The parallel architecture

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8 The Parallel Architecture

Abstract: The Parallel Architecture is a constructional approach to the knowledge of language based on two fundamental ideas. First, semantics, syntax, and phonology are independent combinatorial systems that interact through interfaces, often with mismatch. Second, the lexicon includes not only words but also idioms, collocations, and meaningful constructions. Crucially, it also includes all rules of grammar, which are stated in the form of declarative schemas with the form of pieces of linguistic structure containing variables; sentences are constructed by the operation of Unification over these schemas. This configuration allows syntax to be integrated gracefully with phonology, morphology, semantics, and other cognitive capacities, as well as making it possible to embed the theory of linguistic competence in the theory of performance.

1 Goals

The Parallel Architecture (PA; Jackendoff, 1997, 2002) is a constructional theory, close in many respects to HPSG (Pollard and Sag, 1994; Müller and Machicao y Priemer, this volume), LFG (Bresnan, 1982, 2001; Dalrymple and Findlay, this volume), and Construction Grammar (Goldberg, 1995, 2006; Croft, 2001; Hoffman and Trousdale, 2013; Chaves, this volume). It is intended to address the organization of language as a whole and its place in the mind/brain. Three major subcomponents have been developed in detail: Conceptual Semantics (Jackendoff, 1983, 1990, 2007a), Simpler Syntax (Culicover, 1999; Culicover and Jackendoff, 2005, this volume), and Relational Morphology (Jackendoff and Audring, 2016, forthcoming). However, PA also has implications for phonology, language processing, and language acquisition. The present chapter describes the framework and its bearing on syntactic theory. Culicover and Jackendoff (this volume) demonstrate how Simpler Syntax deals with a number of major syntactic phenomena.

The PA is rooted in a mentalist stance: knowing a language implies something stored in the mind of its speakers. Hence the PA reformulates the traditional concerns of generative linguistic theory as (1).

(1) What is the repertoire of linguistic structures available to a speaker of a language? In particular,
   a. What is stored in memory – both in the lexicon and in the grammar?
   b. In what form is this material stored?
   c. How are items in memory combined to create an unlimited number of novel utterances?

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The theory should also engage with psychological concerns:

(2) How are linguistic structures deployed in the mind when producing and comprehending language?

(1) and (2) raise the question of how the speaker's linguistic repertoire comes about:

(3) How does the mind acquire linguistic knowledge? What prior resources does the mind require, and what does the learner require from the environment? How do these resources constrain possible languages?

Pushing still further, we can ask:

(4) Which aspects of the resources for language acquisition are specifically linguistic, and which belong to general mental phenomena such as the ability to categorize, imitate, and engage in social interaction?[1]

Goals (1)–(4) are articulated in Chomsky, 1965. Even if one questions Chomsky's own implementations of these goals (as the PA does), they still remain central.

Ideally, we would add questions such as:

(5) How can (1)–(4) be instantiated in neural storage and neural computation?

(6) How does the brain develop, such that the genetic code can lead to (5), and thence to (1)–(4)?

(7) How did the genetic code that creates a "language-ready brain" develop over the course of the biological evolution of our species?

These goals are largely beyond reach today. Although brain imaging and computational modeling have made some inroads,[2] it is unknown how something like even simple speech sounds are neurally instantiated, much less how biological development builds a brain. Still, linguistic theory should keep these goals in mind, in the hope of eventually closing the formidable gaps between linguistic theory, neuroscience, and developmental biology. (Fitch, 2010 is a good survey of current progress.)

A more immediate aspiration for the Parallel Architecture is *internal* integration. Here we find much contemporary theory wanting. The most influential contemporary approaches to syntax, semantics, and phonology certainly capture important insights about their own domains, but they each have their own formal machinery, only marginally compatible with the others. In contrast, the PA aspires to a theory of lan-

1 Many approaches – e. g. Cognitive Grammar (Langacker, 1987; Broccias, this volume), connectionism (McClelland and Rumelhart, 1986), some versions of Construction Grammar (Goldberg, 1995; Chaves, this volume; Bybee, 2010; Tomasello, 2003) – posit that *every* aspect of language arises from domain-general factors alone: there is no dedicated language faculty. The PA, however, takes the existence of language-specific aspects of mind to be an empirical issue.

2 Smolensky and Legendre (2006) offer an ambitious account of the connection between the "symbolic" digital character of linguistic representations and the more analog processes of neural computation.

guage in which phonetics, phonology, morphology, syntax, semantics, and pragmatics fit together gracefully.

We would also like a theory that affords a natural approach to signed as well as spoken language; to conversation, narrative, and song; to reading; to bilingualism and code-switching; to gesture; and to social aspects of language use. And we would like the theory to engage with accounts of other faculties of mind, affording explanations of, for instance, how we talk about what we see and how we use language to support reasoning (see Section 3.1).

2 Data

Given its broad goals, research within the Parallel Architecture framework is open to any sort of evidence: from introspection, corpus analysis, computational modeling, and genetics, as well as from experimental studies of processing, acquisition, and language impairment, using both behavioral techniques and brain imaging. The framework is also open to evidence from any language, from language variation and language change, and from other cognitive domains and from neuroscience.

In practice, the data motivating the Parallel Architecture have come predominantly from English, but with frequent reference to other languages, primarily Indo-European, but also including for instance Riau Indonesian (Gil, 2009), Pirahã (Everett, 1986, 2005), Al-Sayyid Bedouin Sign Language (Sandler et al., 2005) and Central Taurus Sign Language (Ergin, 2017) (see also Jackendoff and Wittenberg, 2014). The data has largely come from introspective judgments, but evidence has also come from corpus searches, psycholinguistic experimentation, and computational modeling (Culicover and Nowak, 2003).

An important focus of the data invoked by the Parallel Architecture has been unusual and understudied constructions. These "syntactic nuts" (Culicover, 1999) shed important light on the character of the grammar as a whole, as we will see in Section 3.2 below.

Finally, goal (4) above is to determine what aspects of the language faculty are domain-specific and what aspects are domain-general. This requires evidence concerning the structure of other cognitive domains. Accordingly, the PA has examined music (Lerdahl and Jackendoff, 1983; Jackendoff and Lerdahl, 2006), visual/spatial cognition (Jackendoff, 1987; Landau and Jackendoff, 1993), action planning (Jackendoff, 2007a), social cognition (Jackendoff, 2007a), and sequential visual images such as comic strips (Cohn, 2013).

3 Tools

The Parallel Architecture grows out of four fundamental issues: the arrangement and interaction of levels of linguistic structure, the relation between grammar and lexi-

con, unification-based combinatoriality, and the generative vs. relational functions of linguistic patterns. This section takes these up in turn.

3.1 Parallel combinatorial components and interfaces

The basic premise of the Parallel Architecture is that linguistic structure is determined by three independent generative systems – phonology, syntax, and semantics – plus, crucially, the linkages between them. Similar ideas appear in Stratificational Grammar (Lamb, 1966), Lexical-Functional Grammar (Bresnan, 1982, 2001; Dalrymple and Findlay, this volume), Autolexical Grammar (Sadock, 1991), Role and Reference Grammar (Van Valin and LaPolla, 1997), and others. This contrasts with the traditional "syntactocentrism" of generative grammar (Chomsky, 1965, 1981, 1995), which assumes without argument that the only "generative engine" in the grammar is syntax, and that phonology and semantics are derived from syntactic structure.[3]

The independence of phonology from syntax is motivated by the fact that phonological structure includes syllable and foot structure, a metrical grid, an intonation contour, and, where appropriate, a tone tier, none of which can be derived from syntactic structure (Goldsmith, 1979; Liberman and Prince, 1977; Selkirk, 1984). Similarly, in any substantive theory of meaning,[4] semantic structure is built out of entities such as (conceptualized) objects, events, times, and places, rather than NPs and VPs.

Syntactocentrism presumes that phonological and semantic constituency are determined from syntax. However, constituency often fails to match across components, as seen in (8), for example.

(8) a. *Phonology-syntax mismatch*:
Syntax: [[Sesame Street] [is [a production [of [the Children's Television Workshop]]]]]
Phonology: [Sesame Street is a production of] [the Children's Television Workshop]

b. *Syntax-semantics mismatch*
Syntax: that travesty of a theory [*travesty* is head, *theory* is modifier]
Semantics: 'that theory, which is a travesty' [*theory* is head, *travesty* is modifier]

3 Chomsky makes this assumption explicit several times in *Aspects* (Chomsky, 1965, 16, 17, 75, 198). To our knowledge he has never defended it or even questioned it since, at least on empirical grounds.
4 In addition to Conceptual Semantics (the semantic component of PA), such approaches include formal semantics (Heim and Kratzer, 1998), Cognitive Grammar (Lakoff, 1987; Langacker, 1987; Talmy, 1978; Broccias, this volume), and approaches from artificial intelligence (e. g. Schank, 1973; Minsky, 1975; Rumelhart, 1980).

Syntactocentric approaches account for these mismatches by positing covert syntactic structure that matches the semantics, related to the surface by movement and deletion. In contrast, the PA accounts for these misalignments through *interface principles* that link two kinds of structure. Between phonology and syntax, the default linkage matches constituency and linear order; and between syntax and semantics, the default linkage matches head-argument relations. But non-default linkings such as those in (8) are endemic (see also (22)–(24) below).

The upshot is a conception of grammar like Figure 1. The formation rules define well-formed structures in their respective components. The interfaces define permissible linkings between structures in two domains. Hence a well-formed sentence has well-formed structures in each of the three domains, plus well-formed links among the structures. (The direct link between phonology and meaning in Fig. 1 cannot exist in a syntactocentric grammar, but it is altogether possible in PA, for example to link intonation contour in phonology directly to information structure in semantics.)

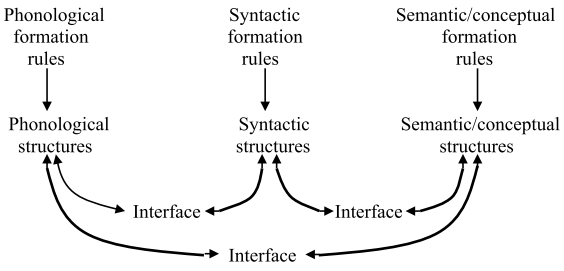


Figure 1: The Parallel Architecture.

The individual components in Fig. 1 have similar fine-scale architecture. Phonology is itself composed of independent generative tiers for segmental structure, tone, metrical structure, and prosodic contour, all linked by interfaces. Similarly, semantics contains quasi-independent but linked subcomponents of argument/event structure and information structure (topic and focus). In syntax, f-structure in LFG (Dalrymple and Findlay, this volume) and the grammatical function tier in Simpler Syntax (Culicover and Jackendoff, this volume) are likewise independent tiers from phrase structure. Exactly what components are necessary, what each of them accounts for, and how they interface with the others are empirical issues (see Section 5.1).

Because its components are related by interfaces rather than derivations, the PA can situate the language faculty comfortably in an overall view of the mind. In particular, it claims that the internal components of language are connected to each other in the same way as language is connected with nonlinguistic mental structure, and in the same way as other faculties of mind are connected with each other, as in Figure 2. For instance, in order to talk about what we see, linguistic representations must

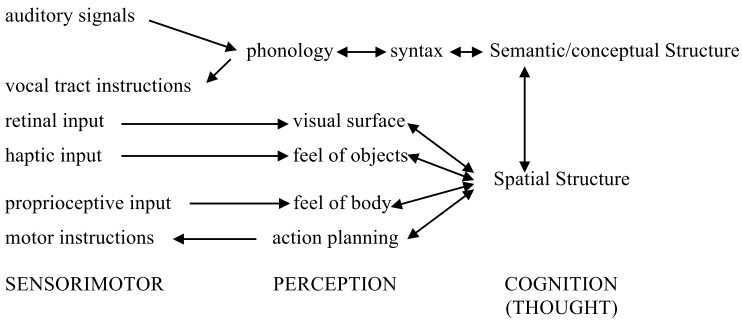


Figure 2: Overall layout of cognitive capacities.

be connected to visually-based representations of how objects look and how they are situated in the environment. Such representations cannot be derived from language or vice versa: vision and language have to connect through a system of linking principles (Jackendoff, 1987, 1996; Landau and Jackendoff, 1993). Similarly, phonological structures must be linked to auditory input and to vocal tract motor instructions by interface principles that have nothing to do with syntax (Jackendoff, 1997, Section 2.1.).

Moving to the rest of the mind, visually based representations of shape and spatial layout must be correlated with representations derived by hapsis (the sense of touch) and proprioception (the body senses). None of these can be derived from the others; rather they must be related by principles that establish equivalences between them – interfaces in our sense. Navigation and manipulating objects can be visually guided, through principled correspondences between visual perception and the formulation of action. This overall uniformity is impossible to achieve in a classical framework. (See Jackendoff, 2011 for more discussion.)

The PA also offers connections to additional domains of linguistic structure. For instance, sign language has phonology built from structured gesture, with interfaces to vision and the motor system. Formal versus casual speech register can be treated as an interface between perceptions of social situation and the use of particular words or expressions. Orthography has internal principles that define the alphabet, plus an interface to the visual system, so that the reader can see writing, plus an interface to phonology and/or morphology that stipulates the correspondence between spelling and speech.[5] (See Jackendoff and Audring, forthcoming.)

5 One near-universal principle of spelling is that orthographic linear order corresponds to phonological temporal order. However, even this basic principle is violated in English orthography (a) by silent *e*, which affects vowels two segments to the left (*can*/*cane*, *pin*/*pine*), and (b) by combinations like <$5>, read in the opposite order, 'five dollars'. Similarly for German numerals, e. g. <29> = 'neunundzwanzig' ('nine-and-twenty').

3.2 The structure of the lexicon

We return to the goals in (1), restated here:

(9) a. What is stored in memory that constitutes one's knowledge of language?
b. In what form is this material stored?
c. How are items in memory combined so as to make it possible to create an unlimited number of novel utterances?

Traditional generative grammar answers that words (or morphemes) are stored in the *lexicon*, while rules constitute the *grammar* and are responsible for all combinatorial processes. Lexical items are taken to be arbitrary associations of phonological, syntactic, and semantic structure. Anything that can be predicted by a rule is absent: the lexicon is "simply an unordered list of all lexical forms" (Chomsky, 1965, 84), "really an appendix of the grammar, a list of basic irregularities" (Bloomfield, 1933, 274). This encourages the view that the grammar and the lexicon are altogether different kinds of knowledge and are stored differently in the brain (as has in fact been claimed by Ullman, 2015).

The PA, along with Cognitive Grammar and especially Construction Grammar, rejects this strict distinction between grammar and lexicon. Rather, rules of grammar are stated in the same format as words: they are pieces of stored linguistic structure, and hence can be considered lexical items. There is a continuum between words and rules: a lexical item is more word-like if it consists of fully specified material; it is more rule-like to the extent that it contains variables (underspecified material). Construction Grammar calls the latter items *constructions*; following the terminology of Construction Morphology (Booij, 2010), we will call them ***schemas***.[6]

Let us illustrate the continuum between words and schemas. Every theory views a word as linking a piece of phonology, a piece of meaning, and a collection of syntactic features such as category, number, grammatical gender, and so on. These components are customarily enclosed in square brackets. Our notation instead coindexes the three components, as in (10).

(10) Semantics: $[\text{CAT}]_1$
Syntax: $[\text{N, SG}]_1$
Phonology: /kæt/$_1$

We take the subscripts to mark the ends of association lines: *this* piece of semantics is linked to *these* syntactic features and *this* pronunciation. Upon hearing /kæt/, one

6 Radical Construction Grammar (Croft, 2001) extends the term *construction* even to words like *dog*. We prefer the term *lexical item*. We also avoid the term *constraint*, used in "constraint-based" theories such as LFG, HPSG, and Optimality Theory (Legendre, this volume). A "constraint" *constrains* what you can say, or stipulates what you *can't* say or want to *avoid* saying. We prefer to think of schemas as encoding affordances for expression – generalizations about what you *can* say.

can posit a noun in syntax and CAT in semantics; and one can express the meaning CAT by connecting it to a noun in syntax and to /kæt/ in phonology. In other words, a word is a small piece of the interface components in Fig. 1, and the coindex serves as an ***interface link***. There is no separate "lexical interface"; words participate in the more general interfaces among the three structures.

(10) is a stereotypical word, with structure in semantics, syntax, and phonology. But some words lack one or more of the components. For instance, the words in (11) can occur alone as full utterances, and they do not combine with other words, except by parataxis (12a) and in quotative and metalinguistic contexts (12b,c), into which anything can be inserted, even a phrase of another language.

(11) *Phonology and semantics, no syntax*:
hello, ouch, yes, oops, gosh, dammit, upsy-daisy, allakazam

(12) a. Hello, Bill.
b. "Hello," she said.
c. the word *hello*

The PA characterizes these words as linkages of phonological and semantic structure. They offer no evidence for syntactic category or for a more canonical "underlying" syntactic structure from which they can be derived. Lacking syntactic features, they appear only in contexts where syntactic features play no role.[7]

A few words of English, underlined in (13), have syntax and phonology but no meaning, functioning only as "grammatical glue."

(13) *Phonology and syntax, no semantics*:
a. It's hot in here.
b. Do you want a drink?
c. a picture of Bill
d. I forgot that it's going to rain.
e. He wants to get out of here.

There are even stored pieces of phonology with neither syntax nor meaning. Their function is just to fill up metrical structure in nursery rhymes and songs. Someone who knows the lyrics in question knows these items.

(14) *Phonology, no syntax or semantics*:
fiddle-de-dee, hey-diddle-diddle, e-i-e-i-o, hickory-dickory-dock, eenie-meenie-minie-moe

7 These items are examples of the dashed phonology-semantics interface in Fig. 1. Hence they are problematic for a syntactocentric theory, in which semantics and phonology must be derived from syntax.

The simplest treatment of these items is to put them in the lexicon alongside ordinary words. They (mostly) obey English phonotactics, so they have phonological structure. But lacking syntax and semantics, they cannot appear in ordinary sentences except as phonological intrusions. In other words, their intrinsic properties account for their distribution, and the theory need not distinguish them further, say as elements of a "babblecon."[8]

Words with argument structure have variables in their lexical representation, so they are already somewhat schema-like. (15) shows the verb *devour*. The underlined parts are variables that must be instantiated.

(15) Semantics: $[_{\text{Event}}$ DEVOUR$_2$ (Agent: $\underline{\text{X}}$, Patient: $\underline{\text{Y}}_{\text{y}}$)]
Syntax: $[_{\text{VP}}$ V$_2$ $\underline{\text{NP}}_{\text{y}}]$
Phonology: /dəvawr/$_2$

Coindex 2 links the semantics with a verb in syntax and with the pronunciation *devour*. The semantic structure is an Event with an Agent and a Patient (plus further omitted details). The Agent (variable *X*) is linked to subject position in syntax by principles we won't describe here (see Jackendoff, 1990); the Patient (variable *Y*) is linked to the direct object position in syntax. The syntactic structure contains a variable NP, which marks this verb as obligatorily transitive, contrasting with, say, *eat*, whose Patient need not be expressed.[9] The coindex that encodes the linking of Patient to direct object is a variable *y* rather than a number. This reflects the fact the Patient variable in semantics is linked to whatever instantiates the direct object variable in syntax.

The lexicon also contains units larger than words: thousands of idioms, clichés, and other "prefabs." For example, *chew the fat* has phonological structure, the syntactic structure of a VP, and a semantic structure approximately equivalent to *converse idly* (again, the variable *X* is the Agent argument).

(16) Semantics: $[_{\text{Event}}$ CONVERSE^IDLY (Agent: $\underline{\text{X}}$)]$_3$
Syntax: $[_{\text{VP}}$ V$_4$ $[_{\text{NP}}$ Det$_5$ N$_6$]]$_3$
Phonology: /čuw/$_4$ /ðə/$_5$ /fæt/$_6$

What makes (16) an idiom is that the entire VP is co-indexed with the meaning (coindex 3), but its words are not (coindices 4, 5, 6). Hence the whole means something different from its parts. We know that (16) has internal syntactic structure, because

8 The items in (13) and (14) are problematic for those versions of HPSG, Cognitive Grammar, and Construction Grammar that insist that every lexical item is a sign that pairs a form (phonology and syntax) with a function (semantics). These items have form, but they have no function in the intended sense.

9 This notation expresses subcategorization without introducing subcategorization features such as [+ ___ NP] or abstract case-marking features.
A complication: In Simpler Syntax, as in LFG, the semantic variable Y is actually linked to the second position in the Grammatical Function tier, which is realized in syntax as either the direct object of an active or the subject of a passive. See Culicover and Jackendoff (this volume, 2005, chapter 6).

the verb conjugates like a normal verb: its past tense is *chewed the fat*, not **chew the fatted*. Again, idioms need not be housed in another "place" in the grammar, separate from words; they are idioms simply by virtue of their internal syntactic structure and their noncompositional meaning.[10]

Stored items need not be semantically idiosyncratic. Clichés and collocations like (17) mean pretty much what they should mean compositionally, but they are still identifiable as stored pieces of English that are part of native command of the language. (Examples from the Wheel of Fortune corpus, Jackendoff, 1997; see also Corrigan et al., 2009.)

(17) baby-blue eyes, open twenty-four hours, quiet as a mouse, reckless driving, rosy cheeks, see you later

The idioms in (18) have argument structure: they take a direct object, encoded as a variable in the idiom's syntactic structure. This is linked to a variable in semantics, parallel to the variables in *devour* (15).

(18) take NP for granted
put NP on ice
give NP the once-over

Most idioms have canonical syntactic structure; for instance (17)–(18) are standard VPs. However, the syntax of idioms like (19) is unusual.[11]

(19) day in day out
by and large
for the time being
all of a sudden
over (and over) (again)

Some idioms with non-canonical structure, such as those in (20), serve as full utterances, and they do not embed except in quotative contexts and possibly in indirect speech.

(20) How about XP? (cf. **I'm wondering* (*whether*) *how about lunch*.)
Prt with NP! (*off with his head*, *down with the government*, etc.)
(cf. **The crowd demanded* (*that*) *off with his head*.)
far be it from NP to VP (cf. **Fred said that far be it from him to give up*.)
suffice it to say that S (cf. **Henk said that suffice it to say that* . . .)]

10 The existence of (16) does not preclude a literal interpretation as well. On the partial mobility of only some idioms (*the cat was let out the bag*; **the bucket was kicked*), see Jackendoff (1997, 166–171).
11 Distributed Morphology (Marantz, 1997; Embick and Noyer, 2007) constructs the syntax of idioms by normal syntax, and the Encyclopedia provides the idiomatic meaning. However, this offers no way to generate idioms with idiosyncratic syntax such as (19) and (20).

Another class of "constructional idioms" have canonical syntax but unusual semantics. These play a major role in both the Parallel Architecture and Construction Grammar. Consider (21) (Jackendoff, 1990, Goldberg, 1995).

(21) *Way*-construction:
[$_{VP}$ V pro's way PP]
Jerry joked his way out of the meeting. (= 'Jerry went out of the meeting joking')

Syntactically, (21) is a typical verb phrase. However:

- The verb *joke* doesn't usually take a direct object, but (21) has the phrase *his way* apparently in object position. The verb cannot have a direct object of its own (**Jerry told jokes his way out of the meeting*).
- *Joke* doesn't normally select a path expression (**Jerry joked out of the meeting*).
- The sentence means that Jerry *went* out of the meeting, even though there is no verb of motion.
- *Joke* describes the manner in which he went out of the meeting (alternatively, the means by which he got out of the meeting).

Hence (21) involves an absurdly non-canonical mapping between syntax and semantics. Any verb of the appropriate syntactic and semantic type is possible: you can drink your way across the country or knit your way through a conference.

The construction can be formalized approximately as the schema in (22), which links semantic, syntactic, and phonological structures. It is noncanonical because the verb is linked to a manner (or means) modifier in semantics (coindex *z*), while the semantic head is the function GO, which does not link to syntax at all. Meanwhile, the direct object in syntax links to the phonology *way* but not to semantics (coindex 8), and the PP links to the path of motion.[12] (We omit notation for binding the pronoun to the subject.)

(22) *Way-construction*
Semantics: [GO (Agent: $\underline{X}$, $\underline{Path}_y$); WHILE ($\underline{F}_z$ (Agent: $\underline{X}$)]$_7$
Syntax: [$_{VP}$ $\underline{V}_z$ [$_{NP}$ $\underline{Pro}$+Poss N_8] PP_y]$_7$
Phonology: /wej/$_8$

(23) illustrates further constructional idioms, with different semantics, marked by *away* and *head* (or other body part) *off*.

(23) a. *Time-away construction*:
[$_{VP}$ $\underline{V}$ [$_{NP}$ (*time*)] away]
Fred drank the afternoon away. (= 'Fred spent/wasted the afternoon drinking')

12 Goldberg, 1995 has a slightly different account of the role of *way*.

b. *Head off construction*:
[$_{VP}$ V Pro's head/tush/butt off]
Suzie sang her head off. (= 'Suzie sang a lot/intensely')

Knowing these constructions is part of knowing English; there are not precise cognates even in its close relatives German and Dutch. For each construction, a speaker has to learn and store its syntactic structure, how its constituents correspond to semantics in other than the normal way, and the phonology of the designated elements *way*, *away*, and *head off* that signal that something unusual is going on.

Other constructions of this sort have no distinguishing phonological content, so they depart still farther from canonical word- and idiomhood.

(24) a. *Sound+motion construction*:
[$_{VP}$ V PP]
The bus rumbled around the corner. (= 'The bus went around the corner, rumbling')

b. *Inverted NP construction*:
[$_{NP}$ a/this/that N of an N]
that travesty of a theory (= 'that theory, which is a travesty')

c. *Light verb construction*:
[$_{VP}$ V NP NP]
Pat gave Kim a hug. (= 'Pat hugged Kim')

d. Casual paratactic conditional:
[S, S]
You break my chair, I break your arm. (Ed Merrin, 12 June 2014)

In (24a), the bus *went* around the corner, making rumbling sounds, but without a verb of motion. In (24b) (= (8b)), the syntactic head is *travesty*, and *theory* is a modifier. But semantically, *theory* is the referent of the expression and *travesty* is an evaluative modifier. In (24c), the direct object *a hug* provides the semantic content normally expressed by a verb, and the verb is a dummy that contributes aspectuality and provides argument positions. Finally, (24d) has no *if-then*, but the conditional meaning is perfectly clear.

A speaker has to learn and store each of these rule-like constructional idioms as an association between a syntactic complex and a semantic complex. But the basic formalism is the same as for words – except that the syntax is composite, as with idioms, and in these cases there is no associated phonology.

Again, it is important to recognize that constructional idioms are not rare oddities: languages are full of them. Within the PA, they emerge as stored pieces of noncanonical syntax-semantics correlations containing variables, sometimes with accompanying phonology, sometimes not.

Now: The very same formalism can be used to state phrase structure rules as syntactic schemas, without any association to phonology or semantics. For instance, the traditional rule (25a) for the English transitive VP can be restated as the declarative schema (25b), a syntactic "treelet" in the sense of Fodor (1998).

(25) a. VP → V – (NP) – . . .
b. Syntax: [$_{VP}$ $\underline{V}$ – ($\underline{NP}$) – . . .]

Such pieces of pure syntactic structure are also basic building blocks for Tree-Adjoining Grammar (Joshi, 1987; Frank and Kroch, 1995).

How should we think of schema (25b)? Extending the analysis of the phenomena in (11)–(24) just one step further, we conclude that (25b) is just another sort of lexical item. The lexicon has items with just phonology like *fiddle-de-dee*, items with just phonology and syntax like do-support *do*, items with just phonology and semantics like *hello*, and items such as idioms and meaningful constructions with phrasal syntactic structure and syntactic variables. (25b) is an item with only syntactic structure – just one more logical possibility. Its variables license novel, freely combined VPs in syntax.

The upshot of all this is that the lexicon – the storehouse of linguistic knowledge – looks very different from the traditional lexicon. Stereotypical words are fully specified lexical items; stereotypical rules (now stated as schemas) are lexical items that consist entirely of variables. In between are many intermediate cases: words that subcategorize complements (and therefore contain variables), idioms, and meaningful constructions with or without phonology. These items are all encoded as pieces of linguistic structure in one or more domains; if in more than one domain, the lexical item specifies the interface links between them.

This continuity between words and rules is an important feature of the Parallel Architecture, shared with Construction Grammar and Cognitive Grammar. It contrasts with LFG and HPSG, which maintain a strict lexicon/grammar distinction. It contrasts more drastically with mainstream generative grammar, whose lexicon is an unstructured "list of exceptions" (Chomsky, 1965) or a collection of "syntactic atoms" (Berwick and Chomsky, 2016), and whose grammar consists of procedural rules.

3.3 Unification-based combinatoriality

We next focus on the role of schemas in the grammar, comparing them to traditional rules. Traditional rules are procedural: combine *this* item with *that* item, move *this* item to *here*, delete *this* item in *this* context. In contrast, schemas are declarative: they stipulate pieces of structure and interface links among them. In order for PA to build novel utterances, a procedural component is necessary. Here PA, like other constraint-based theories, adopts Unification (Shieber, 1986) as the appropriate procedural operation.

Unification is a sort of Boolean union over structures: it *superimposes* one structure on another, preserving the unique parts of both, without doubling the shared parts. For instance, unifying the string ABC with the string BCD yields ABCD, not, say, ABCBCD.

To illustrate how Unification works, suppose we wish to generate the phrase *that cat*. This requires three pieces of stored structure: the two words and the phrase structure schema for (this part of) the NP.[13]

(26)		a.	b.	c.
	Semantics:	$[\text{DISTAL}]_{11}$	$[\text{CAT}]_1$	(*no intrinsic semantics*)
	Syntax:	$[\text{Det, SG}]_{11}$	$[\text{N, SG}]_1$	$[_{\text{NP}}\ [\underline{\text{Det}}, \underline{\alpha}\text{NUM}], [\underline{\text{N}}, \underline{\alpha}\text{NUM}]]$
	Phonology:	$/\text{ðæt}/_{11}$	$/\text{kæt}/_1$	(*no intrinsic phonology*)

(26a) unifies with the part of schema (26c) whose variables it satisfies; (26b) does the same, yielding (27).

(27)		
	Semantics:	$[\text{CAT}_1; \text{DISTAL}_{11}]_{12}$
	Syntax:	$[_{\text{NP}}\ [\text{Det, SG}]_{11}\ [\text{N, SG}]_1\ ]_{12}$
	Phonology:	$/\text{ðæt}_{11}\ \text{kæt}_1\ /_{12}$

Four remarks: First, phrase structure schema (26c) stipulates the word order in syntax, which maps canonically into linear order in phonology. Second, the alphas in schema (26c) stipulate that the noun and determiner must agree in number. In (27) they indeed do agree. But in **those cat* and **that cats* they do not, so these are syntactically ill-formed. Third, DISTAL and CAT supplement each other semantically, so they are in effect conjoined into [CAT; DISTAL]. Fourth, the entire unified expression receives an interface link (coindex 12), to associate the meaning of the whole with the NP and the entire phonological string. We assume this is an automatic consequence of Unification.

For a slightly more complicated case, consider again the lexical representation of *devour*.

(28)		
	Semantics:	$[\text{DEVOUR}_2\ (\text{Agent: } \underline{\text{X}}, \text{Patient: } \underline{\text{Y}}_{\text{y}})]$
	Syntax:	$[_{\text{VP}}\ \text{V}_2\ \underline{\text{NP}}_{\text{y}}]$
	Phonology:	$/\text{dəvawr}/_2$

The selectional restrictions of *devour* are encoded as properties of its semantic variables. *X* in (28) is not just an Agent, it is an animate Agent; and *Y* is not just a Patient, it is an object or substance with appropriate properties or affordances. When *devour* is unified with its arguments, these features of the variables are unified with the features of the corresponding arguments. If the argument is semantically underspecified,

13 DISTAL has structure that denotes the spatial relation of a denoted object to the speaker or hearer. We set these details aside.

as in *It devoured the pie*, the verb supplies the requisite semantic detail through Unification: *it* denotes an animate. If the argument's meaning conflicts with the variable's, the sentence may be coerced into a metaphorical reading, as in *Evil thoughts devoured me*, or, failing that, it will be judged anomalous, as in **My pencil sharpener devoured The Hague*.[14]

3.4 Generative and relational functions of schemas

The PA thus separates the traditional function of a phrase structure rule into two components: a declarative schema that encodes the desired structure, plus the process of combining the parts through Unification. Unification is hence the only *procedural* rule in the grammar.[15] Using Unification to combine words and schemas enables the creation of an unlimited number of novel utterances, like traditional procedural rules. We call this the ***generative*** function of schemas.

However, schemas also have a second function. Consider again a VP idiom such as *chew the fat*. Because of its idiosyncratic meaning, it must be stored in the lexicon. Yet because its syntactic structure is a canonical VP, traditional generative grammar must, paradoxically, construct it *outside* the lexicon. The PA offers a resolution: a schema can be used not only to generate new utterances, it can also capture generalizations among existing lexical items, thereby partially motivating them, decreasing their arbitrariness (Culicover et al., 2017). Thus the VP schema (25b) and the NP schema (26c) together motivate the whole class of VP idioms such as *chew the fat*, *kick the bucket*, and *bite the bullet*, making them less arbitrary than the syntactically exotic *by and large*, *for the time being*, and *day in day out*. We call this use of schemas their ***relational*** function. Traditional generative grammar sometimes attributes this function to "lexical redundancy rules," distinct from the generative rules. In the PA, both functions can be performed by the very same schema.[16]

Crucially, not all schemas have both functions. Some have only the relational function: their instances are all listed, and it is impossible to create new ones. One example is the little determiner construction in (29).

(29) a. [$_{\text{Det}}$ such/what/quite/many/hardly a] tree
b. [$_{\text{Det}}$ [$_{\text{AP}}$ this/that/so/too/how/as tall] a] tree

14 The sentence may still be acceptable if embedded under a predicate that selects for anomaly, as in *It makes no sense to speak of pencil sharpeners devouring The Hague*! For more detail on Unification within the PA, see Jackendoff (1990) (called there Argument Fusion), Jackendoff (2011).

15 This position excludes the possibility of movement rules, the procedural rules par excellence. See Section 5.2.

16 This dual function of schemas is suggested by Jackendoff (1975), Aronoff (1976), and Barlow and Kemmer (1994). However, it makes more sense in the PA, whose rules are all in the lexicon, than in more traditional frameworks where some rules are "in the grammar" and some "in the lexicon."

The overall pattern is a determiner (if one can call it that), of the form *X a*. The pattern has six instances: the five in (29a), plus the subpattern in (29b) of a degree word, an adjective, and *a*. Novelty is possible only in the choice of adjective and noun: e. g. *that beautiful a song*, *so deep a lake*. Otherwise, the pattern is closed; no general, productive rule captures this peculiar range of possibilities. Yet it is certainly a pattern of English, worthy of a schema, even if it only captures a generalization among listed lexical items. Such nonproductive schemas are rather rare in syntax, but they are commonplace in morphology, especially derivational morphology.

Could schemas exist that are used only productively, to create novel structures? No, because any novel form can be memorized; and once memorized, its structure has to be accounted for relationally, like idioms and stored collocations. Hence *all* schemas can be used relationally, but only a subset can be used generatively. Expanding the knowledge of language to include nonproductive patterns enlarges the scope of linguistic theory in what we consider an important fashion. (Jackendoff and Audring, forthcoming show how productive schemas are distinguished from nonproductive.)

The notion of schemas with variables extends readily to poetic forms such as sonnets and limericks. A text counts as a limerick if it conforms to a particular metrical pattern and a particular rhyme scheme; moreover, a large class of limericks begin with the text *There once was a X from Y, who*.... These characteristics can be encoded as a schema for the limerick form, which captures the structure of existing limericks and can also be used to construct novel exemplars. Knock-knock jokes even have a two-person schema; both participants have to know it to perform the joke properly.

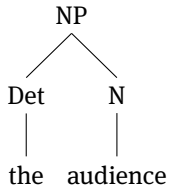
Beyond language, abstract musical forms such as 12-bar blues can be specified as abstract schemas of meter and harmony, to be fleshed out by the creator's choice of conforming notes. And it is plausible to think of knowledge of rituals (formal and informal, including games) as schemas that stipulate what the participants are expected to do. The actual participants on any particular occasion then satisfy the variables in the schema. This is the idea behind Schank's (1973) "scripts," Minsky's (1975) "frames," Fillmore's (2003) frame semantics, Rumelhart's (1980) "schemas," and Goffman's (1974) elaborate "frames." In short, the formal tools of the PA are to some degree domain-general; they did not have to be invented just for syntax.

4 Sample analysis

For a fuller picture of linguistic structure in the Parallel Architecture, we offer an analysis of the clause *After Mary introduced herself to the audience*,.... (Culicover and Jackendoff, this volume, treat the second assigned clause, *she turned to a man that she had met before*.)

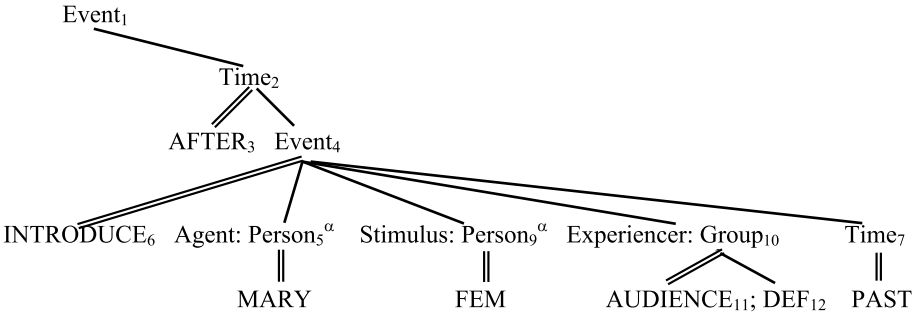
From a traditional perspective, what stands out here is that the words are not terminal elements in the syntactic tree, as in the usual notation (30).

(30)

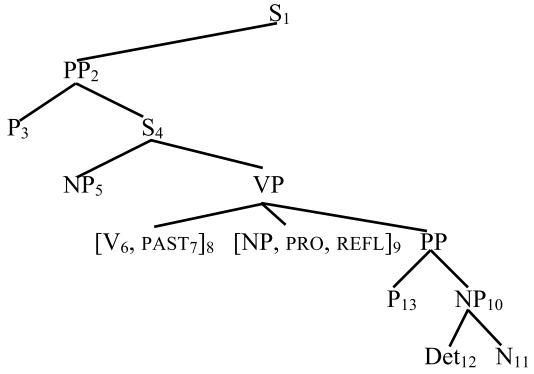


"*The*" and "*audience*" in (30) stand for complexes of semantic, syntactic, and phonological features. The PA insists that semantic and phonological features belong not to syntax, but to their own proprietary structures, *linked* to the syntax. Fig. 3 reflects this perspective: each word is distributed among the three structures. For instance, *audience* consists of the three pieces of structure coindexed 11 in Fig. 3.

Semantic structure (Event$_1$ described by the main clause, not shown here)



Syntactic structure (S_1 is the main clause, not shown here)



Phonological structure

/ /æftə-/$_3$ /mɛri/$_5$ /ɪntrəduws$_6$ t$_7$/$_8$ /hə-sɛlf/$_9$ /tuw/$_{13}$ /ði/$_{12}$ /ɔdiəns/$_{11}$ /$_2$

Figure 3: Structure of *After Mary introduced herself to the audience*.

The phonological structure in Fig. 3 has been simplified, omitting syllable structure, stress, and intonation. Double slashes at the beginning and end surround the entire string, which is linked with the entire clause in syntax and semantics (coindex 2).

Semantic structure is notated as a tree, somewhat more perspicuous than the labeled bracketing used so far; the two are intended as notational variants. A function such as INTRODUCE is connected to its mother by a double line; its arguments, for instance MARY, are connected to the same mother by a single line. Modifiers are connected by a dashed line.

The semantic structure in Fig. 3 says that an Event (coindex 1), described by the clause omitted here (*she turned to a man…*), occurs at a Time (coindex 2) after another Event (coindex 4). In this latter Event, set in the past, a Person (Mary) introduces a female Person to a Group which is an audience and definite. The two Persons are coreferential, as indicated by the co-superscript *α*s; that is, coreference is encoded in semantic structure rather than (or in addition to) syntactic structure. The function INTRODUCE itself is a sort of causative psych predicate: roughly, Mary (an Agent) brings herself (a Stimulus) to the attention of the audience (an Experiencer).

Turning finally to the syntactic structure: Its terminal elements link to words in the phonology, and most of its constituents link to semantic structure. The structure itself is straightforward; we mention only four points. First, the name *Mary* (coindex 5) and the reflexive pronoun *herself* (coindex 8) are full NPs; other treatments are possible. Second, *after* (coindex 3) is semantically a function of an Event or Time. Syntactically, it is a preposition whose complement can be either NP or, as in this case, S. It shares this semantic structure and subcategorization with e. g. *before* and *until* (Klima, 1965; Jackendoff, 1977).

Third, the preposition *to* (coindex 12) has structure in syntax and phonology but not in semantics. No other preposition is possible in this position. Rather, *to* functions like a quirky case-marker or idiom chunk: it is determined by the verb. This stipulation can be encoded in the lexical entry for *introduce* as in (31) (reverting for convenience to labeled bracketing).

(31) Semantics: $[_{\text{Event}}\ \text{INTRODUCE}_6\ (\text{Agent: } \underline{X}, \text{Stimulus: } \underline{Y}_y, \text{Experiencer: } \underline{Z}_z)]$
Syntax: $[_{\text{VP}}\ V_6\ \underline{NP}_y\ [_{\text{PP}}\ P_{12}\ \underline{NP}_z]\ ]$
Phonology: /ɪntrəduws/$_6$ /…/$_y$ /tuw/$_{12}$ /…/$_z$

(31) has a specified verb, like *devour* in (28), plus a specified preposition, with variable direct and oblique objects, corresponding to Stimulus and Experiencer respectively.

The last point of interest is the treatment of tense. Syntactic category (here, V) and inflection (here, PAST) are treated as features of the node in the syntactic tree (Jackendoff and Audring, forthcoming). Thus the regular past tense is a Time modifier in semantics, a morphosyntactic feature in syntax, and a suffix in phonology, linked

by coindex 7 – another mismatch among the components of the grammar. This mismatch is captured directly in the interface links, rather than by any sort of movement. Accordingly, a simplified lexical entry for the regular past tense (ignoring the *d*/*t*/*ed* allomorphy) can be formulated as (32).

(32) Semantics: $[_{\text{Situation}}\ \underline{X};\ [_{\text{Time}}\ \text{PAST}]_7\ ]_y$
Syntax: $[_S\ \underline{\ldots}\ [\underline{V}_x,\ \text{PAST}_7]\ \underline{\ldots}\ ]_y$
Phonology: $/\ \underline{\ldots}\ /\ /\underline{\ldots}_x\ t_7/\ /\underline{\ldots}/_y$

Verbs with irregular past tenses have different links to phonology (see Jackendoff & Audring, forthcoming). But whether the verb is regular or irregular, the syntax contains morphosyntactic PAST, which can link not only to semantic PAST, but also to hypothetical conditional (e. g. *What if I <u>came</u> tomorrow?*). So (32) is only part of the structure associated with the syntactic past tense.

A more traditional semantic account treats the Tense as an operator over the rest of the sentence, as in (33).

(33) $[_{\text{Situation}}\ \text{PAST}_7\ (\ [_{\text{Event}}\ldots\ ]_4\ )]$.

The same problems of mismatch arise, just in a different configuration.

Summing up, linguistic structure in the PA encompasses three linked structures. In simple cases, the constituents of the three components align; but, as also seen in Section 3.2, numerous mismatches are possible, including missing components (no *to* in semantics) and mismatched hierarchical structures (past tense).

5 Evaluation

Evaluation of the Parallel Architecture framework encompasses two different endeavors. "Internal" evaluation compares alternative treatments of a phenomenon *within* the framework; "external" evaluation compares the theory to other frameworks. We take these up in turn.

5.1 Choosing the correct account within the framework

Within the PA framework, a frequent question is which component is responsible for the observed facts: Is this a matter of syntax, of semantics, of their interface, or of some combination? Here are three cases.

First consider the principle that a German determiner agrees in gender and number with its head noun, regardless of whether the gender of the noun is motivated by semantics. We conclude that gender is a morphosyntactic feature, and that gender agreement is firmly lodged in the well-formedness principles for syntax.

For a second case, consider aspectual coercion (Verkuyl, 1972; Talmy, 1978; Dowty, 1979; Platzack, 1979; Hinrichs, 1985; Jackendoff, 1991, 1997). (34a) describes multiple jumps; but (34b), with a different preposition, describes a single jump, and (34c), with a different verb, describes a single act of sleeping.

(34) a. Sam jumped until the bell rang.
b. Sam jumped before the bell rang.
c. Sam slept until the bell rang.

The multiple event interpretation emerges when (a) the verb denotes a completed event and (b) the time expression sets a boundary on an otherwise unbounded event. Multiplicity could potentially be encoded syntactically, using an invisible formative whose presence depends on the right combination of features in the verb and preposition. However, the PA framework offers a simpler solution: the sentences in (34) have identical syntax, with no hidden formatives or features. The aspectual distinctions among them have to be present in semantic structure in any event, because they are part of the interpretation. Thus the semantics can account directly for the sense of multiplicity: when a temporal boundary on a process (denoted by the preposition *until* but not *before*) is imposed on a point-action (denoted by the verb *jump* but not *sleep*), it thereby coerces the action into a sequence of actions. Hence in this case, the phenomenon is localized in semantics.

Finally, consider the construction illustrated in *that travesty of a theory* (8b). In principle, a syntactic movement could derive it from something like *that theory, which is a travesty*. However, such a movement would be unprecedented, raising a noun out of an appositive while demoting the underlying syntactic head. Moreover, the construction has characteristic semantics: the head noun is understood as evaluating the subordinate noun. (35a) is unacceptable, even though its putative source (35b) is fine, because *sailor* cannot be understood as an evaluative term. On the other hand, (35c) is understood as criticizing the violinist's performance – coercing *butcher* into an evaluation.

(35) a. * that sailor of a butcher
b. that butcher, who is a sailor
c. that butcher of a violinist

This sensitivity to meaning requires involvement of semantic structure. The construction therefore must be an interface principle: To express an evaluation of an individual, one may use the canonical structure N_1 *of a* N_2, in which the evaluation is linked to N_1 and the individual being evaluated is linked to N_2, reversing the usual linkage between syntax and semantics.

These three cases illustrate the sorts of decisions faced within the Parallel Architecture, and how they come to be settled in favor of syntax, semantics, and/or the interface.

5.2 External evaluation and summary: Comparing the Parallel Architecture to alternative approaches

For external evaluation, we first mention two common objections to the PA. First, if syntactic rules are stated declaratively, as in the PA (and other "constraint-based" theories), then the procedural notion of movement has to be expunged from syntax. So it is crucial to figure out how a declarative theory deals with passive, subject-auxiliary inversion, wh-question formation, and the like, which have always seemed very natural under a movement hypothesis. HPSG, LFG, Simpler Syntax, and other frameworks work this out, with considerable success. (Some of the arguments are addressed in Culicover and Jackendoff, this volume.)

Second, it has been argued that the PA is not sufficiently constrained (Marantz, 2005; Phillips and Lau, 2004), because it involves three "generative engines" instead of syntax alone. We find this criticism misguided. Every theory of language must account not only for syntactic well-formedness but also phonological and semantic well-formedness – counterparts of the PA's phonological and semantic "generative engines." And every theory must account for the interfaces among these levels, in order to connect sound to meaning.

In fact, PA syntax is *highly* constrained: it lacks movement and cycles/phases, minimizes phonologically null syntactic heads, and makes no distinction of components between lexicon and rules. The PA's interfaces are more flexible than in other approaches, partially compensating for the loss of syntactic power. However, the PA thereby gains coverage of a plethora of noncanonical phenomena such as those in Section 3.2. Many of these have never (to our knowledge) been addressed in traditional generative grammar and its direct descendants, being regarded as irrelevant exceptions or "periphery" (Chomsky, 1981). Still, if anything, the hard question is whether the PA's relatively lean set of formal devices is powerful *enough* to account for the fullest range of linguistic phenomena.

Perhaps the most important innovation of the PA (shared with Cognitive Grammar and Construction Grammar) is to eliminate the distinction between lexicon and grammar, couching both as pieces of linguistic structure with some combination of phonology, syntax, and/or semantics, and with some combination of constants and variables. In the place of this distinction is a greatly enriched lexicon, in many respects like that of Construction Grammar.

The PA also eliminates the distinction between "grammatical" rules and "lexical" rules, which many approaches treat as distinct grammatical modules. In the PA, both are schemas. The PA replaces the distinction between them with a distinction between two uses of schemas. *All* schemas function relationally, supporting or motivating more highly specified lexical items; this use corresponds to "lexical rules." *Some* schemas also function generatively, unifying with other lexical items to create novel structures; this corresponds to productive "rules of grammar." This duality of function is to our knowledge not central to other frameworks.

The PA takes significant steps toward integrating semantics, syntax, morphology, and phonology into a coherent whole, linking these independent sources of combinatorial structure by interface principles. This overall organization arguably obtains in other faculties of mind as well, and permit the language faculty to interact with other faculties such as vision. This feature of the PA is to our knowledge unique.

An important feature of the PA is that it can be integrated smoothly into accounts of language processing and language acquisition, bridging the competence-performance divide (Jackendoff, 2002, 2007b; Jackendoff and Audring, 2016, forthcoming). This compatibility arises because schemas are lexical items, right alongside words. In the course of parsing a heard sentence, all relevant lexical items are activated – both words and schemas; and candidate parses are constructed by Unification. It is not necessary to go to another "place" to apply rules. Similarly, acquiring a rule amounts to adding a new schema to the lexicon. This schema shares the structure of the items that motivate it, but it contains variables where these items differ. There is no need to construct something in an entirely different "rule" format that goes in a different "place." More generally, PA-style analyses have provided a basis for experimental work on sentence comprehension, e. g. Piñango et al. (1999), Paczynski et al. (2014), Wittenberg et al. (2014), Wittenberg (2016).

The PA also responds to goal (4) in Section 1: determining which aspects of the language faculty are domain-specific and which are domain-general. We speculate that Unification is a domain-general cognitive process for creating combinatorial structures (for discussion, see Jackendoff, 2011), and we suggest that the notion of stored schemas with variables appears in a wide range of cognitive domains (Jackendoff and Audring, forthcoming). What is likely to be specific to language is the repertoire of phonological and syntactic elements out of which words and schemas are built. (In a sense this concurs with Bod's (2006) proposal of "Universal Representation" instead of "Universal Grammar.")

To sum up: While we recognize the danger of viewing the world in terms of one's own theory, we believe that the goals set out in Section 1 are appropriate ambitions for linguistic theory. We further believe that, more than other frameworks we are acquainted with, the Parallel Architecture offers an avenue towards reaching those goals.

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