evading ever since I pointed it out more than a decade ago (Bickerton 1990). The cognitive discontinuity between humans and prehumans precisely mirrors the linguistic discontinuity between linear and hierarchical concatenation. Can this be mere coincidence?

Whether it is or not, any gradualist account of language evolution that does not even try to explain why, if language evolved gradually, human cognition and behavior did not evolve equally gradually has little explanatory value. I do not wish to single out Jackendoff in this respect. He himself says, "I see no need at the moment to hold myself to a higher standard than the rest of the field" (p. 237). But if somebody doesn't do just that, we might as well give up on language evolution.

Why behavior should matter to linguists

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Abstract: Jackendoff's *Foundations of Language: Brain, Meaning, Grammar, Evolution* has many points of similarity with Skinner's analysis of verbal behavior, though the former emphasizes structure whereas the latter emphasizes function. The parallels are explored in the context of a selectionist account of behavior in general and of verbal behavior in particular. Part of the argument is that behavior drives evolution and therefore also drives brain organization. Another concerns itself with the nature of explanation. Recent experimental developments in behavior analysis are reviewed as potential contributions to an understanding of language that incorporates its functional as well as structural dimensions.

It is easy to see where the constructive collaboration Jackendoff invites in his Preface (Jackendoff 2002) can be offered; but to present the relevant material within brief compass is hard. Despite many affinities outlined below, I argue that more is to be gained by focusing on how linguistic structures can be illuminated by behavioral functions than by using linguistic structures to illuminate hypothetical brain mechanisms.

It helps that Jackendoff places his account firmly within an evolutionary context, because evolution is driven by behavior. Whether an organism survives and reproduces depends on what it can do and the conditions under which it does it. Its environment consists not only of the physical world but also members of its own and other species. Its brains and muscles and other organ systems all evolved in the service of its behavior. Therefore, it is a reasonable proposition that behavior drives brain structure, not only through evolutionary contingencies that select behaving organisms with certain kinds of brains, but also through environmental contingencies that shape different patterns of behavior and alter brains within the lifetimes of individuals. Jackendoff acknowledges this when he states that "perceptual systems have evolved in order that organisms may act reliably in the real world" (p. 308).[1] But if behavior drives brain organization, behavior is the place to start (Catania 1972; 1995b; 1997; Catania & Harnad 1988; Skinner 1988).

Let us first dispose of some common misconceptions. Behavior is not defined by muscle movements or by glandular secretions. It is defined by function rather than form. Shifts of attention are behaviors, for example, even without overt movement; what matters is that they are modified by their consequences. So, also, are seeing and looking. You can look without seeing and see without having looked; both are subject to contingencies and either can occur in the absence of visual stimulation (Jackendoff calls these actions *percepts,* as in his bug example on pp. 311–12, but thinking of them as actions rather than states has advantages).

In biology, studies of structure and function are respectively called anatomy and physiology. Their priorities were once an issue (Russell 1916). Behavior also has both structure and function. For example, when a horse runs, muscle flexions combine to produce coordinated leg movements that change with shifts from one gait to another. All gaits, either natural (trotting) or trained (the rack), are constrained by neurophysiological and mechanical factors and constitute a grammar of the horse's running. But that grammar is orthogonal to function: for example, when and where the horse runs; with which gait; what consequences follow. As organs differ in anatomy and physiology, so also varieties of behavior differ in what they look like and what they do. A horse may overtake another at lope or gallop, and gallop in overtaking others or in escaping from predators. In the former, actions of different form have similar functions; in the latter, actions of similar form have different functions. Language too has both structure and function.

Beyond the structure-function distinction is the issue of selection. Within individual lifetimes behavior is selected by its consequences, much as organisms are selected over generations by evolutionary contingencies. Operants, classes of behavior selected by their consequences, are fundamental units of behavior defined by function. All operants participate in three-term contingencies in which discriminative stimuli set occasions on which responses have consequences (e.g., at traffic intersections, the consequences that follow from stepping on the gas or the brakes vary with the colors of the traffic lights). Parallels between natural selection in phylogeny and in ontogeny have been explored in detail (Catania 1973a; 1973b; 1987; 1996b; Skinner 1935; 1938; 1981; Smith 1986). Behavioral accounts are often identified with S-R associations, but behavior analysis is a selectionist rather than associationist account (for a more detailed discussion, see Catania 1998; 2000).

The poverty of the stimulus (Chomsky 1959; Crain 1991) takes on a different aspect in the context of selection. The selection of operant classes by their consequences does not depend on extensive sampling of negative instances. Consider the evolutionary analogy: Populations are not selected from pools exposed to all possible environments, and not all variations are included in the pools upon which selection operates. It remains reasonable to consider structural constraints on what is selected, but those constraints do not negate genealogy. As Darwin made abundantly clear, both structure and function must be viewed through the lens of selection.

Other biological analogies are also relevant. For example, organisms have been characterized as theories of their environments. Jackendoff exemplifies this view when he pushes the world into the mind. But it is a risky move (Andresen 1990), and parallel moves in biology have not fared well. For example, genetic material is no longer said to carry blueprints of organisms, nor does it reveal properties of the environments within which it was selected; it is instead best regarded as a recipe for development (Dawkins 1982). It is, similarly, a useful move to think of what is remembered as a recipe rather than a blueprint for recall.

With these preliminaries, let us compare Jackendoff and Skinner. In this undertaking, it is on the one hand not reassuring that Jackendoff disposes of behaviorism with a 1913 reference to John B. Watson (p. 280) and comments on Skinner only in passing without citation (p. 372). On the other hand, it is intriguing that so many of Jackendoff's distinctions and categories have clear parallels in Skinner's (1957) account. Both present modular systems and their modules are necessarily heterogeneous (cf. Jackendoff 2002, p. 160). Both consider how the modules can arise and how they are coordinated with each other. When Jackendoff says "reading, for example, acts like a module in an accomplished reader, but it requires extensive training for most people in a way that the phonology-syntax module does not" (p. 227), he parallels Skinner's textual, tact and echoic classes of verbal responses. Consistent with the status of operant classes, Skinner's modules are based on considerations of function rather than form: "we cannot tell from form alone into which class a response falls" (Skinner 1957, p. 186).

Both Skinner and Jackendoff wrestle with the problem of defining verbal classes in terms of reference or meaning or environ-

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mental determinants, arguing that nouns and verbs cannot be viewed as words corresponding to things and actions, respectively. Both are concerned with how terms for nonexistent entities (e.g., unicorns) arise as extensions from verbal units acquired in the context of real entities (e.g., horns), and with how entities that cannot be pointed to can come into existence through words (e.g., months, nations). While doing so, both also grapple with the transition from the local and concrete to the abstract and metaphorical (e.g., Jackendoff 2002, p. 299; Skinner 1957, pp. 91–116). Because his classes are defined by function, Skinner easily handles cases where members do not share physical properties: "Sometimes a genuine extension seems to occur when no similarity between stimuli expressible in the terms of physical science can be demonstrated" (1957, p. 97).

Both Jackendoff and Skinner reject chaining as a general basis for generating utterances, consistent with Lashley's (1951) arguments about sequential structure, but both allow sequential dependencies (rote sequences) in specific instances. That Skinner made use of such a module, which he called *intraverbal,* demonstrates that he did not regard such sequential processes as universal. Both discuss ways in which sequences, first generated as chains, can become units in their own right. Both recognize that some but not all large verbal units are constructed as they are produced (constructed online versus memorized).

Both deal with single-word "primitive" verbal units, such as *hello* and *ouch* and *psst.* Both allow verbal units of varying size, from phonemes through syllables and words to sentences and larger forms. Both classify and interpret verbal devices such as metonymy and metaphor, and both use errors and pathologies for distinguishing among classes of verbal behavior.

Both are especially concerned with the coordinations that produce new verbal instances. Jackendoff deals with them in terms of multiple components and interface rules, and Skinner, in terms of multiple causation, the simultaneous determination of different aspects of an utterance by different variables (as when participants and timings and actions simultaneously determine sentence features such as nouns and verbs and tenses). Compare Jackendoff on generative components:

> What is new in the present approach is that the idea of multiple generative components . . . has been extended in thoroughgoing fashion to every part of the grammar, so that it becomes a fundamental architectural design principle. (Jackendoff 2002, pp. 129–30)

and Skinner on the active editing of ongoing speech:

> In the processes of composition and editing the speaker arranges, qualifies, withholds, or releases verbal behavior which already exists in some strength in his repertoire. Much of the behavior emitted upon any occasion "just grows" – it springs from the current changing environment and from other verbal behavior in progress. (Skinner 1957, p. 228)

Perhaps most significant, both deal with the hierarchical structure of verbal behavior, and, in particular, with nestings in which higher order structures depend on the speaker's awareness of other levels (as in specifying one's confidence in something said in a phrase like "I am sure that . . ."). Some of these higher order units cannot stand alone. Skinner (1957, pp. 311–43) wrote of them as *autoclitic* processes – in the sense of verbal behavior that leans upon other verbal behavior – and distinguished between relational and descriptive forms further divided into qualitative and quantitative and other dimensions (Catania 1980). Jackendoff makes similar distinctions, though applying the relational and descriptive labels somewhat differently. Though both discuss structure mainly in terms of rearrangements and transformations of units, they also allow a role for frames within which units can be placed (e.g., Jackendoff 2002, pp. 63, 176; Skinner 1957, pp. 336, 346).

When Jackendoff says "we must consider the domain of linguistic semantics to be continuous with human conceptualization as a whole" (p. 282), it is reminiscent of Skinner's argument that thinking and behavior are coextensive; when he says "the seams of the mind must be determined empirically" (p. 283), he seems to address what Skinner (1938) called natural lines of fracture in behavior.

The commonalities have not been exhausted (e.g., Jackendoff's activation and Skinner's priming, or concern with verbal dimensions like tone of voice or with the fuzzy boundaries of verbal classes, or appeals to the practices of verbal communities). But it is also crucial to acknowledge the vast differences, while noting that the convergences evident in such divergent approaches may themselves be of particular significance. Having already considered their different stances on brain and behavior, I concentrate on modes of explanation.

Jackendoff often offers explanations, when what he has provided is description (e.g., pp. 336–42). But the relation between sentence and structural diagram is similar to that between sentence and paraphrase: Diagrams may make subtle structural features easier to see and may help in taxonomic development, but they do not specify where the features came from or how they work or what effects they may have (cf. Skinner 1957, p. 388, on paraphrase).

It is good that Jackendoff is explicit about rules being in the heads of linguists rather than language users: "rules are nowhere present in the f-mind in the form we write them. Rather, these rules *are* indeed just descriptions of regularities in the organization of linguistic memory" (p. 57; cf. p. 167). Structure alone cannot justify explanatory appeals to conformity (p. 171), spontaneous generation (p. 188), convenience of usage (p. 358), or insight (p. 390).

I can only touch on the problems raised when language is interpreted in terms of the metaphors of meaning and communication (Catania 1998, pp. 239–78; Lakoff 1987; Lakoff & Johnson 1980). Those ancient philosophers who thought that vision depended on something traveling from the eye to the thing seen had it backwards, but we can be similarly misled when our language of reference leads us to speak of words as referring to things in the world, and therefore to neglect the other direction, in which events occasion what we say or provide conditions under which we learn what words mean (cf. Day 1969; Wittgenstein 1953). Jackendoff occasionally seems to move in this direction: "We do not have to worry about whether the phrase really refers, only about how language users treat it" (p. 325, n. 24). Furthermore, to speak of communication as the sharing of meanings is to neglect the irreducible function of all verbal behavior, which is that it is a way in which one individual can affect the behavior of another. This is not to dispose of meaning and communication, but rather to recognize that both are derivatives of that more fundamental function (Catania 1990; 1991; 1995b; 2001).

With regard to description as a form of explanation, Jackendoff's statement that "We can determine properties of 'language in the world' only through its manifestations in human linguistic intuition and behavior" (p. 298) seems to share something with Skinner's (1957, p. 6) remark that: "There is obviously something suspicious in the ease with which we discover in a set of ideas precisely those properties needed to account for the behavior which expresses them."

Skinner, instead, looks to the environment. In accounting for the difference between offering a teapot to Nancy and offering Nancy a teapot (p. 54), we need to know whether a teapot was offered to Nancy, not Jane, or whether Nancy was offered a teapot, not a teacup. The practices of verbal communities will be more likely than brain structure to tell us whether the Frisbee on top of the house has been roofed or rooved (p. 158). Though it is unusual to say "John stayed the same distance from me he always stays" (p. 321), the sentence may tell us more about how often we interact with people with bodyguards than about how in general we talk about distance. Verbal religious practices will tell us more about the truth value of "God is a trinity" or "God is a man" than will questions about how these sentences relate to the world (p. 294). And the circumstances under which people say or respond to the word "stop" may be more important than whether the word should be regarded as a symbol (p. 239). If the above instances are to be

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paraphrased or diagrammed, environmental antecedents should be incorporated into those forms.

But commentary would be only of historical interest if it were just that Jackendoff has developed a system whose features Skinner had anticipated. It is more important that the behavioral stance has since expanded to new topics that must be taken into account. For example, Skinner hinted at how multiple causation can yield productivity: "We turn now to a different type of multiple control, in which functional relations, established separately, combine possibly for the first time upon a given occasion" (Skinner 1957, p. 229). But he did not go far enough. Experimental studies have since addressed the spontaneous coming together of responses learned separately, in the phenomenon called adduction (e.g., Catania et al. 2000; Esper 1973; Johnson & Layng 1992). Shaping is another source of novel behavior, and variability itself can be selected (Neuringer 2002; Pryor et al. 1969). Higher order classes provide still another source (Catania 1995a; 1996a), illustrated by generalized imitation, as when a child imitates an action never before seen or imitated (Baer et al. 1967; Gewirtz & Stingle 1968; Poulson & Kymissis 1988; Poulson et al. 1991). Other higher order examples are those of equivalence classes, in which new behavior emerges from reflexivity, symmetry, and transitivity relations among the members of stimulus sets (Catania et al. 1989; D'Amato et al. 1985; Dube et al. 1993). These relations cannot be derived from stimulus properties, and so can only be dealt with in terms of the environmental contingencies that created them (Catania 1996b; Vaughan 1988). They are of particular relevance for interpreting relations among words and other events (in other words, meanings), and provide an easy bridge to many hierarchical structures discussed by Jackendoff.

Other extensions grounded in experimental findings are to the roles of echoic behavior and of responses to pointing in the development of naming in children (Horne & Lowe 1996), functional effects of naming (Wright et al. 1990), developmental transitions from nonverbal to nonverbal behavior (Bentall & Lowe 1987; Bentall et al. 1985; Moerk 1992), the shaping of verbal behavior and correlated changes in subsequent nonverbal responding in verbal governance (Catania, 2003; Catania et al. 1982; 1990; Chadwick et al. 1994; Greenspoon 1955; Lovaas 1964; Rosenfarb et al. 1992; Shimoff & Catania 1998; Skinner 1969), and ways in which verbal governance depends on differential attention to different kinds of verbal stimuli, as when the bringer of bad news is poorly received (Dinsmoor 1983).

Jackendoff has offered "an open-mindedness to insights from whatever quarter" (p. xiii) and has asked for "all the help we can get from every possible quarter" (p. 429), so my hope is that the news offered here in return will not be poorly received. The behavioral bathwater is gone but the baby has thrived and is ready to rejoin the company of linguists to help them with their work.

NOTE

1. Unless otherwise noted, pages refer to Jackendoff (2002).

"Grammar box" in the brain

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Abstract: Brain activity data prove the existence of qualitatively different structures in the brain. However, the question is whether the human brain acts as linguists assume in their models. The modular architecture of grammar that has been claimed by many linguists raises some empirical questions. One of the main questions is whether the threefold abstract partition of language (into syntactic, phonological, and semantic domains) has distinct neural correlates.

There is a growing number of data-giving evidence on brain specialization for language, although many language processes, in spite of their distinct function in the architecture, cannot be localized to just one particular area of the brain. However, as we know from brain measures and especially from brain-imaging data, one particular area or part of the network is involved in different tasks, and there is a spatial and temporal overlapping of the processes. Brain-activity data seem to prove the existence of qualitatively different structures in the brain processing phonological, syntactic, and semantic information. However, the question is whether the human brain acts as linguists assume it does in their models.

Jackendoff has many well-elaborated questions about the nervous system serving language functions, eight of them listed in his concluding remarks (pp. 422–23). His questions will attract the attention of neuroscientists, as Chomsky's concept of Universal Grammar has given place to discussions and studies on relating abstract entities with physiological correlates. According to Jackendoff's statement, Universal Grammar is a limited set of "attractor" structures that guides language acquisition through inheritance. However, the question is what do we mean with inheritance, innateness, and wiring, when referring to the biological relevance of Jackendoff's reconfigured generative grammar.

New findings in genetics further strengthen the belief that language is specified by biological factors. The recent discovery of the FOXP2 gene (Lai et al. 2001) supports the assumption of linguists that the development of language is set by innate factors. As revealed by the data of Cecilia Lai and her coworkers, a mutant version of the FOXP2 within chromosome 7 provokes Specific Language Impairment (SLI). However, the FOXP2 data may irritate some linguists rather than satisfy them, because SLI is a heterogeneous class of verbal disturbances and does not correspond to a single domain of rule applications. Therefore, I think, Jackendoff is correct when he refers to a language toolkit, and assumes innate capacities instead of a language system lodged in the brain.

The modular architecture of grammar claimed by many linguists raises some empirical questions. One of the main questions is whether the threefold abstract partition of language (into syntactic, phonological, and semantic domains) has distinct neural correlates. There are experimental data that prove semantic information has a distinct representation in the brain. Another fundamental question is whether syntactic processing is associated with dedicated neural networks. Syntactic processing during sentence reading has been investigated in several functional neuroimaging studies and showed consistent activation of the *pars opercularis* of Broca's area (Caplan et al. 1998; Just et al. 1996). However, sentences presented in the auditory modality (Caplan et al. 1999) lead to activation of the *pars triangularis.* Moreover, in visual tasks the anterior *cingulate gyrus* and the right *medial frontal gyrus* were activated. This finding was interpreted as a correlate of phonological encoding and subvocal rehearsal. A current study by Newman et al. (2003) adds further empirical evidence to partly distinct networks specialized for syntactic and semantic processing. Their fMRI data suggest that separable subregions of the Broca's area contribute to thematic and syntactic processing. In their study, the *pars triangularis* was more involved in thematic processing and the *pars opercularis* in syntactic processing.

Dapretto and Bookheimer (1999) tried to separate the syntactic and lexicosemantic processing in an fMRI experiment. In the semantic condition single words, in the syntactic condition full sequences, were changed. The authors used passive constructions for syntactic change; and, I am sure Jackendoff would argue, passive constructions do not necessarily preserve the semantic content of their active counterpart. In spite of the assumed semantic change in the passive construction, Dapretto and Bookheimer (1999) found activation in the Broca's *pars opercularis.* In a recent study, Moro et al. (2001) applied syntactic, morphosyntactic, and phonotactic tasks for "pseudosentences" and found activation in the Broca's area *pars opercularis* and in the right inferior frontal region during syntactic and morphosyntactic processing. A local network shared by morphological and syntactic computations