REVIEW ARTICLE AND DISCUSSION

Buzzsaws and blueprints: what children need (or don’t need) to learn language*

MARK A. SABBAGH and SUSAN A. GELMAN
University of Michigan


An old joke that has been circulating for the past decade or so goes as follows: a biologist, a physicist, and a cognitive scientist were sitting around discussing the great achievements of their fields. The biologist waxed eloquent about the insights of Darwin’s theory of evolution; the physicist expounded on the implications of Einstein’s theory of general relativity. Then the cognitive scientist spoke up: ‘Our great discovery is the thermos. You put a cold drink in, the drink stays cold. You fill it with hot soup, the soup stays hot. This is amazing, for how does the thermos know?’

Obviously, this cognitive scientist has asked the wrong question about how the thermos maintains temperatures. In The emergence of language (henceforth, EL), an edited collection of chapters authored by an interdisciplinary group of computer scientists, linguists, and cognitive and developmental psychologists, it is suggested that perhaps language acquisition researchers have been making the same mistake as the errant cognitive scientist. To be sure, language is an extremely complex phenomenon, yet it is also elegant. Recognition of these characteristics in all aspects of language (thanks in large part to Chomskyan approaches to linguistics) highlights a well-known apparent paradox: language is hopelessly complex but children acquire it with ease. Solutions to this paradox have typically inspired researchers to posit rules or other kinds of blueprints – knowledge (innate or acquired) that children have to guide their language acquisition. But are these rules truly necessary? Perhaps children do not know how to acquire language any more than a thermos knows how to maintain temperature.

Although EL does not represent a single consensus viewpoint, the strong version of the hypothesis being advanced is that language develops like other patterns in nature that are characterized by complexity and elegance (e.g.,

[*] We thank Dale Barr and Marilyn Shatz for helpful and insightful comments on a previous draft of this manuscript. Address for correspondence: Mark A. Sabbagh or Susan A. Gelman, Developmental Psychology, University of Michigan, 525 E. University Ave., Ann Arbor, MI 48109-1109, USA. e-mail: sabbagh@umich.edu or gelman@umich.edu.
honeycombs, soapbubbles, etc.). Specifically, the contention is that language emerges not from innate rules, but from pressures that shape interaction between two general sources: 1) children’s domain-general cognitive capacities, and 2) the linguistic environment. A central metaphor, and source of evidence, for this approach is the connectionist parallel distributed processing (PDP) computer model. In these models, an initially random pattern of connectivity is transformed such that input and output are related systematically via a generalized learning procedure without ever requiring an explicitly represented rule. Many of the contributing authors contend that in doing away with the need for rules, ‘emergentist’ approaches remove the necessity for positing any kind of specific linguistic knowledge.

One way of clarifying the distinction between the emergentist perspective and more traditional perspectives is by discussing two classes of tools that have been posited for language learning. One class we’ll call buzzsaws – domain-general cognitive processes of attention, association, memory, and so on. These sorts of tools specify the kinds of operations that can be performed, but do not specify when or where those operations are carried out. The second class of tools children might use we’ll call blueprints – representations that specify when, where, or in some cases how, buzzsaws might be used. Blueprints could involve general rules like ‘pay special attention to things people are looking at’ or ‘associate new words to new things,’ or quite specific rules such as ‘novel words refer to whole objects’ or ‘attach modifiers to closest NPs.’

Put in this language, the strong version of the thesis posed in EL is that children can learn language without language-specific blueprints; domain-general buzzsaws alone can carry the day. As noted above, this notion may be somewhat counterintuitive at first, given the complexity of language and the ease of its acquisition. Since domain-general tools only specify the kinds of things that are possible (a buzzsaw cuts wood, a hammer pounds nails, but their combined activity alone does not result in a bookcase or a house), there seems to be a need for having some principled manner of using the tools in question. We agree with this intuition, and therefore see the following as the central challenge of the proposal: developing an adequate account for how unsophisticated tools give rise to the elegant structures that constitute language, and support its rapid development. Fortunately, over the course of the book, one begins to get a clear sense of how this challenge might be met.

Mechanisms of emergence

The importance of performance and development. One theme that arises over the course of EL is that the key to considering how domain-general buzzsaw tools can give rise to complex and orderly structures lies in the limitations of these tools. Memory, attentional processes, sequence learning skills, auditory
processing, and other domain-general tools are limited, even in adults (e.g. Miller, 1956). The central contention is that these limitations effectively constitute a class of constraints. A given buzzsaw does not just cut; it cuts the only way it can. A number of the EL authors posit that understanding the nature of performance factors – in both adults and children – can give insight into the origins of the elegant structures that constitute language. This hypothesis is radical in proposing that performance (not just competence) can be critical to the acquisition process.

For illustration, we will focus on two specific proposals. The first comes from Gupta & Dell, who note that similarly structured words in a lexicon (i.e. CVC) are less likely to be alliterative (i.e. cat, cab) than they are to rhyme (i.e. cat, mat) (Kessler & Trieman, 1997). Past attempts to account for this regularity have involved stipulating formal rules – namely, that words have an ‘onset-rime’ structure and are generated from additional rules which allow or prohibit particular sounds to occur in the rime. From the emergentist perspective, Gupta and Dell contend instead that the same structure can be accounted for when one considers the dynamics of rapid serial order processing. Cognitive work carried out by Sevald & Dell (1994) has shown that words that start with the same sound, such as CAT and CAB, are difficult to recall together – the ‘AT’ retrieved in ‘CAT’ interferes with the subsequent retrieval of ‘AB’ in ‘CAB’, given that both are cued by the initial ‘C’ sound. A lexicon with many alliterative words would be slow and inefficient whereas a lexicon organized in terms of more frequent rhyming (as English is) efficiently avoids this performance bottleneck. A number of questions remain with respect to this interesting proposal. For instance, is this phenomenon language-specific? How might it work developmentally?

Nonetheless, this research illustrates the manner in which domain-general cognitive factors typically related to performance provide a mechanism that shapes a class of regularities in language, without explicitly requiring a ‘rule.’

MacDonald provides another example of how factors that influence performance lead to principled rule-like linguistic processing. She takes as her starting point the problem of sentence parsing and the resolution of syntactic ambiguity in sentences such as ‘Bill said that John had left yesterday.’ Does ‘yesterday’ tell us when John left or when Bill spoke? Typically, speakers assume that ‘yesterday’ tells us when John left. A number of rule-based theoretical proposals have been offered to account for this regular interpretation (i.e. Frazier, 1987). MacDonald posits, instead, that this phenomenon can be accounted for by considering the distributional characteristics of language that result from performance limitations. Citing previous cognitive work, she notes that shorter phrases require less processing and are more ready to be articulated before longer ones. This processing characteristic leads to a tendency for speakers to produce utterances in which shorter phrases are articulated before longer ones.
Sensitivity to the resulting distributional information (the production of predominantly short-long phrase order) leads a listener to assume speakers are adhering to this order, thereby leading them away from the interpretation that ‘yesterday’ tells us when Bill said what he did. Presumably, a speaker meaning this would have followed the preferred pattern and said ‘Bill said yesterday that John had left.’ Here again, domain-general constraints on performance ultimately lead to principled linguistic processing without necessarily positing explicit language-specific (i.e. grammatical) principles.

**Developmental limitations and constraints.** Importantly, performance limitations of domain-general buzzsaws also provide a framework for thinking about development. Elman lays forth a fascinating discussion of how developmental limitations on children’s attentional capacities, working memory, and neural connectivity may provide structure with respect to how these tools can work on the linguistic input. Elman’s proposal echoes Newport’s (1988, 1990) ‘less-is-more’ speculations regarding how processing limitations make for easy language learning early on, and how ‘being born’ with a mature set of domain-general tools could be problematic. Elman attempts to specify this process by stating that an early limitation on working memory ‘…has the effect of limiting the search space in exactly the right sort of way … to solve a problem that could not be solved in the absence of those limitations’ (p. 15). Although no research involving children is offered in support of this framework, Elman does present the results of an intriguing neural network simulation that demonstrated better learning of more problematic aspects of language (e.g. verb argument structure) when the ‘memory’ of the network (i.e. the context units) was reset at initially short and then increasingly large intervals.

**Specificity and efficiency emerge in development.** Development does not only shape the use of buzzsaw tools by imposing limitations. A second way in which development shapes the use of tools is by changing the problem space such that the domain-general tools become more efficient. In contrast to a view that posits that blueprints are unchanging over development (see, e.g. Keil, 1981), the argument advanced here is that early learning experiences change the system such that the problem is not the same for subsequent acquisition. Building on the rough cuts rendered by the domain-general buzzsaw tools, patterns of processing begin to emerge and in turn serve to guide future processing. Along these lines, Smith puts forth an account of how children’s tendencies to interpret new words according to a shape bias (i.e. things that are the same shape get the same name) emerge from domain-general skills that become more refined through experience. Relatedly, Golinkoff, Hirsh-Pasek & Hollich also emphasize how early biases are elaborated over the course of development, ultimately contributing to highly skilled word learning behavior. Finally, Bates & Goodman, who focus on a lexical approach to grammar acquisition, offer a series of compelling
arguments detailing how development and early acquisition shape the subsequent acquisition of new information.

**Broader implications of the approach**
In short, the approach sketched out in *EL* is enticing. It has the potential to provide mechanisms for a breadth of phenomena, in areas that include syntax, semantics, pragmatics, and phonology. The reliance on domain-general mechanisms challenges researchers to consider known cognitive constants before appealing to *ad hoc* rules in accounting for a wide variety of linguistic behaviors. The approach also takes development seriously, positing that incremental processes can give rise to non-linear developmental trajectories, thereby calling into question developmental theories that concentrate on the significance of stage transitions. Finally, the emergentist framework is exciting in that its mechanistic accounting for organism–environment interactions guides research and theory toward the central question of, as Bates & Goodman put it, ‘What’s the nature of nature?’

**Theoretical and empirical challenges**
In his preface to the volume, MacWhinney admits that there is no consensus view on how precisely to define emergence. The advantage of this ambiguity is that it allows for a variety of approaches, and not a single party line. However, the ambiguity presents problems for someone hoping to learn how emergentists stand in contrast to other theoretical perspectives. At times throughout the volume, the label seemed to describe any non-nativist approach to language development. For example, it is sometimes proposed that bootstrapping is emergence, that development is emergence, or even that learning from experience is emergence. If the concept of emergence is broadened and stretched too far, it arguably loses its power and effectiveness as a theoretical framework because it becomes indistinguishable from other constructivist theories that also emphasize the importance of development, learning from experience, and organism-environment interactions more generally (see e.g. Gopnik & Meltzoff, 1997; Wellman & Gelman, 1998).

For present purposes, we will characterize a ‘strong’ emergentist position as follows: 1) the characteristics of domain-general cognitive tools (attentional biases, working memory, pattern detection, etc.) work on environmental stimuli to render the complex and elegant structures that characterize language – without explicitly representing rules, and 2) the same general principles can be applied to different aspects of language (e.g. syntax and semantics). We recognize that not all of the authors contributing to *EL* would support this strong position. However, we highlight these two claims
because they most clearly distinguish the emergentist perspective from others, and most importantly, they give the framework enormous potential for parsimony. Building on the limited set of known domain-general cognitive processes, the emergentist framework promises to explain a wide array of linguistic phenomena. Below, we address three issues related to evaluating the parsimony of the framework: 1) that only domain-general tools are required to account for language development, 2) that these get the job done as well (or better) than putative language-specific rules, and 3) that these mechanisms can be modelled and are thus more mechanistic and concrete.

*Are only domain-general tools required?*

At the core of acquiring grammar is the ability to extract regular sequential patterns from the ambient speech environment. Recent research has demonstrated that children are indeed skilled at detecting patterns in the input, but there has been considerable debate as to what cognitive capacities these skills entail. One clear hypothesis is that children have a domain-general capacity for 'statistical learning' that affords them considerable leverage on the language acquisition problem (e.g. Bates & Elman, 1996). In line with this hypothesis, one possibility is that children’s grammatical acquisition proceeds from their abilities to detect what kinds of words typically follow one another (e.g. Seidenberg & Elman, 1999). In their chapter, Allen and Seidenberg argue that extracting statistical transitional probabilities between classes of words (e.g. property, thing, action, manner) also provides the basis for making grammaticality judgments. For instance, they suggest that Chomsky’s famous sentence ‘Colorless green ideas sleep furiously’ is judged as grammatical because ‘each of the local (high-level) semantic sequences property, property, thing, action, manner is quite normal English’ (p. 122).

Our concern about this particular argument is that it skirts the question of how speakers come to classify words in terms of abstract categories that enable the relevant statistical learning procedures. The architecture of Allen & Seidenberg’s particular model seems to suggest that the relation between forms and high-level semantic meanings is transparent, and precedes statistical learning. Logically, however, this assumption is problematic. Referring back to the ‘Colorless…’ sentence, an ‘idea’ is only a ‘thing’ with respect to English grammar, which is obvious when one considers how few features ‘ideas’ share with other ‘things’ (e.g. apples, chairs). Similarly, the mapping from the form ‘sleep’ to the high-level semantic class ‘action’ is also not transparent when considered outside of the grammatical domain (see Maratsos, 1982). The lack of transparency is highlighted by cross-linguistic research identifying instances where a given concept is expressed with
different form-classes (e.g. an adjective in one language vs. a verb in another language; Croft, 1991). Thus, it appears that the presumed ‘semantic’ analysis contains hidden syntactic structure. Of course, without the ability to detect regular sequences, grammatical development would not get off the ground. Our concern is whether this domain-general ability alone is sufficient.

The logically problematic assumption of a transparent relation between the linguistic environment and its subsequent higher-level representation also surfaces when one considers the role that similarity is argued to play in language and cognitive development. Several of the models (connectionist or otherwise) described in the book place heavy reliance on similarity as an unanalysed primitive, transparent in the input, that provides a basis for developmental emergent processes. This was especially apparent in Merriman’s mechanistic feature-matching model of how word comprehension proceeds. Yet, as many have noted, similarity is a deceptive notion – it appears to be a quality that is ‘in the world,’ yet it is suffused with biases, some of which are best described as conceptual (Goodman, 1979). For instance, Murphy & Medin (1985) note that, from a logical perspective, any two objects are similar on infinitely many dimensions (e.g. a lawnmower and a feather both weigh less than 500 pounds, are subject to the laws of gravity, can be found outside, etc.). Of course, in everyday cognition, any two objects are not equally similar. What provides the basis for these similarity judgments?

Recent research suggests that mere perceptual similarity is not itself criterial. Things that clearly share distinctive features are easily judged as dissimilar when it is revealed that they have different non-obvious properties (Gelman & Wellman, 1991). By the same token, two things that look identical (i.e. line drawings of balloons and lollipops) can be named/categorized differently when their respective creators’ intentions dictate (Bloom & Markson, 1997). Findings such as these suggest that similarity judgments are constrained and informed by content-laden conceptual considerations (see Medin, Goldstone, & Gentner, 1993 for a review). Things are never simply similar – they are always similar on some selected dimension. By assuming the transparency of similarity judgments, these mechanistic models seem to include a built-in solution to exactly the kind of problem that explicitly represented knowledge structures (i.e. rules) are posited to account for. Thus, these models have hidden, as opposed to removed, the representation of the knowledge required to solve the problem.

[1] This criticism, and other ones related to PDP neural network models echo those made by Marcus (1998, 1999), who argues that these models import rule-like structure either in the way the input is represented, or through the architecture of the network, and that these design features limit the generality of a given architecture.
Do buzzsaws get the whole job done?

Again, we do not doubt that domain-general tools are important for language development, and that they contribute to the process in non-trivial ways. Our question concerns whether they alone are sufficient for the multiplex problem of language development. Another place where this concern is particularly salient is in the realm of social cognition. In her chapter, Snow argues that children are more precocious in the social domain than any other and thus, that the social domain provides the best springboard for children’s language development. However, given the impressive cognitive abilities of infants (e.g. Baillargeon, 1993; Spelke, 1994) and the relatively protracted developments in the social domain (e.g. Baldwin & Moses, 1996), this starting assumption seems questionable. Furthermore, we are not aware of any evidence suggesting that the skills that children do have are sufficient to account for more than a limited set of language-relevant achievements. For instance, Baldwin (1991, 1993) has focused on the role that social perspective-taking skills play in establishing word-to-world mappings. However, as Baldwin herself is careful to note, establishing a mapping does not necessarily render word meaning (see also Woodward & Markman, 1997). Once one figures out that a word is related to something in the world, one needs to figure out how specifically. This problem is an inductive one whose solution is not apparent in the labeling situation.

Following Baldwin et al. (1996) we agree that infants rely on social information to establish initial word-referent links. In this sense, social skills such as perspective-taking are fundamental to language acquisition, and indeed to knowledge acquisition in other domains. However, we do not think that this needs to be characterized as emergentist. Children’s skilled performance in experimental situations designed to tap the relation between social-cognitive skills and word learning (e.g. Baldwin et al., 1996; Akhtar, Carpenter & Tomasello, 1996) is typically ascribed to some kind of pragmatic knowledge — explicitly represented information that guides language acquisition. Positing this kind of pragmatic knowledge, though gleaned from domain-general processes, seems counter to the strong emergentist line described above. For instance, Samuelson & Smith (1998) have argued that children’s apparent success in these same experimental situations is attributable to more basic domain-general cognitive processes, such as memory and attention.

These concerns point to what we feel is the necessity to be clear about two things: 1) what are the candidate domain-general cognitive processes from which language emerges, and 2) what specific linguistic phenomena can be considered emergent from these processes? One chapter that explicitly addressed these questions was the one by Aslin, Saffran & Newport considering the role that statistical learning might play in word segmentation.
Specifically, the authors identify statistical learning as one tool that contributes to the task of word segmentation, but then go on to say that it solves only a part of the problem. They argue that the statistical learning tools have to be combined with constraints (which they think are innate) that operate to select appropriate aspects of the environment for further processing. Put more generally, recognition of the non-trivial contributions that domain-general tools make to language acquisition does not necessarily entail commitment to the proposal that domain-specific knowledge is unnecessary. Indeed, as Aslin et al. point out, it may be just these kinds of interactions that give rise to the complex structures that characterize language.

*Is the mechanism more concrete?*

One of the strengths of the emergentist approach and its connectionist modelling metaphor is that it pushes for a concrete mechanistic accounting of the interaction between organism and environment. Although this mechanistic-computational approach is appealing, we harbour some concerns as to whether it truly provides a better basis for explanation than more traditional models. On occasions, it would appear that many of the putatively concrete mechanisms are said to work through processes that are rather vague and underspecified. For instance, Snow claims that ‘social, communicative achievements…constitute the bootstraps with which children levitate themselves into language proper’ (p. 265). Similarly, MacWhinney’s thought-provoking chapter outlining how grammar might emerge out of perspective-taking processes regularly appeals to processes such as ‘converting images,’ and ‘assuming perspective’ of events such as ‘cyclones hammering.’ While we can see that these processes might be domain-general, it is difficult to accept them as a more solid basis for explanation relative to more standard alternatives since it is not completely clear as to what is involved in ‘levitating’ or ‘converting images.’

The paradigm demonstration of mechanistic accounting within the emergentist framework is the connectionist model. Unfortunately it is difficult for us to evaluate the connectionist models presented in *EL* because we are outsiders to this methodology. We fault only ourselves for these limitations. Nonetheless, we raise some general questions about the explanatory power of such models. It would appear that the success of a given model lies in how the input to the model is specified (Mikkulainen & Mayberry; Allen & Seidenberg, Plaut & Kello). In at least some cases the representation of the input to the model appears to be exquisitely sensitive to many (though certainly not all) dimensions of the phenomenon in question. This input is then presented to a model which discriminates some of the regularities given in the input, the way a person might. The actual mechanism by which this occurs, however, is not that well understood. A number of decisions that are relevant to the mechanism (how the input is
simplified, the exact learning rule, the learning constant, the number of units in the hidden layers) seem to be relatively unconstrained. Does this leave us, then, with purpose-built machines that have ungeneralizable architectures which render them just as ad hoc as the rules they are supposed to replace? Given these difficulties, it is difficult to get a hold on their explanatory power as it pertains to human development (see McCloskey, 1991).

Nonetheless, we do agree that the connectionist paradigm offers very interesting opportunities for achieving a high degree of rigour, specificity, and explanatory power. From our background as experimentalists, we wonder whether the following methods could be employed to further improve the explanatory power of connectionist models: 1) CONTROL MODELS that either have or lack certain theoretically-motivated features in order to determine which aspects of the structured input are crucial and which are not, 2) EXPERIMENTS with models that sensitively test and report the strengths and limitations of a particular theoretically-motivated architecture, and 3) use of simulations less as the sole evidence for the plausibility of a particular model, and more to generate new and interesting hypotheses for experiments with people.

**Notes on ‘input’**

As we noted above, the emergentist framework is a constructivist one in that it emphasizes the interplay between the organism and the environment. Many of the ideas presented in *EL* focus on the role that regularities (statistical or otherwise) in the input play in children’s acquisition. Above, we questioned whether it is always appropriate to view these regularities as simply existing in the input. However, even if this problem were solvable within the emergentist framework, another issue arises. When one considers examples of emergence in the physical world (e.g. the structure of a honeycomb) it seems innocuous to assume that the ‘input’ has a structure independent of the organism. However, in the case of human communication, the input is itself the result of the developmental process one is trying to elucidate. Attributing direct causal power to the regularities of the input seems to beg the question, how did the input become so regular?

A second noteworthy aspect of this characterization of the organism–environment interaction is that it renders a picture of children who are fairly passive participants in development – they absorb statistical regularities and similarity, but they do not necessarily specially seek them out. This view stands in stark contrast to alternative constructivist approaches which focus on the child’s motivation to learn as integral to guiding the acquisition process (Gopnik & Meltzoff, 1997, Wellman & Gelman, 1998). In these alternative views, the input is not something that is simply out there from which regularities can be extracted, but something that the child needs to interpret in conceptual terms. This line of reasoning grants a very different
role to input wherein parent–child conversations are seen as an important source of information guiding children’s language learning (Callanan, 1990), categorization (Gelman et al., 1998), and development in other cognitive domains (Sabbagh & Callanan, 1998).

SUMMARY

EL provides an intriguing view of language and its development seen through the lenses of a multi-disciplinary group disenchanted with the limitations of formal approaches to the problem. In the course of the volume, the reader gets a wealth of examples demonstrating how domain-general tools, through their limitations and development, render the processing patterns that give us the apparently rule-driven structures that characterize language, without requiring an explicit representation of the rules. We noted that there is much for language development researchers to be excited about regarding this framework. Nonetheless, we raised a number of concerns regarding whether the framework can truly live up to its promise. Naturally, one would expect that at its inception, a new framework such as the one offered in EL would need refining. Our primary concerns centre around the fact that the most exciting and potentially revolutionary claims are the most difficult to substantiate.

Finally, it is important to emphasize the point that there is no strong consensus viewpoint on what constitutes an emergentist framework. Here, for purposes of evaluation, we have characterized one view, recognizing that it is not held by all (or perhaps even most) of the authors contributing to EL. One important decision we made was to consider emergentism in its strong form as a commitment to the idea that domain-specific knowledge need not exist to create language learning. However, we can envision an emergentist approach that includes a role for simple domain-specific principles that interact with the environment to create complexity. A few of the chapters included in this volume seemed to consider emergentism in this manner, and this will certainly be an interesting starting point for future research.

REFERENCES


