. We will, then, refrain from deploying here a cogent critique based on representative samples of the host of intriguing and deep linguistic facts from many languages that generative grammar has grappled with successfully over the last several decades, but which his approach has nothing to say about (for this line of argumentation see, among others, (Lightfoot, 2000; Piattelli-Palmarini, 1989; Uriagereka, 1998, 2002)). Like other radical adversaries of generative grammar (Lieberman, 2000) Arbib would probably consider such facts irrelevant, and the explanations offered by generative grammar suspect. Nonetheless, several of the extravagant linguistic hypothesis presented in this paper deserve at least a brief counter. For instance, he claims what follows:

“In Section 2, I asserted that in much of protolanguage, a complete communicative act involved a unitary utterance, the use of a single symbol formed as a sequence of gestures, whose component gestures—whether manual or vocal—had no independent meaning. As pantomime yielded to the conventionalized gestures of protolanguage, unitary utterances such as “grooflook” or “koomzash” might have encoded quite complex descriptions such as “The alpha male has killed a meat animal and now the tribe has a chance to feast together. Yum, yum!” or commands such as “Take your spear and go around the other side of that animal and we will have a better chance together of being able to kill it.” (page 41)

Putting things more soberly, the claim is that a fully compositional language has sprung from a non-compositional, entirely conventional one. Arbib belabors at length on how this might have happened as a result of collective inventions (see his conjectures about the invention of adjectives on page 41 and passim, where “invention” is a misnomer for a series of little miracles). On the basis of a vast literature on the compositionality of the semantics of natural languages, it should be clear that we are very close to another logical impossibility (Fodor and Lepore, 2002; Heim and Kratzer, 1998; Higginbotham, 1997; Higginbotham, 1985; Higginbotham, 1989; Higginbotham, 1991; Larson and Segal, 1995). Compositionality is intimately tied to productivity (syntactically legitimate novel combinations of meaningful units are themselves meaningful) and systematicity (different meanings of different composite expressions obey internally represented rules). Short of being another miracle to be added to Arbib's list, there is no conceivable continuity, conceptual or factual, between a communication system based on monolithic conventional signs and a fully compositional language. Noncompositional languages are un-learnable, each symbolmeaning pair has to be memorized (the need of an explicit convention for each expression is a result of that). Fractionation (in Arbib's terminology) of monolithic expressions presupposes an access to internal principles of phonology, morphology and syntax and cannot create these principles from scratch. Likewise, recombination (again, in Arbib's terminology) presupposes internally represented laws of compositionality,

productivity and systematicity and cannot create them.

The closest real equivalent to Arbib's improvised "grooflook" and "koomzash" are idioms (Kick the bucket, Hits the fan etc.) that are, *prima facie* at least, semantically non-compositional. However, they all obey, in all languages, strict syntactic constraints entirely based on the compositionality of ordinary (non-idiomatic) expressions of the syntactic type to which they belong and containing the same words (Hale and Keyser, 1989; Hale and Keyser, 2002; Marantz, 1997; Williams, 2003). The semantics of idioms is, in fact, arbitrary (a child or a foreigner have to be told explicitly what they mean), but their syntax retains some compositionality, some productivity and some systematicity (kicks the bucket, kicked the bucket, will kick the bucket, might have kicked the bucket etc.) Even the most extravagant, narrowly group-restricted idiom cannot help activating the standard lexical-morphosyntactic machinery (Marantz, 1997). The willful use of language as a conventional code (as in the BBC messages to partisans in Nazi-occupied Europe during World War II) is totally divorced from its normal use. Arbib's hypothesis that an Ur-language entirely made of un-analyzable idioms may have progressively turned into a fully compositional language via a sequel of inventions not only has no evidence to back it, but it comes close to a logical impossibility.

In essence, even conceding that there ever was a transition from proto-language to language, that may only have taken place if the species already had the mental equipment needed for recursive syntactic and semantic compositionality, for word-formation and morphological assemblage. Maybe such capacity had not yet been activated, but then the story is one of progressive activation, not one of buildup from scratch. The construction of these capacities out of a sheer capacity to use monolithic noncompositional signs would represent an inexplicable mystery. Suggesting that it may have been slow, piecemeal, progressive and collective does not help. A collective miracle that takes a long time to happen remains a miracle.

The puzzle of thematic roles

Against practically every linguist's well-grounded persuasion, Arbib maintains that adjectives, verbs and nouns are not "natural categories" (we assume he means natural categories for linguistic inquiry), and that linguistic universals must be "based on universals of communication that take into account the processing loads of perception and production rather than as universals of autonomous syntax" (page 45). He dwells upon thematic roles (agent, patient) and suggests that they are derived from the observation of the intrinsic structure of actions. Neglecting syntax, especially in these matters, leads immediately to major problems. Why do all languages on this earth only have verbs with two, maximum three, thematic roles (agent, theme, instrument)? Why not have also thematic roles for a variety of topics that are of genuine concern in human communication (frequency, duration, motivation, origin, normal/exceptional nature of the action, effortful/effortless character, and so on)? In some languages some of these are expressed by classifiers (i.e. by morphology). In other languages (such as English, French, Italian,

Spanish etc.) these optional pieces of information are syntactically expressed by means of adjunction (and it was heavy, but he only did it once etc.). A related difference is the one between languages that overtly and regularly express "light" verbs (semantically similar to the English do, make, get) and languages (like English) that overwhelmingly maintain them lexically covert in the structure of the VP (to be more precise, of the little vP, that has VP as an internal component). How can communicative needs begin to explain such facts? Why develop thematic roles and classifiers, and adjunction, and light verbs, overt or covert, with options subject to parametric choices over languages? Why are these options so limited? Why not have verbs with 5 or more thematic roles? Why not have only mono-thematic verbs and express everything else by means of adjunction? The answer is exquisitely syntactic, in terms of the nature of available positions in the internal structure of the vP and the universally fixed number and configuration of these positions (Hale and Keyser, 1993, 2002). Pace Arbib, there are quintessentially syntactic linguistic universals. Their identification is the result of the accumulation of diligent and honed linguistic and philosophical inquiries, in which counter arguments have already been made and used to refine the claims. This objection to Arbib's rejectionist views of language structure is critical all by itself, that is, if Arbib accepted every OTHER claim of linguistics but rejected this very well supported and understood one, his program would collapse on that basis alone.

Arbib's special conundrum

The physical world may offer "affordances" that interact with evolved capacities such as opposed thumbs, that can explain further developments without assuming more evolution. But Arbib's suggestion that there are language "affordances" of corresponding explanatory power meets immediate factual refutation. In the case of tool use, the past hundred years of anthropological study of various cultures has documented stages of tool development. That is, "primitive" tribes have been found, with corresponding primitive tools. But there is no such variation found in the complexity and nature of languages. Surely, if the essence of language indeed had accumulated culturally, there would be serious variations in the complexity of language, corresponding to the variation in complexity of other kinds of cultural artifacts. A related fact is that in the case of tool development, or cooking and food methods, even advanced cultures indeed can differ greatly - one culture's food is often another's curious garbage (witness the oriental view of western cheese, or the western view of fermented soy products). The difference in relation to the essence of language is that there are language universals (see supra). That is, the essence of language that allegedly accumulates culturally ends up with the same apparent kinds of processes and structures, completely unlike the situation in the case of cultural artifacts that truly accumulate.

But, again, let's grant for a moment, Arbib's idea that there ARE language affordances that explain the cultural accumulation of the essence of language, once protolanguage evolved biologically. We see that this leads to a conundrum, that will bring Arbib back full circle to postulating some kind of direct explanatory innateness for language.

Here is how the conundrum works. Languages are all the same in important regards that transcend the universals of protolanguage. Such convergence can be explained in two alternative ways.

a) First, we can postulate that the essence of language is "invented" culturally, as a result of human cognition. But this is equivalent to the claim that language is "innate" in a strong sense. That is, all the cognitive components that go into making a language have to be organized in specific ways in relation to language, and the laws of that organization is what we would have to accept as the basis for language universals.

b) Or we can postulate that the essence of language is "discovered", just as one might view the emergence of tools or of methods of food preparation. In those cases, certain methods work just because they interact felicitously with affordances of the physical world. In fact, the idea that the essence of language might be discovered by the child rather than invented, has been discussed in the past few decades. Jerrold Katz, and then Katz and Postal, and Langendoen and Postal revived the notion that the essence of language is in fact a Platonic object, such as numbers geometrical figures and other abstract entities (Katz, 1985; Langendoen and Postal, 1984). One of us (TGB) discussed the implications of this view for the acquisition of language - he noted that it changes what we think must be innate, but it does not change how much must be innate (Bever, 1982). The speed and characteristic universals with which children acquire language, shows that there must be innate mechanisms that direct the child to "discover" language quickly and in just the right way (Bever, 1981). This is in sharp contrast, as we said, with the millennia it took to discover what we now know about mathematics and geometry, and the fact that only a few of us know it, and that only after years of special education.

After all, if children did learn mathematics in a world where everybody produced equations and proofs, that might argue against a special math gene, especially if the child's mistakes were carefully noted and corrected. But the point in the case of language is that people produce language garbage, mistakes, strange accents, and the child is rarely corrected, yet she gets things right. The canonical Poverty of the Stimulus Argument applies with full force. That is crucial in forcing the hypothesis that each child invents or discovers language individually de novo every time.

Thus, even if we (counterfactually, or at least counter-theoretically) grant all of Arbib's claims about protolanguage and the subsequent cultural emergence of language, we still have to postulate that either there is a set of cognitive universals innately tuned to connect computational capacities in just the right and same way to create the essential language universals; or we have to postulate a set of "discovery" procedures, equally exquisitely tuned to recognize just the right properties and connect them with the computationally appropriate mechanisms, that result in the essential language universals.

Conclusions

The discovery of mirror neurons opens up a vast domain of novel testable hypotheses in the domain of language, including novel issues in the evolution of language. But these are very different from the ones suggested by Arbib. For instance, it would be interesting to determine whether the deep structural (that is lexical and syntacticosemantic) commonality between spoken and sign languages has actually been made possible by mirror neurons, or whether mirror neurons only facilitate an inter-translatability that has separate neuronal grounds. The role of mirror neurons in the child's acquisition of the lexicon, especially for verbs expressing actions (but, let's insist, under the specific constraints imposed by morphology and syntax – see above) is also potentially very interesting. The remarkable equivalence between ostension and verbal description in the child's acquisition of a considerable portion of lexical meanings may be found to be grounded on the role of mirror neurons.

At the level of phonology and in very early language acquisition, it will be most interesting to rephrase and retest several old hypotheses (notably put forth long ago by scholars at the Haskins Laboratory) to the effect that the hearer builds up online internal motor representations of the production of the speaker's utterances (but the blunt "symmetry principle" invoked by Arbib is in need of considerable tuning. Comprehension is almost always better than production, except maybe in the schizophrenics (Moro et al. in preparation), but there are also cases of the reverse).

Finally (for the moment) it will be no less than fascinating to examine the repercussion onto higher, more global linguistic abstractive capacities of the amazing abstractive capacity of individual mirror neurons. It has been rightly stressed (Chomsky, 1995) that many individual lexical meanings cover seamlessly and without effort both abstract and concrete interpretations (a reactionary book that weighs 2 pounds), a variable and its specific value (the price of wheat, that was 5 dollars a bushel yesterday, is rising rapidly), a geographic enclosure and the political organization of the society that lives in it (France is a hexagon and a republic). Many other instances of the same ilk could be cited. These elusive linguistic facts still escape our full understanding (for a recent insightful review, see (Pietroski, 2003)). Hopefully, an inquiry into their possible foundations in the abstractive properties of mirror neurons may allow for yet unsuspected explanations.

To sum up: Arbib has correctly detected a capital of rich gains to be reaped in the future integration of linguistics with the neurobiology of mirror neurons. The stock of theories and explanations in which he recommends to invest are not, however, the ones that may bear fruit.

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