J Psycholinguist Res (2015) 44:27–46
DOI 10.1007/s10936-014-9329-z

Aligning Grammatical Theories and Language Processing Models

Shevaun Lewis · Colin Phillips

Published online: 19 November 2014

Abstract We address two important questions about the relationship between theoretical linguistics and psycholinguistics. First, do grammatical theories and language processing models describe separate cognitive systems, or are they accounts of different aspects of the same system? We argue that most evidence is consistent with the one-system view. Second, how should we relate grammatical theories and language processing models to each other?

Keywords Parsing · Grammatical theories · Abstraction · Cognitive architecture of language

Introduction

Theoretical linguists and psycholinguists have historically been housed in different buildings. This geographical divide has led to the perception that there are principled differences between the objects of study of the two fields. We encounter renewed interest in bridging the divide, but to do so it is useful to explore the relation between the concerns of the two fields, and what it would mean for them to be more closely aligned.

In accounts of sentence-level phenomena, which is the area that we know best, theoretical linguists and psycholinguists differ primarily in their methods and the types of phenomena they seek to explain. One group focuses on developing accounts of *offline* data—judgments made under "ideal" conditions, with no time limit and minimal impact from memory limitations. The other group focuses on developing accounts of *online* data, typically gathered using time-sensitive measures.

S. Lewis (✉)
Department of Cognitive Science, Johns Hopkins University, Krieger Hall 237,
3400 N Charles St, Baltimore, MD 21218, USA
e-mail: shevaun@jhu.edu

C. Phillips
Department of Linguistics, Maryland Language Science Center,
University of Maryland, College Park, MD, USA

Offline and online data have much in common. Grammarians and psycholinguists alike often base their inferences about language competence on people's ability to discriminate word strings in terms of acceptability or interpretation. For example, a competent speaker of English can discriminate (1) and (2) based on acceptability and (1) and (3) based on interpretation. We can observe this discrimination in many different kinds of behavioral or neural responses, ranging from simple acceptability judgments to reading time measures to electrophysiological recordings.

(1) The dog follows the man.
(2) *The dog follow the man.
(3) The man follows the dog.

What distinguishes offline from online data is the time when the response is elicited. Offline responses are elicited with no time restrictions, after the presentation of a complete unit of linguistic information, such as a sentence. Online responses are elicited during limited time windows, often after the presentation of an incomplete unit of linguistic information, such as in the middle of a sentence.

Now that the two fields have collected substantial bodies of reliable offline and online data, we must confront the theoretical and practical problems of reconciling the claims that are made based on each kind of data.

The theoretical problem is a question about the object of study. Do grammatical theories and language processing models describe separate cognitive systems—independent functions of the human mind? Or are they accounts of different aspects of the same system? This question is the main focus of this paper. We discuss the relevant empirical evidence, with particular attention to cases of apparent mismatches between online and offline phenomena. We argue that most evidence is consistent with the view that grammatical theories and language processing models describe a single cognitive system (see also Phillips and Lewis (2013)).

The practical problem is to determine what we should do, as linguists or psycholinguists. How should we relate grammatical theories and language processing models to each other? What should linguists do with online data, if anything? The answers depend in part on the answer to the first theoretical question, but either way, there is good reason to bridge the divide between linguistics and psycholinguistics.

One Language System, or Two?

Our main question is whether the grammar and language processing mechanisms are distinct cognitive systems. By *system* we mean a collection of cognitive mechanisms with a distinct purpose, operating over representations of a distinct kind. So, to determine whether the grammar and language processing mechanisms are different in this sense, we ask whether the grammar has a purpose other than comprehension and production, and whether language processing mechanisms operate over representations other than those described by the grammar. Here we outline the two alternatives and the motivations for each, keeping in mind what they have to say about the purpose of the language system(s) and the representations employed. The difference between these views is rarely discussed, and we have been surprised to learn from discussions with linguists and psycholinguists that many researchers take one or the other of these positions for granted and assume that it is what everybody else assumes, contrary to fact.

The Two-System Hypothesis

Under the two-system hypothesis, the cognitive system responsible for the grammar is separate from the system(s) responsible for language processing. Under this view, the grammar system is often thought of as a static body of knowledge, whereas the language processing system is a set of procedures for comprehension and production. It is assumed that the properties of the grammar system are more clearly revealed in offline data, and the properties of the language processing system are more clearly revealed in online data. There are a number of different motivations for the two-system hypothesis, relating to the purpose of language or the representations involved. It is certainly not the case that all those who endorse some version of the two-system view would agree with all of the motivations; here we simply attempt to marshal a range of different arguments.

One motivation derives from the suggestion that the core of the human language capacity is the ability to productively and recursively combine concepts. This ability to store and manipulate complex representations could have conferred a substantial evolutionary advantage, independent of the ability to use it for communication (Berwick et al. 2013; Jacob 1977). There is some interesting evidence that language confers cognitive benefits in tasks unrelated to communication. For example, Spelke and her colleagues have argued that language allows humans to create representations that integrate information from different cognitive domains. Humans can represent concepts from different domains with lexical items and combine them using the grammar. For example, the thought *to the left of the blue wall* integrates representations of geometry and color. Navigation using such combinatory concepts appears to depend on linguistic encoding: it is difficult or impossible for young children lacking the relevant words or structures, adults whose language systems are occupied with verbal shadowing, and individuals who have experienced extreme language deprivation (Hermer and Spelke 1996; Hermer-Vazquez et al. 1999; Hyde et al. 2011; Spelke 2003). Similarly, language has been argued to confer advantages in reasoning about other people's mental states (de Villiers 2007; de Villiers and de Villiers 2009; de Villiers and Pyers 2002) and representing exact quantities (Condry and Spelke 2008; Pica et al. 2004).

A somewhat weaker claim about the different purposes of the grammar and the language processing mechanism is less controversial. Comprehension and production have different purposes at some level, and are plausibly served by distinct, task-specific systems. However, they clearly exploit the same words, rules, and constraints. Under this view, the "purpose" of the grammar is somewhat elusive, but clearly it would be something more abstract than either comprehension or production. Since comprehension and production have been studied largely independently, there is little evidence that they recruit distinct mechanisms and representations. Nevertheless, to the extent that the mechanisms proposed in the comprehension and production literatures differ from one another, this provides a serious argument for the two-system hypothesis.

Representing complex thoughts and achieving efficient communication are two very different kinds of goals. Given the different pressures associated with these two different functions, it may be that they are best implemented with different kinds of systems. In that case, we might expect the representations employed by each system to be particularly suited to their purpose.

Some researchers argue that comprehension and production mechanisms use simple, more linear representations to achieve efficient communication. Proponents of this view emphasize the fact that most utterances have simple structures that do not require reference to complex grammatical constraints. They argue that people rarely need to consult their grammatical knowledge, because simple heuristics are sufficient for most tasks (Ferreira et al.

2002; Ferreira and Patson 2007; Frank et al. 2012). Others argue that in fact the grammar is quite simple; it only appears complex because of the overlay of systematic properties of the language processing system (Trotzke et al. 2013). In either case, each system employs distinct representations, so we should see differences in how the two systems respond to the same input. Assuming that offline responses reflect the representations of the grammar and online responses reflect those of processing mechanisms, we should see frequent misalignments between offline and online responses. Since there is quite a large literature on these misalignments, we will discuss them separately in the "Empirical Arguments: Alignment and Misalignment" section.

The most important challenge for the two-system hypothesis is to explain how the language processing system and the grammar system interact. Some interaction between the two systems is necessary to explain why the outputs of comprehension and production look so similar to the representations licensed by the grammar, and how offline judgments come to reflect the grammar, despite being mediated by comprehension or production mechanisms. We know of no instantiation of the two-system view that addresses these problems by providing an explicit theory of how the two systems interact with each other. Townsend and Bever (2001) provide some initial psycholinguistic suggestions, but they do not begin to address the grammatical richness of online processes, and hence fall short of explaining how the human parsing system might exploit detailed grammatical constraints. Meanwhile, in computer science there are well-specified methods for translating a grammar into a corresponding parsing device (Aho et al. 2006; Grune and Jacobs 2008; for an application to minimalist grammars see Stabler 2013). However, these methods presuppose a highly transparent mapping from grammar to parser, and they may be understood as relating different levels of analysis, as in a one-system approach, rather than relating independent cognitive systems.

The One-System Hypothesis

Under the one-system hypothesis, there is only one cognitive system for language, and it is suitable for real-time comprehension and production. Under this view, the grammar is an abstract description of the representations that this cognitive system builds.

Under the one-system view, the capacity for language might have developed under simultaneous pressures to represent complex thoughts and to externalize them for communication. Under this view, the grammar would be shaped by the need for representations that can both encode complex thoughts and be transmitted through a serial medium. This view seems to be accepted either explicitly or implicitly by most people who study language evolution and take syntax seriously (e.g., Bickerton 2003; Pinker and Bloom 1990).

Language may serve complex thought only in virtue of the translation in and out of a linear form. Interestingly, even non-communicative uses of language seem to make use of externalization mechanisms. For example, the cross-domain representations that Spelke claims are parasitic on linguistic abilities appear to be available only when the person knows the external (phonological) properties of the relevant lexical items. Children who understand the difference between right and left, but do not know which word applies to which direction, are unable to use a concept like "to the left of the blue wall" to plan actions (Hermer-Vazquez et al. 2001).

If the grammar and language processing are one and the same, we should not observe any differences between online and offline responses. Under this view, online and offline responses represent different "snapshots" of processes that take some amount of time to complete, and grammatical theories and language processing models are characterizations of different outputs of those processes, stated at different levels of description.

The one-system hypothesis certainly allows for divergence between online and offline responses. The real-time mechanisms that implement the grammar may not be perfectly suited to the task, especially when they recruit domain-general resources like working memory and cognitive control. Under time and resource limitations, these mechanisms may produce unintended outputs. Since these unintended outputs can be regarded as errors rather than features of the system, they could be overlooked in the higher-level descriptions of the system that grammarians provide.

However, the fact that the language processing system might be error-prone does not give free license to maintain a one-system hypothesis in the face of arbitrary mismatches between what the language processor constructs and what the grammar licenses. The most important challenge for the one-system hypothesis is to provide an explanation of how and why real-time language processes sometimes give rise to representations that are not licensed by the grammar. It is easy to provide post-hoc accounts of differences between online and offline responses in particular cases. A more convincing one-system theory should be able to systematically predict where these mismatches occur. In light of the importance of this concern, we turn next to specific cases of alignment and misalignment between online and offline responses to assess whether they are systematic and predictable within a one-system approach.

Empirical Arguments: Alignment and Misalignment

The empirical evidence that we focus on speaks to whether the linguistic representations that are built in the earlier stages of real-time processing match those that are motivated by offline measures such as untimed acceptability judgments. In other words, do parsing and production systems build representations that are licensed by the grammar?

Alignment

The closer the alignment between the representations tracked by online and offline measures, the more feasible it is to maintain a one-system view. Although close alignment is also compatible with a two-system view, it cannot be explained or predicted without an explicit theory of how the two systems interact.

A growing body of evidence suggests that the representations built during online language processing are usually constrained in the same way as those licensed by the grammar. Online measures often show rapid detection of grammatical anomalies and avoidance of ungrammatical parses or interpretations.

In anomaly-detection paradigms, especially the sizeable literature based on event-related brain potentials (ERPs), it is routine for grammatical anomalies to be detected within a few hundred milliseconds (Friederici et al. 1993; Neville et al. 1991; Osterhout and Holcomb 1992; for reviews see Kaan 2007; Sprouse and Lau 2013). ERP responses typically track the same fine-grained degrees of anomaly measured in offline tasks (e.g., Nevins et al. 2007). In fact, rapid detection of grammatical anomalies is so common that it is newsworthy when anomalies are not immediately registered (negative polarity: Vasishth et al. 2008; Xiang et al. 2009; subcategorization: Wagers and Phillips 2014; agreement: Wang et al. 2012).

Studies of long-distance dependencies demonstrate that the parser generally avoids constructing dependencies that would be unacceptable in offline judgments. For example, the interpretation of a reflexive pronoun (e.g., *himself, herself, themselves*) requires a dependency between the reflexive and an antecedent, which is usually found earlier in the sentence. Stud-

ies on the online interpretation of reflexives in comprehension have tested whether the parser considers only antecedents that would be acceptable in offline judgments, c-commanding clausemates (Binding Principle A: Chomsky 1981). That is, when interpreting (4), does the parser ever consider *Jonathan* as a potential antecedent for *himself*?

(4) The surgeon who treated Jonathan had pricked himself with a used syringe needle.

Most studies suggest that grammatically illicit antecedents are not considered, based on evidence from cross-modal priming (Nicol and Swinney 1989), eye-tracking during reading (Dillon et al. 2013; Sturt 2003), self-paced reading (Badecker and Straub 2002, experiments 4–5; Clifton et al. 1999), visual world eye-tracking (Clackson et al. 2011), and ERPs (Xiang et al. 2009). Thus, online and offline responses both indicate the same set of candidate antecedents.[1]

The parser also successfully avoids unacceptable antecedents when it must search forward instead of backward. Studies on the processing of *backwards anaphora* or *cataphora,* where a pronoun precedes its antecedent, have demonstrated that the parser respects Principle C (Chomsky 1981; Büring 2005): it does not consider potential antecedents that are c-commanded by the pronoun (English: Cowart and Cairns 1987; Kazanina et al. 2007; Japanese: Aoshima et al. 2009; Russian: Kazanina and Phillips 2010; Dutch: Pablos et al. 2012). For example, comprehenders never take *Kathryn* to be a potential antecedent for *she* in sentences like (5).

(5) Because last semester she was taking classes full-time while Kathryn was working two jobs to pay the bills, Erica felt guilty.

The interpretation of *filler-gap dependencies* in *wh*–questions and relative clauses requires a similar forward search: a displaced element like a *wh*-word must be associated with a "gap" later in the sentence. Many studies have tested whether comprehenders ever attempt to associate fillers with gap positions that would not be acceptable in offline judgments, i.e., those inside syntactic "islands." That is, when interpreting (6), does the parser ever consider the illicit gap site marked with an asterisk, taking *the book* to be the object of *wrote*?

(6) We like the book that the author who wrote * unceasingly and with great dedication saw __ while waiting for a contract.

Most studies have found that the parser respects island constraints that are observed offline (Bourdages 1992; Neville et al. 1991; Omaki and Schulz 2011; Phillips 2006; Stowe 1986; Traxler and Pickering 1996; Wagers et al. 2009; Yoshida et al. 2004). Other studies have found that comprehenders readily detect the boundaries of islands while parsing filler-gap dependencies (Kluender and Kutas 1993; McElree and Griffith 1998; Neville et al. 1991).[2]

Taken together, these findings and many others indicate that online responses exhibit fine-grained sensitivity to many of the constraints identified by grammarians using offline measures. They do not lend support to the notion of a comprehension system that deploys

[1] Some studies have challenged the generality of these conclusions about reflexives (Badecker and Straub 2002, experiment 3; King et al. 2012; Patil et al. 2011; Runner and Sussman 2006), but it is clear that the parser is able to ignore at least some grammatically irrelevant material in memory access.

[2] A couple of studies have reached more equivocal conclusions (Clifton and Frazier 1989; Pickering et al. 1994), but have stopped short of concluding that the parser is insensitive to island constraints. Some further studies have argued that the parser is able to construct island-violating filler-gap dependencies when other parses are not available (Freedman and Forster 1985; Hofmeister and Sag 2010), but these findings do not conflict with the findings about island effects in active dependency formation. We discuss these apparent misalignments between online and offline responses in the next section.

rough-and-ready mechanisms that sacrifice grammatical detail for efficiency, and as such they are encouraging for a one-system view. But we also find many cases, which we turn to next, where online and offline responses appear to diverge.

Misalignment

There are a number of interesting cases of misalignment in the literature. Arbitrary mismatches between online and offline representations provide motivation for a two-system view, in which comprehension and production mechanisms may frequently make use of task-specific rules that differ substantially from the grammar. Misalignments may be consistent with a one-system view, but only if the explanation for those mismatches is based on general properties of the language processing system.

We argue that the observed misalignments plausibly arise from limitations of general-purpose mechanisms—particularly memory access and control mechanisms—that are used to implement language-specific processes. We do not observe the diverse and arbitrary misalignments that would be consistent with a two-system view. We discuss four categories of misalignment: garden paths and revision failures, resource overload, consequences of memory access mechanisms, and internal stages of computation. We first discuss each type of mismatch individually, and then consider how they may be related to one another.

Garden Paths and Revision Failures

Misalignment between online and offline responses can arise in comprehension in cases where the incrementality of the input to the system ends up misleading the parser. A famous and uncontroversial example of this is garden path sentences like (7) (Bever 1970). Readers or listeners initially perceive the sentence to be ungrammatical, but with enough time they can recognize that it does have an acceptable parse. This misalignment between online and offline responses to the sentence does not suggest that parsing ignores grammatical constraints. Quite the contrary: it is the parser's zeal in pursuing a grammatical and highly likely syntactic structure (with *horse* as the subject of *raced*) that increases the difficulty of considering an alternative structure.

(7) The horse raced past the barn fell.

Comprehenders not only misjudge the acceptability of garden-path sentences, but also sometimes maintain the interpretation associated with their initial parse. For example, in (8), the noun phrase *the baby that was small and cute* is likely to be initially parsed as the direct object of the verb *dressed*, but it must later be reanalyzed as the subject of the verb *spit up*. After reading a sentence like (8), speakers answer "yes" about 60 % of the time to the question *Did Anna dress the baby?*, compared to only 12 % of the time when the sentence was disambiguated with a comma or a different clause order (Christianson et al. 2001).

(8) While Anna dressed the baby that was small and cute spit up on the bed.

Christianson and colleagues interpret their finding as evidence that in cases of high processing load, real-time comprehension processes can give rise to "good enough" representations that are not consistent with grammatical constraints. For example, in (8), comprehenders might fail to fully reanalyze the embedded clause object as a main clause subject and end up with a "good enough" parse in which *the baby that was small and cute* is simultaneously an argument of both *dressed* and *spit up*. A subsequent study, however, shows that interpretations associated with initial (mis-)analyses persist even in cases where syntactic reanalysis

is relatively easy and there is no reason to suppose that the parser resorts to good-enough representations (Sturt 2007).

The persistence of incorrect interpretations in cases like (8) is less surprising if we consider that conceptual representations are not the same as syntactic-semantic representations. It is relatively uncontroversial to assume that comprehenders incrementally update their beliefs as they parse incoming sentences. But once a parse of the sentence has been used to update the comprehender's non-linguistic representation of the event described by the sentence, the link between the parse and the updated beliefs need not be maintained. If the parse is subsequently revised, there is no straightforward way to automatically update the corresponding beliefs. Thus, the persistence of interpretations following syntactic reanalysis need not reflect a parser-grammar misalignment, but may simply reflect the memory limitations for tracking links between linguistic representations and non-linguistic beliefs.

Notorious cases of illusory comparative sentences like (9) present an apparent mismatch between online and offline judgments, which we argue arises from a garden path at the semantic level. Sentences like (9) sound natural at first, but further reflection reveals that they are incoherent. The first clause establishes a comparison involving a number of entities, but there is no corresponding countable noun in the comparative clause to complete the comparison. These cases provide potential evidence for a two-system view: if the initial percept of acceptability and the subsequent judgment of incoherence are the product of separate systems, then the mismatch is unsurprising (Townsend and Bever 2001).

(9) More people have been to Russia than I have.

Closer investigation suggests that illusory comparatives might be more akin to garden path phenomena, reflecting detailed use of grammatically licit semantic options, rather than reflecting the operations of a grammar-independent heuristic analyzer (Wellwood et al. 2014). English allows sentences that have the form of assertions about quantities of individuals to be understood as assertions about quantities of events. For example, (10a) is intended as a claim about the number of events in which a car crossed the George Washington Bridge, not about the number of distinct cars that crossed the bridge. Real-world knowledge tells us that the total probably includes many cars that crossed the same bridge 10 times per week. (10b) shows that this use of individual quantification to express event quantification extends to comparatives. But (10c) shows that the use of this strategy appears to be contextually constrained: in situations where the tracking of distinct individuals is likely to be relevant to the assertion, the event quantification interpretation is less available. (10c) might be regarded as a misleading description of a scenario where more hamburgers were eaten by the same number of individuals.

(10) a. 106 million cars crossed the George Washington Bridge in 2007.
b. More cars crossed the George Washington Bridge in 2007 than in any other year.
c. More Americans ate at McDonald's last year than in any other year.

Wellwood et al. argue that illusory comparatives like (9) induce semantic garden path effects, in which speakers initially interpret the first clause as an instance of event quantification. In support of this, they show in a series of judgment studies that people are less susceptible to comparative illusions when the predicate in the initial clause is non-repeatable; i.e., it cannot be carried out multiple times by the same person, and hence disfavors an event quantification reading. What is left unexplained under this account is why comprehenders are oblivious to the failure of their initial semantic "parse" in sentences like (9), in contrast to their rapid detection of the problem with syntactic garden paths like (7). Summarizing,

it is becoming clearer why comparative illusions are triggered: they are initiated due to an entirely legitimate semantic option in English. What remains unclear is why the illusions are not readily detected.

In syntactic and semantic garden paths, misalignments between online and offline responses arise because partial information is misleading. Even with full knowledge of the space of grammatical possibilities, reanalysis is often difficult because of the limitations of memory and control mechanisms. These phenomena do not motivate a two-system view.

Processing Overload

A second type of misalignment between online and offline responses arises when the comprehension system's resources are overloaded to the point that it is difficult to arrive at any parse for the incoming sentence, as in the well-known examples of unparsable center embedded sentences like (11). While these cases look like misalignments—the parser fails to construct a representation licensed by the grammar—they are not misalignments at the level of representational capacity: the parser can in principle build structures with multiple center embedding, and succeeds in doing so in easier cases like (12).

(11) The student who the professor that the counselor recommended disappointed appealed the grade.
(12) Every student that the professor you work with wrote a recommendation letter for ended up getting a job.

More relevant to our current concerns are cases where there is a conflict between the representations constructed online and in time-unlimited tasks—for example, when online comprehension processes seem to allow sentences that are recognized as ill-formed in offline tasks. An example of this can be found by comparing (11) with (13). Whereas (11) is grammatical but hard to parse, (13) is simply ungrammatical: it contains three clauses but only two verbs. Yet a number of studies have found that the ungrammatical (13) is judged as more acceptable than the grammatical (11) (Frazier 1985; Gibson and Thomas 1999; Gimenes et al. 2009).

(13) * The student who the professor that the counselor recommended appealed the grade.

The relative acceptability of (13) presents an interesting case of misalignment, and such effects have been argued to motivate a two-system architecture for language (Trotzke et al. 2013). Like the comparative illusion in (9), the contrast between initial acceptance of (13) and its status as uncontroversially ungrammatical fits with the view that online comprehension and associated percepts of acceptability are implemented by a system that is distinct from—and imperfectly related to—the grammar. However, it may be premature to regard such examples as evidence for a two-system view. First, the fact that (13) is judged as more acceptable than (11) is a relative judgment, which does not entail that speakers reliably judge it to be a well-formed sentence of English. That is reassuring, since speakers are surely unable to report a well-formed interpretation for (13), as it does not have one. A plausible account of how speakers overlook the missing verb in (13) is that the second and third subject NPs (*the professor, the counselor*) are successfully associated with the most deeply embedded verb (*recommended*), at which point speakers shift their attention to the needs of the one remaining disconnected NP (*the student*), while failing to notice that the second NP (*the professor*) needs to be the subject of a further verb (Whitney 2004). The unsatisfied dependency may fail to generate an error signal because it has simply been "forgotten," leading to a percept

of acceptability. Thus, this misalignment could arise because of limitations on memory and control mechanisms. There is no need to assume two distinct structure building systems.

Properties of Memory Access Mechanisms

We attributed the first two types of apparent misalignments to simple limitations of the capacity of memory access and control mechanisms. Even when capacity is not a problem, the properties of domain-general memory mechanisms can lead to other kinds of misalignment. In comprehension and production, speakers frequently fail to notice unacceptable number marking on the verb when some NP other than the subject has features that match with the verb (Bock and Miller 1991; Clifton et al. 1999; Pearlmutter et al. 1999), as in (14).

(14) *The key to the cabinets are missing.

Three types of evidence suggest that these illusions of acceptability should not be regarded as instances of "proximity concord," attributable to memory capacity limitations or to "good enough" representations more concerned with linear proximity than hierarchical relations (e.g., Francis 1986; Quirk et al. 1985). First, production evidence from more complex NPs shows that nouns that are closer to the agreeing verb are less disruptive than nouns that are closer to the true subject noun (Bock and Cutting 1992; Franck et al. 2002). Second, nouns that are more distant from the verb than the true subject noun, as in (15), can induce agreement illusions in both production (Bock and Miller 1991) and comprehension (Staub 2009, 2010; Wagers et al. 2009). Third, people rarely experience the opposite phenomenon, i.e., illusions of ungrammaticality, in sentences like those in (16), although we might expect such illusions to be equally frequent if speakers are simply ignoring structure in computing agreement[3].

(15) *The musicians who the reviewer praise so highly will probably win a Grammy.
(16) a. The keys to the cabinet are on the table.
b. The musicians who the reviewer praises so highly will probably win a Grammy.

The full pattern of results can be explained by appealing to independently motivated properties of memory retrieval mechanisms, under the hypothesis that agreement relations are implemented in real-time processing by retrieving the subject at the point of the verb using a parallel, cue-based memory access mechanism (Wagers et al. 2009). Parallel, cue-based memory access works by simultaneously probing all objects in memory for their match to particular featural cues—[+subject] and [+plural], for example. This kind of mechanism is less affected by distance between the subject and the verb but would be subject to interference from "partial matches" (Lewis and Vasishth 2005; McElree et al. 2003). In the sentences that give rise to illusions of grammaticality, each NP preceding the verb satisfies only one of the two search criteria: the true subject is [+subject] and [−plural], while the "attractor" is [−subject] and [+plural]. In such configurations, the retrieval process launched by the verb may frequently retrieve the wrong NP rather than the right one, leading to an illusion of grammaticality in some cases. Illusions of ungrammaticality are predicted to not occur, since in those cases the attractor noun is a poor match to the retrieval cues. Under this account, the parser's actions are fully compatible with the grammar, in the respect that the retrieval instructions are entirely consistent with offline grammatical generalizations. The errors arise simply because the grammar's constraints are implemented within a noisy general memory architecture. If this characterization of the errors is accurate, then it is consistent with a single-system hypothesis.

[3] For small-but-reliable illusions of ungrammaticality, see Lago and Phillips 2014 and Wagers 2008.

Other examples of grammatical illusions can be captured in a similar fashion under the view that grammatically licensed operations are implemented in a noisy memory architecture. German speakers overlook certain classes of case mismatches (Bader et al. 2000) and are susceptible to case attraction effects similar to agreement attraction (Sloggett 2013). In the domain of anaphora processing, a few studies have reported evidence of fleeting misretrieval of grammatically inappropriate antecedents for pronouns (Badecker and Straub 2002; Kennison 2003; but see Chow et al. 2014; Clifton et al. 1997; Nicol and Swinney 1989).

Misretrieval of partially matching items in memory has also been invoked to explain the robust illusory licensing effects that have been found for the negative polarity item (NPI) *ever*. The contrast between (17a) and (17b) shows that *ever* must be licensed by a negative element. The quantifier *no* is just one among many potential licensors (Giannakidou 2011; Ladusaw 1996; Linebarger 1987). The unacceptability of (17c), in which the negative element is embedded inside a relative clause, illustrates the fact that the NPI must be licensed by a c-commanding element.

(17) a. No bills [that the senators voted for] will ever become law.
b. *The bills [that the senators voted for] will ever become law.
c. *The bills [that no senators voted for] will ever become law.

Although offline judgments show that the NPI *ever* in (17c) is unacceptable, online studies in German (Drenhaus et al. 2005; Vasishth et al. 2008) and English (Xiang et al. 2009) consistently find that it is fleetingly treated as if it is appropriately licensed: initial responses to (17c) typically fall between responses to acceptable (17a) and unacceptable (17b). There are competing accounts of this illusion, treating it either as reflecting a partial match to memory retrieval cues, as has been proposed for agreement illusions (Vasishth et al. 2008), or as reflecting the over-application of a pragmatic licensing mechanism (Xiang et al. 2009). But this disagreement reflects a corresponding debate in the grammatical literature on NPI licensing, and whether it should be treated as an instance of an item-to-item dependency like agreement and anaphora, or as a case of licensing by the compositional meaning of the entire sentence (cf. Giannakidou 2011). Therefore, the licensing mechanisms that are invoked to explain the illusions are transparently related to grammatical accounts of NPI licensing. A case for true misalignment of mechanisms arises only if we find that one type of licensing constraint is invoked online and a different type of licensing constraint is most appropriate for capturing offline judgments.

Therefore, in all of these cases, the mismatch between online and offline judgments arises not because there are performance mechanisms that implement an alternative set of grammatical constraints, but rather because online mechanisms use grammatical constraints in a cognitive architecture that creates opportunities for error. The difference between immediate responses and slower responses may simply reflect the improvement with time of the signal-to-noise ratio in the responses, rather than the deployment of distinct mechanisms: if a slow judgment involves repeated attempts at retrieval in a noisy architecture, then increased time for judgment should improve grammatical accuracy. An outcome that has a 25 % probability of occurrence on a single retrieval trial has a much smaller probability of being the dominant outcome over the course of multiple retrieval trials.

Internal Stages of Computation

A final way in which misalignments between online and offline percepts can arise is via access to internal stages of linguistic computation. Real-time linguistic computation takes

some amount of time, and it is relatively uncontroversial that the computation might sometimes involve multiple steps. It is therefore possible that some sensitive experimental measures might tap into the results of intermediate steps of that computation. This can create the impression of mismatches between the representations revealed by online and offline processes, but such situations clearly should not be taken as evidence for a two-system view, as the following two examples illustrate.

The first example comes from studies on island constraints on unbounded dependencies. There is a difference between what we are able to represent in our native language and what we judge to be acceptable. For example, we can readily understand (18) and (19), despite the presence of an agreement violation and an argument structure violation, respectively.

(18) *John are happy.
(19) *She explained them the story.

The difference between what is representable and what is well-formed plays a larger role in some grammatical theories that distinguish a powerful generative component from a set of filters or constraints that apply to the output of the generative component. This distinction is prominent in Government-Binding (GB) theory (Chomsky 1981), and it is a core property of Optimality Theory (Prince and Smolensky 2004). In the past this has led to some interesting psycholinguistic arguments, in which evidence for "overgenerated" representations has been offered as evidence for specific grammatical models. Freedman and Forster (1985) used evidence from a sentence-matching task to argue that certain island constraint violations, which in GB theory are claimed to be representable but ungrammatical, patterned with well-formed sentences rather than with flat-out ungrammatical sentences. Freedman and Forster argued that these results show that their experimental task is sensitive to the class of representable sentences rather than the class of acceptable sentences. The results do not challenge the view that island constraints have rapid online effects. These experimental findings have been disputed (Crain and Fodor 1987), but the argument remains interesting.

A different example of access to internal stages of linguistic computation comes from research by Peter Gordon and colleagues on the *repeated name penalty*, a discourse constraint that makes it infelicitous to repeat a name that is already prominent, as in (20a). Gordon and colleagues found that ERP N400 responses are larger to the repeated name than to a non-repeated counterpart (20b), reflecting the difficulty caused by violation of the discourse constraint (Ledoux et al. 2007; Swaab et al. 2004). In contrast, early eye-tracking measures show the opposite pattern: repeated names are read more quickly than non-repeated names, presumably due to repetition priming (Ledoux et al. 2007). This suggests that the status of the repeated name is different at the stages of lexical access and discourse integration. One representation is favored at one moment and then disfavored just a couple of hundred milliseconds later. But these representations are different steps in the workings of a single parsing mechanism, not the results of separate systems.

(20) a. # Tom moved the desk because Tom needed room.
b. Dave moved the desk because Tom needed room.

Misalignments such as these are what we should hope to find if we have sufficiently sensitive tools for investigating language processing: we want to be able to look inside the stages of linguistic computation.

Summary: The Argument for the One-System Hypothesis

We claim that all the different cases of potential parser-grammar misalignment can be accounted for without recourse to a two-system view. This conclusion invites the objection that perhaps anything could be explained under a one-system view by invoking an ad hoc series of noise factors, garden paths, or multi-step computations in order to account for any kind of misalignment that might arise.

We acknowledge this concern, but we think that our account of the misalignments is far from ad hoc. In fact, the four different sub-types of misalignment described here fit naturally into an account of real-time linguistic computation, as outlined in (21).

(21) *Types of misalignment between online and offline responses*

i. Computations that are not yet complete (Internal Stages of Computation)
ii. Computations that fail to complete, due to resource limitations (Processing Overload)
iii. Computations that complete, but inaccurately, due to noisy architecture (Properties of Memory Access Mechanisms)
iv. Computations that complete successfully, but that are later challenged by subsequent input (Garden Paths and Revision Failures)

According to this approach, online and offline representations are the product of a single structure-building system (the grammar) that is embedded in a general cognitive architecture, and misalignments between online ("fast") and offline ("slow") responses reflect the ways in which linguistic computations can fail to reflect the ideal performance of that system. The computations and their failures are all independently motivated.

First, the grammatical computations that we assume operate in real time reflect independently motivated grammatical constraints. For example, the linguistic features that are used to retrieve agreement controllers or antecedents of anaphors are the same features that govern offline acceptability. Similarly, the constraints that are used to license NPIs online should be the same constraints that govern the offline acceptability of NPIs, even if the online implementation of those constraints is noisy. Additionally, in appealing to the internal stages of linguistic computation to account for misalignments, we rely on plausible claims about what those internal stages are.

Second, the properties of the general cognitive architecture are independently motivated based on non-linguistic evidence. For example, the account of "illusions of grammaticality" as misretrieval of items from memory is based on independently motivated assumptions about parallel access in content-addressable memory. This is attractive, as it provides constraints on accounts of retrieval errors.

Third, it would be ideal if an account of misalignments based on resource limitations were based on independently motivated measures of individual memory resources and cognitive control abilities. This should make it possible to predict individual variation in language processing abilities. However, our theories are not yet as advanced as we would like in that regard. There is evidence that individuals with greater working memory resources or better cognitive control abilities can parse more complex sentences or can more readily handle garden-path sentences (working memory: Just and Carpenter 1992; MacDonald et al. 1992; cognitive control: Hussey and Novick 2012; Novick et al. 2014), but more precise predictions are not yet available.

Although the sketch given here provides a schematization of the general types of online-offline misalignments that we should expect to encounter, we should ultimately be able to

predict which linguistic phenomena should yield illusions and misalignments, and which phenomena should not. It should be possible to make predictions about the profile of as-yet unstudied phenomena, in English or in other languages. This is something that we have begun to do (e.g., Phillips et al. 2011), but many specifics remain poorly understood. For example, Dillon et al. (2013) show that subject-verb agreement and reflexive licensing in English exhibit sharply different susceptibility to interference from irrelevant NPs, despite being subject to very similar grammatical constraints. They capture the contrast by proposing that person/number/gender features are used as retrieval cues for subject-verb agreement, giving rise to misretrievals in cases of partial matches, but that those same features are only used as post-retrieval well-formedness checks in reflexive licensing, thereby avoiding misretrieval. This contrast does not follow straightforwardly from our proposal here (for suggestions see Dillon 2011; Kush 2013).

Meanwhile, under the alternative two-system view, the outlook is rather worse, given the lack of constraint on the relations between the language processing mechanisms, grammatical constraints, and general cognitive mechanisms. Under this view, the degree of alignment between online and offline processes is surprising. There is less independent motivation for a general account of which linguistic phenomena should and should not yield illusions and misalignments. To our knowledge, there have been no attempts under a two-system view to construct a general theory of such phenomena.

Practical Considerations: "Aligning" Linguistics and Psycholinguistics

Our starting point was the fact that linguists and psycholinguists have taken responsibility for understanding different types of phenomena. Linguists have focused on abilities reflected in *offline* data—explicit judgments of meaning or well-formedness given by expert judges under ideal conditions with no time limits. Psycholinguists have focused on abilities reflected in *online* data, generally consisting of implicit responses to meaning or well-formedness given by naïve participants and measured using time-sensitive techniques.

We have discussed two contrasting views of the relation between the theories that linguists and psycholinguists construct about the phenomena that they study. Under the two-system view, online and offline phenomena are the products of distinct-but-related cognitive systems: (at least) one system that is designed for efficient communication in real time, and another task-neutral system designed for representing complex thoughts. In contrast, under the one-system view, online and offline phenomena are merely different reflections of the behavior of a single cognitive system, which builds representations that are used in speaking and understanding.

We have endorsed the one-system view; others may prefer the two-system view. Either way, what effect does the decision have on how we should go about our research? Should linguistics and psycholinguistics be better connected, and if so, how?

Alignment in a Two-System Architecture

The two-system view suggests a deceptively simple methodological approach. If grammatical theories and language processing models describe separate cognitive systems with different purposes and representations, their properties need not be tightly related. Under this view, linguists who are concerned with offline data need not pay attention to online data and processing models because they are irrelevant for describing the grammar system. Likewise,

psycholinguists need not pay attention to offline data and grammatical theory because they are irrelevant for describing language processing.

We doubt that many researchers would explicitly endorse this degree of separation between the fields. Psycholinguists cannot ignore insights from offline data since, as we have reviewed above, existing evidence shows that grammatical distinctions typically have immediate impact on online processes. There have also been occasional waves of enthusiasm among theoretical linguists about the prospect of using evidence from real-time phenomena to decide among alternative grammatical theories. The late 1980s saw a surge of interest in the use of online evidence to resolve a theoretical dispute about the need for empty categories ("traces") created by movement operations (Chomsky 1973; Sag and Fodor 1994). More recently, similar discussions have emerged over the use of online evidence to decide among competing theories of ellipsis (Culicover and Jackendoff 2005; Merchant 2001), quantification (Hackl et al. 2012; Szabolcsi 2013), and scalar implicature (e.g., Bott and Noveck 2004; Breheny et al. 2006; Grodner et al. 2010; Huang and Snedeker 2009). In each case, the debate has been limited by the lack of clear timing predictions from linguistic theories (traces: Gibson and Hickok 1993; Phillips and Wagers 2007; ellipsis: Phillips and Parker 2013; implicature: Lewis 2013). Under a two-system view, this kind of argument is impossible in principle without an explicit theory about how the grammar and the language processing system(s) interact. Clearly the construction of such a theory will require the consideration of both online and offline data.

A second problem is that we ultimately will want a detailed low-level account of how the grammar is neurocognitively implemented, even if it is distinct from language processing systems. Regarding the grammar as a distinct task-neutral and process-neutral body of knowledge does not exempt the linguist from the task of specifying how the grammar is instantiated in the brain, or how that knowledge is consulted by other systems, such as the language processor. This is a very difficult challenge. While research on the implementation of information processing systems has made significant progress in various cognitive domains, we still know very little about the implementation of "static" knowledge systems, especially systems that share the grammar's property of specifying an unbounded class of possible compositional representations. There are no successful examples to follow.

Alignment in a One-System Architecture

Under a one-system view, grammatical theories and psycholinguistic models describe a single system. This system links strings of sounds or symbols to complex conceptual representations. Grammatical theories describe the general properties of this linking function: how the linear strings are related to hierarchical structures, and how those structures relate to meanings. Psycholinguistic models describe how mental processes implement that linking function using available cognitive operations, including information about the time course of such processes, and specifying how the system operates under situations of uncertainty.

A one-system architecture avoids the main challenges that we outlined for the two-system approach. There is no need to specify an additional theory of how the language processor and the grammar interact: if they are the same system, then they do not need to interact. There is also no need to provide a separate description of how the grammar is implemented neurocognitively—we can rely on the psycholinguists and neurolinguists for that. However, important challenges remain for this approach.

First, it is important to understand the cases of apparent misalignment between online ("fast") and offline ("slow") responses. If these truly are products of the same system, misalignments should be few in number and, more importantly, they should be predictable from

independent cognitive constraints or from the temporal unfolding of the system's computations. This is what we have outlined in the "Summary: The Argument for the One-System Hypothesis" section above. Furthermore, to the extent that there are differences between the data obtained using fast and slower measures, we need an explicit process model that explains how the offline judgments arise. It is insufficient for high-level grammatical theories to provide accounts only of offline judgments, and for more process-oriented psycholinguistic models to restrict their attention to accounts of phenomena that happen quickly. In other words, we need a psycholinguistic model of slow linguistic processes.

Second, in order to maintain a one-system view, it is necessary to show that the same system can carry out both comprehension and production. Conflating comprehension and production systems is not straightforward, although some interesting initial attempts have been made (Kempen 2014; Kempen et al. 2012).

Conclusion

We are very encouraged to encounter renewed interest in bridging the divide between grammatical theories and psycholinguistic theories. We think that successfully bridging the two fields requires more than simply using psycholinguistic notions to explain away traditional grammatical generalizations, or using online evidence to answer old questions about competing grammatical theories. Instead, closing the gap between grammatical theories and language processing models requires answers to two classes of questions that are rarely investigated. First, it is important to identify the relation between the cognitive systems that the two fields are studying—are they separate cognitive systems (a "two-system architecture"), or are they simply different descriptions of the same cognitive system (a "one-system architecture")? In our assessment, the existing empirical evidence favors the second of these positions. Second, for both of these architectures, we have laid out a series of theoretical and empirical challenges that should be addressed in order to properly understand the relation between theories of fast and slow phenomena in language.

Acknowledgments Preparation of this paper was supported in part by NSF #BCS-0848554 to CP, by NSF IGERT #DGE-0801465 to the University of Maryland, and by a University of Maryland Flagship Fellowship to SL. For useful discussion we are indebted to Brian Dillon, Janet Fodor, Norbert Hornstein, Dave Kush, Bradley Larson, Jeff Lidz, and Amy Weinberg.

References

Aho, A. V., Lam, M. S., Sethi, R., & Ullman, J. D. (2006). *Compilers: Principles, techniques, and tools* (2nd ed.). Addison-Wesley.

Aoshima, S., Yoshida, M., & Phillips, C. (2009). Incremental processing of coreference and binding in Japanese. *Syntax*, *12*, 93–134.

Badecker, W., & Straub, K. (2002). The processing role of structural constraints on the interpretation of pronouns and anaphora. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 748–769.

Bader, M., Meng, M., & Bayer, J. (2000). Case and reanalysis. *Journal of Psycholinguistic Research*, *29*, 37–52.

Berwick, R. C., Friederici, A. D., Chomsky, N., & Bolhuis, J. J. (2013). Evolution, brain, and the nature of language. *Trends in Cognitive Sciences*, *17*, 89–98.

Bever, T. G. (1970). The cognitive basis for linguistic structures. In J. R. Hayes (Ed.), *Cognition and the development of language* (pp. 279–362). New York: Wiley.

Bickerton, D. (2003). Symbol and structure: A comprehensive framework for language evolution. In M. H. Christiansen & S. Kirby (Eds.), *Language evolution* (pp. 77–93). Oxford: Oxford University Press.

Bock, J. K., & Cutting, J. C. (1992). Regulating mental energy: Performance units in language production. *Journal of Memory and Language*, *31*, 99–127.
Bock, K., & Miller, C. A. (1991). Broken agreement. *Cognitive Psychology*, *23*, 45–93.
Bott, L., & Noveck, I. A. (2004). Some utterances are underinformative: The onset and time course of scalar inferences. *Journal of Memory and Language*, *51*, 437–457.
Bourdages, J. S. (1992). Parsing complex NPs in French. In H. Goodluck & M. S. Rochemont (Eds.), *Island constraints: Theory, acquisition and processing* (pp. 61–87). Dordrecht: Kluwer.
Breheny, R., Katsos, N., & Williams, J. (2006). Are generalised scalar implicatures generated by default? An on-line investigation into the role of context in generating pragmatic inferences. *Cognition*, *100*, 434–463.
Büring, D. (2005). *Binding theory*. Cambridge: Cambridge University Press.
Chomsky, N. (1973). Conditions on transformations. In S. Anderson & P. Kiparsky (Eds.), *A festschrift for Morris Halle* (pp. 232–286). New York: Holt, Rinehart, & Winston.
Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht: Foris.
Chow, W. Y., Lewis, S., & Phillips, C. (2014). Immediate sensitivity to structural constraints in pronoun resolution. *Frontiers in Psychology, 5*, 630.
Christianson, K., Hollingworth, A., Halliwell, J. F., & Ferreira, F. (2001). Thematic roles assigned along the garden path linger. *Cognitive Psychology*, *42*, 368–407.
Clackson, K., Felser, C., & Clahsen, H. (2011). Children's processing of reflexives and pronouns in English: Evidence from eye-movements during listening. *Journal of Memory and Language*, *65*, 128–144.
Clifton, C, Jr., & Frazier, L. (1989). Comprehending sentences with long-distance dependencies. In M. K. Tanenhaus & G. N. Carlson (Eds.), *Linguistic structure in language processing* (pp. 273–317). Dordrecht: Kluwer.
Clifton, C, Jr., Frazier, L., & Deevy, P. (1999). Feature manipulation in sentence comprehension. *Rivista di Linguistica*, *11*, 11–39.
Clifton, C, Jr., Kennison, S., & Albrecht, J. (1997). Reading the words *her*, *him*, and *his*: Implications for parsing principles based on frequency and on structure. *Journal of Memory and Language*, *36*, 276–292.
Condry, K., & Spelke, E. (2008). The development of language and abstract concepts: The case of natural number. *Journal of Experimental Psychology: General*, *137*, 22–38.
Cowart, W., & Cairns, H. S. (1987). Evidence for an anaphoric mechanism within syntactic processing: Some reference relations defy semantic and pragmatic constraints. *Memory and Cognition*, *15*, 318–331.
Crain, S., & Fodor, J. D. (1987). Sentence matching and overgeneration. *Cognition*, *26*, 123–169.
Culicover, P., & Jackendoff, R. (2005). *Simpler syntax*. Oxford: Oxford University Press.
de Villiers, J. G. (2007). The interface of language and theory of mind. *Lingua*, *117*, 1858–1878.
de Villiers, J. G., & de Villiers, P. A. (2009). Complements enable representation of the contents of false beliefs: The evolution of a theory of theory of mind. In S. Foster-Cohen (Ed.), *Language Acquisition*. New York: Palgrave Macmillan.
de Villiers, J. G., & Pyers, J. E. (2002). Complements to cognition: A longitudinal study of the relationship between complex syntax and false-belief understanding. *Cognitive Development*, *17*, 1037–1060.
Dillon, B. W. (2011). *Structured access in sentence comprehension*. PhD dissertation, University of Maryland.
Dillon, B., Mishler, A., Sloggett, S., & Phillips, C. (2013). Contrasting interference profiles for agreement and anaphora: Experimental and modeling evidence. *Journal of Memory and Language*, *69*, 85–103.
Drenhaus, H., Saddy, D., & Frisch, S. (2005). Processing negative polarity items: When negation comes through the back door. In S. Kepser & M. Reis (Eds.), *Linguistic evidence: Empirical, theoretical, and computational perspectives* (pp. 145–165). Berlin: de Gruyter.
Ferreira, F., Ferraro, V., & Bailey, K. G. D. (2002). Good-enough representations in language comprehension. *Current Directions in Psychological Science*, *11*, 11–15.
Ferreira, F., & Patson, N. (2007). The 'good enough' approach to language comprehension. *Language and Linguistics Compass*, *1*, 71–83.
Francis, W. N. (1986). Proximity concord in English. *Journal of English Linguistics*, *19*, 309–317.
Franck, J., Vigliocco, G., & Nicol, J. (2002). Attraction in sentence production: The role of syntactic structure. *Language and Cognitive Processes*, *17*, 371–404.
Frank, S. L., Bod, R., & Christiansen, M. H. (2012). How hierarchical is language use? *Proceedings of the Royal Society B*, *279*, 4522–4531.
Frazier, L. (1985). Syntactic complexity. In D. Dowty, L. Karttunen, & A. Zwicky (Eds.), *Natural language processing: Psychological, computational, and theoretical perspectives* (pp. 129–189). Cambridge: Cambridge University Press.
Freedman, S. E., & Forster, K. I. (1985). The psychological status of overgenerated sentences. *Cognition*, *19*, 101–131.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological, and syntactic violations. *Cognitive Brain Research*, *1*, 183–192.
Giannakidou, A. (2011). Negative and positive polarity items. In K. von Heusinger, C. Maienborn, & P. Portner (Eds.), *Semantics: An international handbook of natural language meaning* (pp. 1660–1712). Berlin: de Gruyter.
Gibson, E., & Hickok, G. (1993). Sentence processing with empty categories. *Language and Cognitive Processes*, *8*, 147–161.
Gibson, E., & Thomas, J. (1999). Memory limitations and structural forgetting: The perception of complex ungrammatical sentences as grammatical. *Language and Cognitive Processes*, *14*, 225–248.
Gimenes, M., Rigalleau, F., & Gaonach, D. (2009). When a missing verb makes a French sentence more acceptable. *Language and Cognitive Processes*, *24*, 440–449.
Grodner, D. J., Klein, N. M., Carbary, K. M., & Tanenhaus, M. K. (2010). "Some", and possibly all, scalar inferences are not delayed: Evidence for immediate pragmatic enrichment. *Cognition*, *116*, 42–55.
Grune, D., & Jacobs, C. J. H. (2008). *Parsing techniques: A practical guide*. New York: Springer.
Hackl, M., Koster-Hale, J., & Varvoutis, J. (2012). Quantification and ACD: Evidence from real-time sentence processing. *Journal of Semantics*, *29*, 145–207.
Hermer, L., & Spelke, E. (1996). Modularity and development: The case of spatial reorientation. *Cognition*, *61*, 195–232.
Hermer-Vazquez, L., Moffet, A., & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition*, *79*, 263–299.
Hermer-Vazquez, L., Spelke, E., & Katsnelson, A. S. (1999). Sources of flexibility in human cognition: Dual-task studies of space and language. *Cognitive Psychology*, *39*, 3–36.
Hofmeister, P., & Sag, I. A. (2010). Cognitive constraints and island effects. *Language*, *86*, 366–415.
Huang, Y., & Snedeker, J. (2009). Online interpretation of scalar quantifiers: Insight into the semantics-pragmatics interface. *Cognitive Psychology*, *58*, 376–415.
Hussey, E. K., & Novick, J. (2012). The benefits of executive control training and the implications for language processing. *Frontiers in Psychology*, *3*, 1–14.
Hyde, D. C., Winkler-Rhoades, N., Lee, S. A., Izard, V., Shapiro, K. A., & Spelke, E. S. (2011). Spatial and numerical abilities without a complete natural language. *Neuropsychologia*, *49*, 924–936.
Jacob, F. (1977). Evolution and Tinkering. *Science, 196*, 1161-1166.
Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*, 122–149.
Kaan, E. (2007). Event-related potentials and language processing: A brief overview. *Language and Linguistics Compass*, *1*, 571–591.
Kazanina, N., Lau, E. F., Lieberman, M., Yoshida, M., & Phillips, C. (2007). The effect of syntactic constraints on the processing of backward anaphora. *Journal of Memory and Language*, *56*, 384–409.
Kazanina, N., & Phillips, C. (2010). Differential effects of constraints in the processing of Russian cataphora. *Quarterly Journal of Experimental Psychology*, *63*, 371–400.
Kempen, G. (2014). Prolegomena to a neurocomputational architecture for human grammatical encoding and decoding. *Neuroinformatics*, *12*, 111–142.
Kempen, G., Olsthoorn, N., & Sprenger, S. (2012). Grammatical workspace sharing during language production and language comprehension: Evidence from grammatical multitasking. *Language and Cognitive Processes*, *27*, 345–380.
Kennison, S. (2003). Comprehending the pronouns her, him, and his: Implications for theories of referential processing. *Journal of Memory and Language*, *49*, 335–352.
King, J., Andrews, C., & Wagers, M. (2012). Do reflexives always find a good antecedent for themselves? In *Poster at the 25th annual CUNY conference on human sentence processing*, New York, NY.
Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERPs on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience, 5*, 196–214.
Kush, D. (2013). *Respecting relations: Memory access and antecedent retrieval in incremental sentence processing*. PhD dissertation, University of Maryland.
Ladusaw, W. (1996). Negation and polarity items. In S. Lappin (Ed.), *The handbook of contemporary syntactic theory* (pp. 321–341). Oxford: Blackwell.
Lago, M. S., & Phillips, C. (2014). Agreement processes in Spanish comprehension. Ms. University of Maryland.
Ledoux, K., Gordon, P. C., Camblin, C. C., & Swaab, T. Y. (2007). Coreference and lexical repetition: Mechanisms of discourse integration. *Memory and Cognition*, *35*, 801–815.
Lewis, S. (2013). *Pragmatic enrichment in language processing and development*. PhD dissertation, University of Maryland.

Lewis, R. L., & Vasishth, S. (2005). An activation-based model of sentence processing as skilled memory retrieval. *Cognitive Science*, *29*, 1–45.
Linebarger, M. (1987). Negative polarity and grammatical representation. *Linguistics and Philosophy*, *10*, 325–387.
MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive Psychology*, *24*, 56–98.
McElree, B., Foraker, S., & Dyer, L. (2003). Memory structures that subserve sentence comprehension. *Journal of Memory and Language, 48*, 67–91.
McElree, B., & Griffith, T. (1998). Structural and lexical constraints on filling gaps during sentence comprehension: A time-course analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 432–460.
Merchant, J. (2001). *The syntax of silence: Sluicing, islands, and identifying in ellipsis*. Oxford: Oxford University Press.
Neville, H., Nicol, J. L., Barss, A., Forster, K. I., & Garrett, M. F. (1991). Syntactically-based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*, *3*, 151–165.
Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research*, *18*, 5–19.
Nevins, A., Dillon, B., Malhotra, S., & Phillips, C. (2007). The role of feature-number and feature-type in processing Hindi verb agreement violations. *Brain Research*, *1164*, 81–94.
Novick, J., Hussey, E. K., Teubner-Rhodes, S., Harbison, J. I., & Bunting, M. (2014). Clearing the garden path: Improving sentence processing through executive control training. *Language, Cognition and Neuroscience, 29*, 186–217.
Omaki, A., & Schulz, B. (2011). Filler-gap dependencies and island constraints in second language sentence processing. *Studies in Second Language Acquisition*, *33*, 563–588.
Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language*, *31*, 785–806.
Pablos, L., Ruijgrok, B., Doetjes, J., & Cheng, L. (2012). Processing cataphoric pronouns in Dutch: An ERP study. In *Talk at the GLOW workshop on timing in grammar*. Potsdam.
Patil, U., Vasishth, S., & Lewis, R. (2011). Early retrieval interference in syntax-guided antecedent search. In *Talk at the 24th annual CUNY conference on human sentence processing*. Stanford, CA.
Pearlmutter, N. J., Garnsey, S. M., & Bock, K. (1999). Agreement processes in sentence comprehension. *Journal of Memory and Language*, *41*, 427–456.
Phillips, C. (2006). The real-time status of island phenomena. *Language*, *82*, 195–823.
Phillips, C., & Lewis, S. (2013). Derivational order in syntax: Evidence and architectural consequences. *Studies in Linguistics*, *6*, 11–47.
Phillips, C., & Parker, D. (2013). The psycholinguistics of ellipsis. *Lingua*. doi:10.1016/j.lingua.2013.10.003.
Phillips, C., & Wagers, M. W. (2007). Relating structure and time in linguistics and psycholinguistics. In G. Gaskell (Ed.), *The Oxford Handbook of psycholinguistics* (pp. 739–756). Oxford: Oxford University Press.
Phillips, C., Wagers, M. W., & Lau, E. F. (2011). Grammatical illusions and selective fallibility in real-time language comprehension. In J. Runner (Ed.), *Experiments at the interfaces (syntax and semantics, vol. 37)* (pp. 153–186). Bingley: Emerald.
Pica, P., Lemer, C., Izard, V., & Dehaene, S. (2004). Exact and approximate arithmetic in an Amazonian Indigene group. *Science*, *306*, 499–503.
Pickering, M., Barton, J. S., & Shillcock, R. (1994). Unbounded dependencies, island constraints, and processing complexity. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 199–224). London: Lawrence Erlbaum.
Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioral and Brain Sciences*, *13*, 707–727.
Prince, A., & Smolensky, P. (2004). *Optimality theory: Constraint interaction in generative grammar*. Oxford: Blackwell.
Quirk, R., Greenbaum, S., Leech, G., & Svartvik, J. (1985). *A comprehensive grammar of the English language*. New York, NY: Longman.
Runner, J. T., Sussman, R. S., & Tanenhaus, M. K. (2006). Processing reflexives and pronouns in picture noun phrases. *Cognitive Science*, *30*, 193–241.
Sag, I. A., & Fodor, J. D. (1994). Extraction without traces. In R. Aronovich, W. Byrne, S. Preuss, & M. Senturia (Eds.), *Proceedings of the 13th annual meeting of the West Coast Conference on Formal Linguistics* (pp. 365–384). Stanford: CSLI Publications.

Sloggett, S. (2013). Case licensing in processing: Evidence from German. In *Poster at the 26th annual CUNY conference on human sentence processing*. Columbia, SC.
Spelke, E. S. (2003). What makes us smart? Core knowledge and natural language. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in Mind* (pp. 277–311). Cambridge, MA: MIT Press.
Sprouse, J., & Lau, E. F. (2013). Syntax and the brain. In M. den Dikken (Ed.), *The Cambridge handbook of generative syntax*. Cambridge: Cambridge University Press.
Stabler, E. P. (2013). Two models of minimalist, incremental syntactic analysis. *Topics in Cognitive Science*,. doi:10.1111/tops.12031.
Staub, A. (2009). On the interpretation of the number attraction effect: Response time evidence. *Journal of Memory and Language*, *60*, 308–327.
Staub, A. (2010). Reponse time distributional evidence for distinct varieties of number attraction. *Cognition*, *114*, 447–454.
Stowe, L. A. (1986). Parsing WH-constructions: Evidence for on-line gap location. *Language and Cognitive Processes*, *3*, 227–245.
Sturt, P. (2003). The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language*, *48*, 542–562.
Sturt, P. (2007). Semantic re-interpretation and garden path recovery. *Cognition*, *105*, 477–488.
Swaab, T. Y., Camblin, C. C., & Gordon, P. C. (2004). Reversed lexical repetition effects in language processing. *Journal of Cognitive Neuroscience*, *16*, 715–726.
Szabolcsi, A. (2013). Quantification and ACD: What is the evidence from real-time processing evidence for? A response to Hackl et al. (2012). *Journal of Semantics*. doi:10.1093/jos/ffs025.
Townsend, D. J., & Bever, T. G. (2001). *Sentence comprehension: The integration of habits and rules*. Cambridge, MA: MIT Press.
Traxler, M. J., & Pickering, M. J. (1996). Plausibility and the processing of unbounded dependencies. *Journal of Memory and Language*, *35*, 454–475.
Trotzke, A., Bader, M., & Frazier, L. (2013). Third factors and the performance interface in language design. *Biolinguistics*, *7*, 1–34.
Vasishth, S., Brüssow, S., Lewis, R., & Drenhaus, H. (2008). Processing polarity: How the ungrammatical intrudes on the grammatical. *Cognitive Science*, *32*, 685–712.
Wagers, M. W. (2008). *The structure of memory meets memory for structure in linguistic cognition*. PhD dissertation, University of Maryland.
Wagers, M., Lau, E., & Phillips, C. (2009). Agreement attraction in comprehension: Representations and processes. *Journal of Memory and Language*, *61*, 206–237.
Wagers, M. W., & Phillips, C. (2014). Going the distance: Memory and decision making in active dependency construction. *Quarterly Journal of Experimental Psychology, 67*, 1274–1304.
Wang, L., Bastiaansen, M., Yang, Y., & Hagoort, P. (2012). Information structure influences depth of syntactic processing: Event-related potential evidence for the Chomsky Illusion. *PLOS One*, *7*, 1–9.
Wellwood, A., Pancheva, R., Hacquard, V., & Phillips, C. (2014). *Deconstructing acomparative illusion*. Ms. Northwestern University, University of Southern California, and University of Maryland.
Whitney, C. S. (2004). *Investigations into the neural basis of structured representations*. PhD dissertation, University of Maryland.
Xiang, M., Dillon, B., & Phillips, C. (2009). Illusory licensing effects across dependency types: ERP evidence. *Brain and Language*, *108*, 40–55.
Yoshida, M., Aoshima, S., & Phillips, C. (2004). Relative clause prediction in Japanese. In *Talk at the 17th annual CUNY conference on human sentence processing*. College Park, MD.