CHAPTER 25

Sentence-level deficits in aphasia

Randi C. Martin, Loan C. Vuong, and Jason E. Crowther

25.1 Introduction

Studies in the 1970s and early 1980s demonstrated impaired sentence comprehension in conjunction with good single word comprehension in some aphasic patients (e.g. Caramazza and Zurif, 1976; Schwartz et al., 1980; von Stockert and Bader, 1976). These findings generated a good deal of excitement among aphasiologists and psycholinguists because they seemed to provide strong evidence for an independent syntactic processing module (see e.g. Caramazza and Berndt, 1978; Jackendoff, 1993: Ch. 11). That is, the results appeared to provide support for linguistic theories that hypothesized a system of rules for specifying grammatical well-formedness that was independent of semantics. A number of findings quickly followed these initial findings which caused problems for interpreting the patient data in terms of a deficit to an independent syntactic processing module. The complications that surfaced have given rise to heated debates concerning the proper interpretation of sentence comprehension deficits—mirroring to some extent the debates in linguistics on generative vs. non-generative grammar and in psycholinguistics on syntax-first vs. constraint-based sentence processing theories. An additional issue in the study of patient deficits, not unrelated to the debate on theoretical interpretation, is a debate on the appropriate methodology for studying patient deficits—specifically, the debate on group vs. case study approaches. For reasons outlined below, the focus of this review will be on the results from case studies in drawing theoretical conclusions, though the results of group studies will be discussed, particularly in domains in which few case studies are available. The emphasis will be on the implications of the findings from language deficits for psycholinguistic theory, rather than with the implications for the organization of language function in the brain.

The hypothesis of a specific impairment in a syntactic processing module was formulated in order to account for sentence production and comprehension patterns demonstrated by Broca's aphasics. We will begin with a brief review of the original findings from the 1970s and 1980s taken to support this hypothesis, and the findings that undermined that claim. We will also review the evidence regarding the complementary claim that syntactic comprehension deficits in patients without obvious syntactic difficulties in production could be attributed to a short-term memory deficit. We will then consider more recent versions of the syntactic deficit hypothesis for Broca's aphasia. As all these claims are problematic, given the heterogeneity of deficits in patients classified as Broca's aphasics, we will then turn to some case study evidence regarding the independence of semantic and syntactic knowledge. Although evidence for independence of these knowledge structures exists, we will show that during sentence processing, semantic, lexical, and syntactic factors interact to determine patient comprehension. We conclude with a discussion of revised versions of the short-term memory hypothesis, in which deficits in working-memory capacity (which is thought to encompass both processing and storage capacity) are posited as the source of patient sentence comprehension deficits.

25-Gaskell-Chap25 3/10/07 7:11 PM Page 426

25.2 Syntactic deficit hypothesis and related short-term memory deficit hypothesis

25.2.1 Syntactic deficit hypothesis and early challenges to this hypothesis

The speech of Broca's aphasics, which is slow and labored, is often "agrammatic," i.e. marked by simplified grammatical structure and the omission of function words and inflections (Goodglass and Kaplan, 1972). On clinical exam, these patients' comprehension appears to be well preserved. Thus, Broca's aphasics were traditionally thought to demonstrate a dissociation between production and comprehension. Indeed, the term "expressive aphasia" is sometimes used interchangeably with "Broca's aphasia." However, studies from the 1970s and 1980s revealed a sentence comprehension deficit for Broca's aphasics when comprehension depended on understanding the syntactic structure of the sentence. In a study that employed a sentence–picture matching task, Caramazza and Zurif (1976) reported that the errors that Broca's aphasics made on complex center-embedded object relative sentences (e.g. *The lion that the tiger chased was yellow*) were almost exclusively reversal errors (e.g. choosing a picture depicting a lion chasing a tiger). Wernicke's aphasics were just as likely to make a lexical error (i.e. choosing a picture with a lexical distracter, such as a different noun or verb) as a reversal error. Schwartz et al. (1980) demonstrated that such reversal errors for Broca's aphasics could be obtained on even simple active and passive sentences. These co-occurring production and comprehension difficulties for Broca's aphasics led Berndt and Caramazza (1980) to hypothesize a syntactic deficit as the defining feature the syndrome. This syntactic module, which was utilized during both production and comprehension, was presumably located in Broca's area in the left inferior frontal cortex. The large majority of studies on sentence comprehension since the original findings of Caramazza and Zurif (1976) have focused on patterns demonstrated by Broca's aphasics.

While the syntactic deficit hypothesis appeared to present an elegant account of the production and comprehension problems of Broca's aphasics, even the original findings of Caramazza and Zurif (1976) were problematic for this hypothesis. In their study, conduction aphasics, who have a specific difficulty in reproducing spoken utterances and do not have agrammatic speech, demonstrated comprehension performance indistinguishable from that of the Broca's aphasics. Other studies of conduction aphasics reported reduced verbal short-term memory spans; thus, it was subsequently claimed that the comprehension deficits of the conduction aphasics arose from their short-term memory deficits (Caramazza et al., 1981; Friedrich et al., 1985). It should be noted that Broca's aphasics also have reduced short-term memory capacity (Martin, 1987).

Additional problems developed for the syntactic deficit hypothesis shortly after its proposal (see Berndt, 1991; 1998; Martin, 2000, for overviews of this literature). Large-scale groups studies of comprehension revealed that all aphasic groups (i.e. Broca's, conduction, transcortical, Wernicke's) demonstrated similar rank orderings of the comprehension of different syntactic structures, with differences mainly being due to the overall level of impairment (Caplan and Hildebrandt, 1988; Naeser et al., 1987). The conclusion that all patient groups had similar comprehension deficits varying only in severity may be criticized, as more complex structures typically contain more elements overall, and thus it could be that different sources of impairment would result in similar patterns of performance. For instance, more complex sentences typically contain more words, so problems in processing such sentences could be due to difficulties in perceiving, comprehending, or retaining the words in the sentences. However, it should be noted that a case study of a mild Wernicke's aphasic revealed poor comprehension of simple passive sentences, even though the patient did not have deficits in noun comprehension or in verbal short-term memory (Martin and Blossom-Stach, 1986).

The coexistence of syntactic comprehension deficits without agrammatic speech was mirrored by the opposite dissociation of patients with agrammatic speech who did not have syntactic comprehension deficits (Kolk et al., 1985; Miceli et al., 1983; Nespoulous et al., 1988). Kolk and Van Grunsven (1985) reported the performance of eleven agrammatic patients on a sentence-picture matching task of reversible active and passive sentences. As shown in Figure 25.1, the patients varied on a continuum between chance performance on both structures to 100 per cent correct on both. Thus, the patients did not demonstrate all-or-none deficits in syntactic processing. A study of four patients with

25-Gaskell-Chap25 3/10/07 7:11 PM Page 427

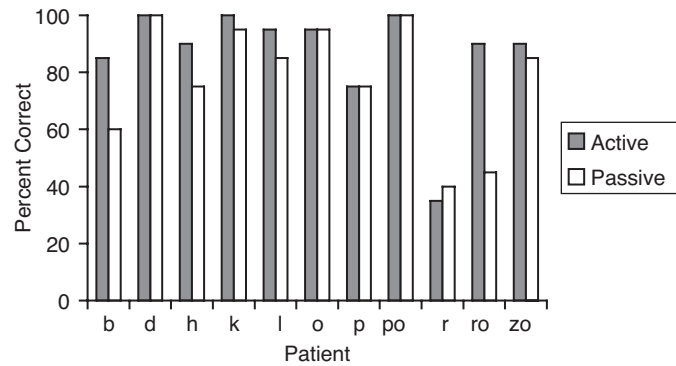

Figure 25.1 Percentage correct on sentence–picture matching for active and passive sentence for eleven agrammatic patients. Data are from Kolk and Van Grunsven (1985).

some degree of agrammatic speech found no match between degree of production deficit and degree of syntactic comprehension deficit (Martin et al., 1989), which contradicted the idea that the comprehension and production deficits were related to one another.

Another serious challenge to the syntactic deficit hypothesis came from studies of grammaticality judgements in Broca's aphasics. It was found that some patients who scored at chance in sentence–picture matching of simple active or passive sentences nevertheless performed remarkably well on grammaticality judgements (Linebarger et al., 1983; Lu et al., 2000; Lukatela et al., 1988). These studies have been criticized because they are of off-line metalinguistic tasks, and thus may require processes different from natural language comprehension (Zurif and Grodzinsky, 1983); however, studies using online grammaticality judgement techniques have also shown preserved performance (Shankweiler et al., 1989; Wulfeck, 1988). In order to account for the dissociation between comprehension and grammaticality judgements, Saffran and colleagues put forth the "mapping deficit hypothesis" (Linebarger, 1990; Saffran and Schwartz, 1988), which proposes that such patients are able to parse a sentence (e.g. analyze its syntactic structure), but are unable to assign thematic roles (e.g. agent, patient) based on the grammatical roles (e.g. subject, object) of the syntactic structure. Their findings thus implicate a separation between the processes used to determine hierarchical structure and those used to determine thematic roles based on that structure.

25.2.2 Short-term memory deficits as source of syntactic comprehension deficits

As discussed earlier, the syntactic comprehension difficulties of conduction aphasics were attributed to short-term memory deficits, and several early studies seemed consistent with that claim (Caramazza et al., 1981; Friedrich et al., 1985; Saffran and Marin, 1975). As discussed by Martin (1987), however, the theoretical account of the connection between phonological storage and syntactic processing was not clearly laid out. Caramazza et al. (1981) proposed that a limited phonological capacity would cause comprehension difficulties by narrowing the number of words that could be considered simultaneously. It is not obvious, though, how a patient with restricted phonological capacity would fail to understand a simple passive sentence such as *The boy was chased by the dog*, if the patient could comprehend *the boy* followed by comprehension of *was chased*. Presumably, once the lexical information is accessed and integrated into a syntactic frame, the original phonological code becomes irrelevant. Further, Martin (1987) found that patient EA, who had a memory span of about 1.5 words, scored 100 per cent correct in comprehending the main clause of sentences such as *The boy that carried the girl had red hair*, when, according to Caramazza et al. (1981), it would be expected that she would erroneously associate *red hair* with *the girl*.

A number of more recent case studies have documented preserved syntactic processing for patients with very reduced short-term memory capacities (Butterworth et al., 1986; Friedmann

25-Gaskell-Chap25 3/10/07 7:11 PM Page 428

and Gvion, 2003; Hanten and Martin, 2001; Martin et al., 1995;[1] Waters et al., 1991). A particularly striking case, patient BO, was presented by Waters et al. Even though BO had a span of about two words, she was able to understand a range of syntactically complex sentences. For example, on a task in which she heard a sentence and acted out the action using stuffed animals, she scored ninety-two per cent correct on dative passives (e.g. *The bear was given to the donkey by the goat*) and ninety-two per cent correct on center-embedded object relative sentences (e.g. *The bear that the donkey kissed patted the goat*).

A large body of data indicates the importance of the maintenance of phonological codes for digit and word span (Baddeley, 1986). For many of the patient studies described above, documenting a dissociation between reduced span and preserved syntactic processing, evidence was provided that the patient's deficit was specifically in the maintenance of phonological codes (Butterworth et al., 1986; Hanten and Martin, 2001; Waters et al., 1991).[2] Consequently, these studies indicate that the maintenance of phonology is not critical for the processes needed to integrate syntactic and semantic information across words in a sentence. The findings suggest that patients with reduced phonological capacity can access the semantic and syntactic features of each word as they hear it and construct and maintain the syntactic analysis and semantic interpretation of the sentence. Such a claim is consistent with a great deal of evidence from healthy subjects indicating immediacy of processing during sentence comprehension (Marslen-Wilson and Tyler, 1980; Altmann and Steedman, 1988). Even when the comprehender must presumably re-access a word earlier in a sentence (e.g. in a center-embedded object relative construction), they can apparently do so on the basis of the maintenance of non-phonological representations of that word. For the patients in whom reduced span was associated with a syntactic comprehension deficit, it is likely that other processes important to sentence comprehension were impaired or slowed in these patients, resulting in a greater reliance on a phonological code than would normally be the case (see Romani, 1994 for discussion).

[1] The patient MP reported by Martin et al. (1995) had a normal auditory span, but reduced visual span. Nonetheless, his reading comprehension for syntactically complex sentences was excellent even for sentences presented in a word-by-word fashion with a rapid presentation rate.

[2] Waters et al. attributed BO's short-term memory deficit to a rehearsal deficit, which was consistent with her articulatory difficulties. However, BO failed to show a phonological similarity effect on word span even with auditory presentation. Given that the phonological similarity effect persists in normal subjects for auditory presentation under articulatory suppression (Longoni et al., 1993), the failure to observe this effect with BO suggests that she had difficulty with phonological storage in addition to whatever rehearsal deficit she might have had.

25.2.3 Modifications of the syntactic deficit hypothesis

Despite the evidence against the syntactic deficit hypothesis and against the corollary of a short-term memory deficit as the source of syntactic comprehension deficits in non-agrammatic speakers, research on the link between agrammatism and syntactic deficits has persisted. Some have argued for a deficit in agrammatic Broca's aphasics' processing mechanisms such as slowed syntactic parsing (Haarmann and Kolk, 1991). Others hypothesized a deficit in some type of linguistic knowledge such as a deficit in structures involving double dependency (Mauner et al., 1993) or a deficit in structures involving moved elements, termed the Trace Deletion Hypothesis (TDH) (Grodzinsky, 1990; 1995; 2000; Grodzinsky and Finkel, 1998). We will focus on the TDH because it has had considerable currency in the literature, even in the face of inconsistent evidence and questions about the legitimacy of the methodology used to gather support for it.

Briefly, the latest version of the TDH (Grodzinsky, 2000) claims that agrammatic Broca's aphasics have a selective deficit in the representation of moved constituents (see examples in 1).

(1) a. $[\text{The boy}]_i\ [_{VP}\ \boldsymbol{t}_i$ kissed [the girl]].
b. $[\text{The boy}]_i$ was $[_{VP}\ \boldsymbol{t}'_i$ kissed $\boldsymbol{t}_i]$ by [the girl].

According to a number of linguistic theories (e.g. Chomsky, 1981), a moved constituent leaves in its original position a phonologically empty but psychologically real marker, called a "trace." The TDH assumes that traces are involved in both canonical structures (e.g. English actives (as in 1a), subject relatives, and subject clefts) and non-canonical structures (e.g. English passives (as in 1b), object relatives, and object clefts). The verb assigns thematic role directly to the trace in the original position (e.g. Agent role to the ***t*** in 1a, Theme role to the ***t*** in 1b), which is then transmitted to elements ***t*** is co-indexed with (e.g. the Agent role to *the boy* in (1a), the Theme role to ***t***' in (1b), which in turn passes the Theme role to *the boy)*. The TDH makes two

25-Gaskell-Chap25 3/10/07 7:11 PM Page 429

main assumptions: (1) traces are deleted from agrammatic Broca's aphasics' representation; and (2) these patients use a nonlinguistic, linear default strategy that assigns an Agent role to clause-initial subject NPs (e.g. *the boy* in 1 receives the Agent role). For canonical structures, role assignment based on this strategy and syntactic processing matches. For non-canonical structures, the strategy assigns the Agent role to the subject NP while syntax assigns the same role to the other NP argument of a transitive verb (e.g. the NP in the by-phrase *the girl* in 1b). The TDH suggests that the patients determine filler of the Agent role by randomly choosing between the two NPs. It, therefore, predicts above-chance performance on the canonical structures and at-chance performance on the non-canonical structures.

Many studies have tested the TDH and, as mentioned above, have presented evidence refuting it (e.g. Badecker et al., 1991; Berndt et al., 1996; Druks and Marshall, 1991; 1995; Martin, 1987; Wilson and Saygin, 2004). None of these studies found a single comprehension pattern of above-chance performance on the canonical sentences and at-chance performance on the non-canonical sentences as predicted by the TDH. For example, in a review of sixty-four data sets from forty-two patients from studies that had assessed Broca's aphasics' comprehension of semantically reversible actives and passives, Berndt et al. (1996) showed that approximately one-third of the patients did well on both structures, about one third scored at chance on both structures, and the other third showed above-chance performance on actives and at-chance performance on passives. More recently, Wilson and Saygin (2004) showed that the Broca's aphasics in their study were not more impaired on grammaticality judgements of sentences with traces than of those without traces when the level of syntactic difficulty was controlled for. Specifically, they found that the patients had the most difficulty with trace/hard sentences (e.g. **Which woman did John think that saw Tony?*), the least difficulty with trace/easy sentences (e.g. **Me the dog which bit was black*), and in-between levels of difficulty with other/hard (e.g. **She donated the library the books*) and other/easy sentences (e.g. **Have they could left the city*?), respectively. Even when the patients were divided into those who showed the sentence comprehension pattern predicted by the TDH and those who did not, no difference in performance on the grammaticality judgements was found. Results from these studies are clearly at odds with the TDH.

Advocates of the TDH have rejected the disconfirming findings. Noticeably, most of those findings have been provided by studies using the case study approach. The supportive evidence for the TDH, on the other hand, has been supplied by studies using the group study approach. The appropriateness of the methodology used to test the TDH has thus been the focus of sharp exchanges between researchers from each side (e.g. Berndt and Caramazza, 1999; Caplan, 2001; Caramazza et al., 2001; Drai and Grodzinsky, 1999; Drai et al., 2001; Druks and Marshall, 1995; 2000; Grodzinsky et al., 1999; Zurif, 1996; 2001; Zurif and Pinango, 1999). The disagreement provides a clear illustration of the debate in the field over the case study vs. group study approach that we alluded to at the beginning of the chapter. As an example, Grodzinsky et al. (1999) argued that their data on the active/passive contrast had to be analyzed at the group level rather than at the single-subject level. However, this is clearly untenable if the claim is that all agrammatic Broca's aphasics show a certain pattern of sentence comprehension. Their approach is rather like arguing that one can support the claim that *all* Norwegians have an IQ of 100 by showing that the group mean for a sample does not deviate from 100. One may rebut this, as Grodzinsky et al. (1999) did, by arguing that the data had to be analyzed as a group so as to detect chance performance. The reasoning is that, if the patients randomly choose between two alternatives, then "guessing behavior, which results in chance performance, cannot, and should not, be fifty per cent correct per subject" (p. 137). As Caramazza et al. (2001) pointed out, Grodzinsky et al. appeared to have confused the number of subjects with the number of trials. The argument advanced by Grodzinsky et al. holds only for cases in which a particular patient is tested on a small number of trials. Given a score of eighty per cent correct, one can in fact have a reliable degree of confidence ($p < .0001$) in drawing implications from a single patient's data if the patient is tested on forty or more items (see Caramazza et al., 2001 for more detail).

Another account of the syntactic processing deficits in aphasia comes from Ullman and colleagues. Ullman et al. (1997) tested patients on a sentence completion task requiring production of a past-tense verb. They found that their Alzheimer's patients and posterior aphasic patients as groups were more impaired in the production of irregular past tenses, whereas their Parkinson's group and one anterior aphasic patient were more impaired in the production of

25-Gaskell-Chap25 3/10/07 7:11 PM Page 430

regular past-tense verbs. They argued that this dissociation was due to general properties of posterior vs. frontal systems in which posterior regions support declarative, memory-based representations, whereas frontal/basal ganglia regions support procedural or rule-based knowledge, including grammatical knowledge that is drawn on in computing past tenses for regular verbs. Ullman et al.'s (1997) conclusions have been called into question by a number of researchers. Some have argued that a single-mechanism connectionist system supports retrieval of the past tense for both regular and irregular forms (Rumelhart and McClelland, 1986). Joanisse and Seidenberg (1999) and Patterson et al. (2001) have provided computational and empirical evidence for a single-system approach, arguing that the observed double dissociation derives from other factors, specifically semantic deficits in patients with posterior deficits and phonological deficits in patients with frontal deficits (but see Tyler et al., 2002).

The empirical facts supporting the dissociation reported by Ullman et al. have also been questioned, as numerous studies have documented cases of agrammatic patients who perform better on regular than irregular morphological transformations (de Diego Balaguer et al., 2004; Faroqi-Shah and Thompson, 2003; Laiacona and Caramazza, 2004; Marslen-Wilson and Tyler, 1997; 1998; Penke et al., 1999; Shapiro and Caramazza, 2003). It is beyond the scope of this chapter to delve into the fine points of the different positions, as the claims have to do mainly with language production rather than comprehension. It should be noted, however, that the plausibility of the claim that frontal brain regions support rule-based grammatical processing hinges in part on evidence that anterior aphasics have difficulty with such processes in comprehension as well as in production. The findings from grammaticality judgements discussed earlier provide strong evidence against such a generalization.

25.3 The independence of syntactic and semantic knowledge and the interactions of lexical, semantic, and syntactic factors in comprehension

The original findings of Caramazza and Zurif (1976) generated a great deal of excitement because they appeared to demonstrate the independence of syntactic and semantic knowledge by showing that syntactic knowledge could be selectively disrupted. As indicated above, a focus on agrammatic Broca's aphasia as a clinical syndrome did not provide the hoped-for evidence of such a dissociation, particularly when one considered the evidence from grammaticality judgements. Clearer evidence for the independence in the representation of semantic and syntactic abilities has instead been provided by case studies. Despite this representational independence, several studies show that syntactic, semantic, and lexical factors interact during processing. We will next turn to these findings.

Two single case studies provide clear dissociations between syntax and semantics. Patient JG, who had a left temporo-parietal lesion, showed impaired performance in syntactic tasks and unimpaired performance in tasks tapping lexical-semantic processing (Ostrin and Tyler, 1995). He exhibited an asyntactic comprehension pattern when tested in a sentence-picture matching task. That is, his performance was poor on semantically unconstrained sentences (e.g. *The cow bit the horse*) and was better on semantically constrained sentences (e.g. *The boy threw the ball*). In a word-monitoring experiment and a grammaticality judgement experiment, he also showed an insensitivity to a variety of grammatical violations—violations of subcategorization frame, violations of inflectional and derivational morphology, and, in a previous study, violations of word order (Tyler, 1992). However, like normal subjects, he showed semantic priming in a lexical decision task, both at the single-word level and at the sentence level. In contrast to JG, patient DM, a semantic dementia patient, performed at a high level (ninety-five per cent—within normal range) on a grammaticality test tapping a wide range of grammatical structures during a time period in which performance on semantic tasks declined dramatically (Breedin and Saffran, 1999). DM also showed a preserved ability to assign thematic roles based on sentence structure when tested in a sentence-enactment matching task using test animals that he had difficulty recognizing by name. He carried out the matching by consistently relying on syntactically based role assignments to the animal subjects. For example, when asked to identify the animal object "tiger" after hearing the sentence *The tiger is carrying the lion (the tiger* thus received the Agent role here) and seeing the demonstration of a lion carrying a tiger, DM pointed to the agentive object in the demonstration (which was, in fact,

25-Gaskell-Chap25 3/10/07 7:11 PM Page 431

the lion). This pattern of performance remained even when syntactically more complex sentences, such as passives, cleft subjects, and cleft objects, were used.

The doubly dissociated patterns of disruptions and preservations of syntax and semantics exhibited by patient DM (Ostrin and Tyler, 1995) and patient JG (Breedin and Saffran, 1999) argue strongly that syntactic knowledge is represented autonomously from semantic knowledge. Studies on normal subjects suggest that constraints from these knowledge systems simultaneously interact with each other and with other sources of linguistic information, including lexical and discourse information, to determine sentence interpretation (e.g. Spivey and Tanenhaus, 1998; Trueswell et al., 1994). It is thus possible for brain damage to affect the syntactic knowledge system such that all of the outputs from the system are weakened and consequently play a lesser (but not nonexistent) role than other constraints in sentence interpretation. A study by Saffran et al. (1998) gave evidence for this interactive effect on aphasic sentence comprehension. Broca's and non-Broca's aphasics, who had shown syntactic comprehension deficits on sentence–picture matching tasks, were asked to make plausibility judgements to spoken active, passive, subject-cleft, and object-cleft sentences. Semantic constraints converged with syntactically based role assignment in plausible sentences (e.g. *The dog barked at the kitten*). In implausible sentences (e.g. #*The cheese ate the mouse*, #*The worm swallowed the bird*), the two sources of information conflicted. Results for the implausible sentences showed that when semantic constraints were strong, i.e. when one NP could plausibly fill only one of the two argument positions of a transitive verb (as in *The cheese ate the mouse*), the patients made many errors that were consistent with a semantically based thematic role assignment, even for simple active sentences. More interestingly, when semantic constraints were weaker, i.e. when both NPs were possible fillers of both thematic roles of a transitive verb (as in *The worm swallowed the bird*) and only our knowledge of the world tells us which NP is likely to be the Agent and which the Theme (e.g. it is more likely that a bird swallows a worm than vice versa), the patients made substantially fewer errors. (This pattern was shown both by Broca's and by non-Broca's aphasic patients.) The interpretation of this result is that when semantic constraints were weaker the patients were able to utilize their residual syntactic ability to assign thematic roles, thus making more correct responses.

The findings from Saffran et al. (1998) are consistent with models of sentence comprehension that suggest parallel semantic and syntactic processes (e.g. Boland, 1997; Ferreira and Stacey, 2005). In the dual-route model proposed by Ferreira and Stacey, for example, sentence input immediately activates both syntactic and semantic processes, and their output determine thematic roles assigned to participants in the sentence. The syntactic process, called theta-transmission, assigns thematic roles grammatically. The other process, called schema-transmission, assigns thematic roles based on schemas (i.e. stereotypical knowledge of events and states) that are activated from long-term memory. For example, as the sentence *The dog was bitten by the man* is processed, the concepts DOG, MAN, and BITE may activate a dog-biting schema, leading to an assignment of an Agent role to *the dog* and a Patient role to *the man.* If theta-transmission does not yield a secure set of thematic role assignment (e.g. due to increased difficulty with non-canonical sentence structures such as passive sentences or to an impairment in the system as in brain-damaged patients), then role assignment by schema-transmission will have a larger influence, causing a misinterpretation of the sentence as the dog biting the man. In the Saffran et al. study, the implausible sentence set that had stronger semantic constraints also consisted of a number of items that could potentially lead to schema activations (e.g. CAT, PUPPY, BARK; CHEESE, MOUSE, EAT; DEER, HUNTER, SHOOT). Because the patients had impaired syntactic abilities, their increased error rates in judging the plausibility of these items might have been due to the interference from schema-based role assignment

As discussed above, recent models of sentence comprehension also allow for interactions between lexical factors and sentence structures in processing. A number of studies in neuropsychology have suggested an important role for verb processing deficits in patients' sentence comprehension impairments (e.g. Berndt et al., 1997; Breedin and Martin, 1996). More recently, Berndt et al. (2004) showed that features of verb representation interacted with sentence syntax to cause differential levels of difficulty in the processing of semantically reversible passives. The authors used a sentence–picture matching task to test a group of control subjects and two groups of aphasic patients, the "good comprehenders" who had no impairment on reversible sentences and the "poor comprehenders" who were impaired on those sentences. Verb sets were chosen such that their agents and patients

25-Gaskell-Chap25 3/10/07 7:11 PM Page 432

varied in the amount of role prototypicality. A "proto-agent" of an action verb is one that is actively moving, while a "proto-patient" is stationary and caused to change state by agents (as in verbs like *bury*, *wash*, *kick*, *shoot*, *slap*, *spray*). Results showed that the good comprehenders were least accurate on passive sentences whose agents and patients of the verbs were not prototypical (e.g. *pull*, *push*, *chase, follow*, *guide*, *lead*, in which thematic agents and patients were moving and both participated in the action). They were also slower to respond when the verbs contained non-prototypical agents and patients than when the verbs contained prototypical agents and patients. These patterns of performance were in accord with the control subjects' performance patterns. Although the poor comprehenders' data were contaminated by response biases, they also showed lower response accuracy for active sentences containing non-prototypical agents and patients. Along with the results from Saffran et al. (1998), these results demonstrate that the assignment of thematic roles to noun arguments depends on a confluence of lexical, syntactic, and semantic constraints.

While processing difficulty of a sentence structure may be exacerbated by verb-specific attributes (Berndt et al., 2004), it can conversely be mitigated when verb-specific biases are matched with sentence structures (Gahl, 2002; Gahl et al., 2003). Using a sentence anomaly task, Gahl (2002) manipulated whether the structure of a sentence matched the transitive or intransitive bias of a verb (i.e. the relative frequency with which the verb appears in either form). For example, the verb *crumble* has an intransitive bias, so the intransitive sentence *The crackers crumbled in our hands* would match the verb's bias, while the transitive sentence *The children crumbled the crackers* would have a mismatch between bias and structure. Gahl found that a mixed group of aphasic patients performed at a higher level when the structure of the sentence matched the verb's bias for being either transitive or intransitive. Gahl et al. (2003) further showed for a mixed group of aphasic patients that comprehension of the passive was significantly better for passive-bias verbs (e.g. *elect*) than for active-bias verbs (e.g. *disturb*). No evident difference was found between the pattern for the Broca's aphasics and that for the fluent patients.

Together, findings from the studies reviewed above suggest representational independence of syntactic and semantic abilities and an interaction between them and lexical factors in sentence processing. These findings can be accounted for by sentence-processing models like those of Boland (1997) or Ferreira and Stacey (2005), which assume that syntactic and semantic processes occur in parallel. If we assume that the strength of all syntactic representations have been reduced for the patients, then when semantic constraints on the assignment of nouns to thematic roles about the verb are strong, they override the relatively weak outputs of the syntactic system. When semantic constraints are nil or weak, the results of syntactic processing can play a larger role. Similarly, Gahl et al.'s (2003) results showing better comprehension of passives for passive-bias verbs could be explained on the grounds that a greater weight is given to a passive interpretation for a passive-bias verb than for an active-bias verb. Although early theorizing on syntactic processing and representation may have led to the prediction of all-or-none loss, the assumption of a decrease in the strength syntactic weights would allow for continuous variation in the degree of impairment, such as that reported by Kolk and van Grunsven (1985).

25.3.1 Varieties of working memory deficits and their relation to sentence comprehension

Some researchers take the fact that patient deficits are not all-or-none as evidence that these deficits should not be attributed to a loss of syntactic knowledge but instead to some type of working-memory deficit (e.g. Miyake et al., 1994). As mentioned above, however, the application of approaches like that of Boland (1997) to patient data allows for continuous variation in the strength of syntactic representations. One might question whether it is still necessary to posit working memory deficits as the source of some comprehension deficits. Certainly some structures would seem to require some type of working memory capacity—for example when a noun that appears early in a sentence needs to be integrated with a verb that appears later, as in center-embedded object relatives like *The boy that the girl carried had red hair*. Boland's (1997) model does not provide explicit descriptions of how such connections are made. Some recent approaches to syntactic processing give an important role to working memory requirements in predicting the difficulty of different syntactic structures (Gibson, 2000; Gordon et al., 2001; Van Dyke and Lewis, 2003). Consequently, there still seems to be a need to

25-Gaskell-Chap25 3/10/07 7:11 PM Page 433

posit working-memory involvement, and to consider the potential negative consequences of working-memory limitations. In this section, we will consider recent neuropsychological evidence on the relation between syntactic processing and working memory.

As reviewed earlier, phonological short-term memory, as measured by traditional span measures, appears unrelated to syntactic processing ability. However, some researchers have argued that other measures of capacity that tap both processing and storage do relate to syntactic comprehension (Just and Carpenter, 1992). One such measure is reading span, in which subjects are asked to read a set of sentences aloud and recall the sentence-final words from each sentence at the end of the set. Caplan and Waters (1999) reviewed the evidence from normal and brain damaged populations on the relation between short-term memory, working memory, and sentence processing. As discussed by Caplan and Waters (1999), a number of studies of neurally intact individuals relating sentence processing to either working-memory capacity (as far from reading span) or the effect of an external load have found additive rather than interactive effects of these variables and the effect of syntactic complexity and memory capacity or load. According to additive-factors logic (Sternberg, 1998), the additive effects imply that different capacities are involved in working memory span and syntactic processing. Patient studies have provided converging results. For instance, Caplan and Waters discussed evidence that patients with dementia of the Alzheimer's type (DAT) and Parkinson's disease (PD) do not have deficits in phonological storage and rehearsal, but do have deficits in the executive function component of working memory, and have very reduced sentence spans. However, these patients did not show greater effects of syntactic complexity than did controls on sentence–picture matching, even when maintaining a concurrent digit load (e.g. see Waters et al., 1995). The DAT patients did, however, show a greater than normal effect of the number of propositions in a sentence. Caplan and Waters attribute the effect of number of propositions to non-syntactic sources. Although some previous studies have reported greater effects of syntactic complexity for DAT or PD patients than for controls (e.g. Emery, 1988; Natsopoulos et al., 1991), Caplan and Waters suggested that these deficits may have resulted from non-syntactic demands of the tasks employed (e.g. having to choose from a large number of picture choices in sentence-picture matching).

The findings from healthy and brain-damaged participants led Caplan and Waters (1999) to postulate that there is a working-memory capacity specific to the initial phases of sentence processing that is independent of the capacities tapped by short-term and working-memory tasks. They divide the procedures involved in sentence processing into interpretive and post-interpretive processes. Interpretive processes include all online syntactic and semantic processes, including those involved in semantic interpretation based on the ongoing discourse. Post-interpretive processes involve using the products of interpretive processing to carry out some task, such as sentence–picture matching or enactment of the action in the sentence. Caplan and Waters argue that interpretive processing draws on a capacity specific to sentence processing, whereas post-interpretive processing draws on the capacity tapped by standard span tasks or working-memory tasks. One problematic finding for this conclusion is that working-memory capacity and an extraneous load interact with number of propositions in a sentence in determining comprehension performance for patients and controls. It is unclear why an influence of number of propositions should be relegated to "post-interpretive" processing. (See Ferreira, 1999 for related discussion.)

Martin and colleagues (Hanten and Martin, 2000; Martin and He, 2004; Martin and Romani, 1994; Martin et al., 1994) have provided a different view on the relation between the capacities involved in span tasks and sentence processing. Specifically, they argue that span tasks tap both phonological and semantic retention (see also N. Martin and Saffran, 1997). The phonological component of span tasks is independent of the capacity involved in sentence processing. On the other hand, the semantic component does play a role in sentence comprehension in the maintenance of word meanings prior to their integration with other word meanings (Martin and He, 2004). Supporting this contention were results from patients with a semantic retention deficit who had difficulty detecting the semantic anomaly in sentences with two or three adjectives preceding a noun (e.g. *The rusty old red swimsuit*) or with two or three nouns preceding a verb (e.g. *Rocks, trees, and shrubs grew in the back yard*). These patients (AB and ML) did better when there was only one adjective before the noun or one noun before the verb, and when the adjectives followed the noun (e.g. *The swimsuit was old, red and rusty*) or the nouns followed the verb (e.g. *The gardener grew shrubs, trees and rocks in*

25-Gaskell-Chap25 3/10/07 7:11 PM Page 434

the backyard) (Hanten and Martin, 2000; Martin and He, 2004; Martin and Romani, 1994). A patient with a phonological short-term memory deficit (EA) did not show this pattern. Although she showed worse performance overall than controls, the effect of number of adjectives or nouns and of the before/after manipulation were within the range of controls. Figure 25.2 presents the data from patients ML and AB (with semantic short-term memory deficits) and from EA (with a phonological short-term memory deficit). The results are averaged across the adjective–noun and noun–verb sentences in terms of the difference in percentage errors when there were two or three adjectives vs. one adjective (or two or three nouns vs. one noun) in the before and after conditions. Martin and colleagues argued that when the adjectives preceded the noun, they had to be maintained as individual word meanings until the noun was processed, whereas when the adjectives followed the noun, they could be integrated with the noun as each was heard. Similarly, when the conjoined nouns preceded the verb, the role of the nouns with respect to the verb could not be determined until the verb was processed, whereas when the nouns followed the verb, their role with respect to the verb could be determined as each was heard. The patients' better performance in the "after" than in the "before" conditions indicate that the patients were better able to maintain integrated semantic representations than individual word meanings. (See Haarmann et al., 2003 for related results from normal subjects.) Martin and colleagues agree with Caplan and Waters (1999) to some extent, as both groups assume that the retention of specifically syntactic structural information is independent of both phonological and semantic capacities (Martin and Romani, 1994).

MacDonald and colleagues (MacDonald et al., 2001; MacDonald and Christiansen, 2002) have offered yet another way to conceptualize the relation between working memory and sentence processing. Whereas Caplan and Waters (1999) and Martin and colleagues (e.g. Martin and Romani, 1994) assume the existence of temporary spaces devoted to the storage and processing of linguistic information in online operations, MacDonald and colleagues postulate a language system in which storage of linguistic knowledge, locus of linguistic processing and working memory resources used in processing are functionally and neuroanatomically intertwined. In this framework, a linguistic working memory task and a comprehension task are assumed to measure the same language-processing skills if they share common task demands.

MacDonald et al. (2001) used data from Alzheimer's disease (AD) patients to support their proposal. The AD patients' working memory capacities were tested in a digit-ordering task, in which participants were asked to reorder a random list of digits to a numerically increasing list.

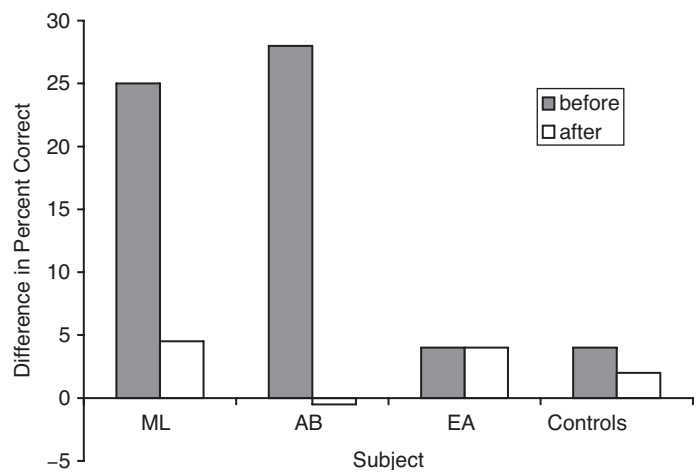

Figure 25.2 Difference in percentage errors on sentence anomaly judgements for the mean of two and three adjectives or nouns vs. one adjective or noun in the before and after conditions. Patients ML and AB showed evidence of a semantic short-term memory deficit, whereas EA had a phonological STM deficit. Data are from Martin and Romani (1994) and Martin and He (2004).

25-Gaskell-Chap25 3/10/07 7:11 PM Page 435

The patients showed impaired performance in the digit-ordering task, which was found to correlate significantly with (1) their impairment in offline grammaticality judgement of sentences containing violations of subject–verb number agreement and verb transitivity, and (2) their impairment in an online cross-modal priming task tapping processing of pronoun anaphors. As the digit-ordering performance correlated with both offline and online performance (the latter of which presumably eliminated extraneous working memory requirements), MacDonald and colleagues concluded that the digit-ordering task did not measure any independent working-memory capacity. Rather, it was argued to be just another measure of language- processing skills (as would be the case for traditional working-memory tasks such as the reading span task). However, although the task assessing pronoun reference required participants only to name a written pronoun, the latency effect for controls on naming the pronoun depended on the match between the pronoun and material presented two sentences back that could serve as the referent of the pronoun. Waters and Caplan (1996) argued the determination of pronoun reference across several sentences does not depend on syntactic factors, but instead depends on reasoning processes, which would be part of their post-interpretive processes. Consequently, the correlation between digit-ordering and pronoun resolution performance would be predicted according to the Caplan and Waters (1999) view. Moreover, it is unclear how the approach of MacDonald et al. could account for the many failures to find an interaction between working memory and syntactic complexity reported by Caplan and Waters if both draw on the same representations and processes.

25.4 **Concluding comments**

This chapter began with a discussion of claims of the independence of syntactic and semantic information. Although basing that claim on evidence from the clinical syndrome of Broca's aphasia proved to be a mistake, there nonetheless appears to be striking evidence from case studies demonstrating their independence (Breedin and Saffran, 1999; Tyler, 1992). Along with data supporting representational independence, however, data from patients have also been reported that show an interaction between lexical, semantic, and syntactic influences during sentence processing (Berndt et al., 2004; Gahl, 2002; Saffran et al., 1998). In one such study, patients were been shown to have a sensitivity to grammatical structure when semantic influences were weak, but a relative insensitivity to grammatical structure when semantic influences were strong (Saffran et al., 1998). Some might take these findings to be cautionary, as evidence of syntactic processing deficits might be undermined if patients were tested on materials with fewer semantic or other constraints. However, if one abandons the notion that syntactic deficits have to be all-or-none, but can be a matter of degree, such findings are entirely consistent with a syntactic disruption.

Important findings from neuropsychological deficits have also been reported regarding the role of short-term and working memory in sentence comprehension. Substantial evidence indicates that the retention of phonological codes does not play a critical role in syntactic processing. Even the more complex working-memory measures that tap both processing and storage do not appear to predict syntactic processing abilities, as patients with very reduced reading spans do not show a greater than normal effect of syntactic complexity on comprehension. Span measures do relate to some aspects of sentence comprehension, and the interpretive vs. post-interpretive distinction suggested by Caplan and Waters (1999) may go some way towards accounting for what is or is not related to span. However, some findings, such as the relation between effect of number of propositions and working-memory capacity and the relation between a semantic STM deficit and difficulty maintaining unintegrated semantic representations (e.g. Martin and He, 2004), seem difficult to account for in terms of demands on post-interpretive processes.

Although some progress has been made in understanding sentence processing deficits and their implications for theories of normal sentence comprehension, it is clear that much work remains to be done. Despite the abundant research on sentence processing in normal subjects, much of it has focused on a narrow range of topics specifically having to do with the questions of the autonomy of syntax or its interaction with other factors. There is a great deal of underspecification with regard to any number of issues: the means by which hierarchical structure is computed, the processing of long-distance dependencies in different constructions, the means by which thematic role mapping is carried out, the nature of lexical constraints on the generation of syntactic structure. Clearly, theoretical developments along any of these

25-Gaskell-Chap25 3/10/07 7:11 PM Page 436

lines would be an aid in guiding research on neuropsychological cases. Conversely, findings from neuropsychology could play an important role in the future in helping to address these issues.

Author Note

Preparation of this manuscript was supported in part by NIH grant DC-00218 to Rice University. Address correspondence to: Randi C. Martin, Psychology Dept., Rice University, P.O. Box 1892, Houston, Texas 77251, e-mail: rmartin@rice.edu.

References

Altmann, G., and Steedman, M. G. (1988) Interactions with context during human sentence processing. *Cognition*, 30: 191–238.

Baddeley, A.D. (1986) *Working Memory*. Oxford University Press, Oxford.

Badecker, W., Nathan, P., and Caramazza, A. (1991) Varieties of sentence comprehension deficits: a case study. *Cortex*, 27: 311–21.

Berndt, R. S. (1991) Sentence processing in aphasia. In M. T. Sarno (ed.), *Acquired Aphasia*, 2nd edn, pp. 223–70. Academic Press, San Diego, Calif.

Berndt, R. S. (1998) Sentence processing in aphasia. In M. T. Sarno (ed.), *Acquired Aphasia*, 3rd edn, pp. 229–67. Academic Press, San Diego, Calif.

Berndt, R. S., and Caramazza, A. (1980) A redefinition of the syndrome of Broca's aphasia: implications for a neuropsychological model of language. *Applied Psycholinguistics*, 1: 225–278.

Berndt, R.S., and Caramazza, A. (1999) How "regular" is sentence comprehension in Broca's aphasia? It depends on how you select the patients. *Brain and Language*, 67: 242–247.

Berndt, R. A., Haendiges, A., Mitchum, C., and Sandson, J. (1997) Verb retrieval in aphasia, 2: Relationship to sentence processing. *Brain and Language*, 56: 107–137.

Berndt, R.S., Mitchum, C., Burton, M., and Haendiges, A. (2004) Comprehension of reversible sentences in aphasia: the effects of verb meaning. *Cognitive Neuropsychology*, 21: 229–245.

Berndt, R. S., Mitchum, C., and Haendiges, A. (1996) Comprehension of reversible sentences in "agrammatism": a meta-analysis. *Cognition*, 58: 289–308.

Boland, J. (1997) The relationship between syntactic and semantic processes in sentence comprehension. *Language and Cognitive Processes*, 12: 423–484.

Breedin, S., and Martin, R. (1996) Patterns of verb deficits in aphasia: an analysis of four cases. *Cognitive Neuropsychology*, 13: 51–91.

Breedin, S., and Saffran, E. (1999) Sentence processing in the face of semantic loss: a case study. *Journal of Experimental Psychology: General*, 128: 547–562.

Butterworth, B., Campbell, R., and Howard, D. (1986) The uses of short-term memory: a case study. *Quarterly Journal of Experimental Psychology*, 38A: 705–737.

Caplan, D. (2001) The measurement of chance performance in aphasia, with specific reference to the comprehension of semantically reversible passive sentences: a note on issues raised by Caramazza, Capitani, Rey, and Berndt (2001) and Drai, Grodzinsky, and Zurif (2001). *Brain and Language*, 76: 193–201.

Caplan, D., and Hildebrandt, N. (1988) *Disorders of Syntactic Comprehension*. MIT Press, Cambridge, Mass.

Caplan, D., and Waters, G. S. (1999) Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*, 22: 77–126.

Caramazza, A., Basili, A. G., Koller, J., and Berndt, R. S. (1981) An investigation of repetition and language processing in a case of conduction aphasia. *Brain and Language*, 14: 235–271.

Caramazza, A., and Berndt, R. S. (1978) Semantic and syntactic processes in aphasia: a review of the literature. *Psychological Bulletin*, 85: 898–918.

Caramazza, A., Capitani, E., Rey, A., and Berndt, R. S. (2001) Agrammatic Broca's aphasia is not associated with a single pattern of comprehension performance. *Brain and Language*, 76: 158–184.

Caramazza, A., and Zurif, E. (1976) Dissociation of algorithmic and heuristic processes in language comprehension: evidence from aphasia. *Brain and Language*, 3: 572–582.

Chomsky, N. (1981) *Lectures on Government and Binding*. Foris, Dordrecht.

de Diego Balaguer, R., Costa, A., Sebastián-Gallés, N., Juncadella, M., and Caramazza, A. (2004) Regular and irregular morphology and its relationship with agrammatism: evidence from two Spanish-Catalan bilinguals. *Brain and Language*, 91: 212–222.

Drai, D., and Grodzinsky, Y. (1999) Syntactic regularity in Broca's aphasia: there's more of it than you ever imagined. *Brain and Language*, 70: 139–143.

Drai, D., Grodzinsky, Y., and Zurif, E. (2001) Broca's aphasia is associated with a single pattern of comprehension performance. *Brain and Language*, 76: 185–192.

Druks, J., and Marshall, J. C. (1991) Agrammatism: an analysis and critique, with new evidence from four Hebrew-speaking aphasic patients. *Cognitive Neuropsychology*, 8: 415–433.

Druks, J., and Marshall, J. C. (1995) When passives are easier than actives: two case studies in aphasic comprehension. *Cognition*, 55: 311–331.

Druks, J., and Marshall, J. C. (2000) Kicking over the traces: a note in response to Zurif and Pinango (1999). *Brain and Language*, 75: 461–464.

Emery, O. B. (1988) The deficit of thought in senile dementia Alzheimer's type. *Psychiatric Journal of the University of Ottawa*, 13: 3–8.

Faroqi-Shah, Y., and Thompson, C. K. (2003) Regular and irregular verb inflections in agrammatism: dissociation or association? *Brain and Language*, 87: 9–10.

Ferreira, F. (1999) Distinguishing interpretive and post-interpretive processes. *Behavioral and Brain Sciences*, 22: 98–99.

25-Gaskell-Chap25 3/10/07 7:11 PM Page 437

Ferreira, F., and Stacey, J. (2005) The misinterpretation of passive sentences. MS.

Friedmann, N., and Gvion, A. (2003) Sentence comprehension and working memory limitation in aphasia: a dissociation between semantic-syntactic and phonological reactivation. *Brain and Language*, 86: 23–39.

Friedrich, F., Martin, R. C., and Kemper, S. (1985) Consequences of a phonological coding deficit on sentence processing. *Cognitive Neuropsychology*, 2: 385–412.

Gahl, S. (2002) Lexical biases in aphasic sentence comprehension: an experimental and corpus linguistic study. *Aphasiology*, 16: 1173–1198.

Gahl, S., Menn, L., Ramsberger, G., Jurafsky, D. S., Elder, E., Rewega, M., and Audrey, L. H. (2003) Syntactic frame and verb bias in aphasia: plausibility judgements of undergoer-subject sentences. *Brain and Cognition*, 53: 223–228.

Gibson, E. (2000) The dependency locality theory: A distance-based theory of linguistic complexity. In A. Marantz, Y. Miyashita, and W. O'Neill (eds.), *Image, Language and Brain*, pp. 95126 MIT Press, Cambridge, Mass.

Goodglass, H., and Kaplan, E. (1972) *The assessment of aphasia and related disorders*. Lea and Febiger, Philadelphia.

Gordon, P. C., Hendrick, R., and Johnson, M. (2001) Memory interference during language processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27: 1411–1423.

Grodzinsky, Y. (1990) *Theoretical Perspectives on Language Deficits*. MIT Press, Cambridge, Mass.

Grodzinsky, Y. (1995) A restrictive theory of agrammatic comprehension. *Brain and Language*, 50: 27–51.

Grodzinsky, Y. (2000) The neurology of syntax: language use without Broca's area. *Behavioral and Brain Science*, 23: 1–71.

Grodzinsky, Y., and Finkel, L. (1998) The neurology of empty categories: aphasics' failure to detect ungrammaticality. *Journal of Cognitive Neuroscience*, 10: 281–292.

Grodzinsky, Y., Pinango, M. M., Zurif, E., and Drai, D. (1999) The critical role of group studies in neuropsychology: comprehension regularities in Broca's aphasia. *Brain and Language*, 67: 134–147.

Haarmann, H. J., Davelaar, E. J., and Usher, M. (2003) Individual differences in semantic short-term memory capacity and reading comprehension. *Journal of Memory and Language*, 48: 320–345.

Haarmann, H., and Kolk, H. (1991) Syntactic priming in Broca's aphasia: evidence for slow activation. *Aphasiology*, 5: 247–263.

Hanten, G., and Martin, R. (2000) Contributions of phonological and semantic short-term memory to sentence processing: evidence from two cases of closed head injury in children. *Journal of Memory and Language*, 43: 335–361.

Hanten, G., and Martin, R. (2001) A developmental phonological short-term memory deficit: a case study. *Brain and Cognition*, 45: 164–188.

Jackendoff, R. (1993) *Patterns in the Mind: Language and Human Nature*. Harvester Wheatsheaf, New York.

Joanisse, M. F., and Seidenberg, M. S. (1999) Impairments in verb morphology after brain injury: a connectionist model. *Proceedings of the National Academy of Sciences of the United States of America*, 96: 7592–7597.

Just, M. A., and Carpenter, P. A. (1992) A capacity theory of comprehension: individual differences in working memory. *Psychological Review*, 99: 122–149.

Kolk, H., and Van Grunsven, M. (1985) Agrammatism as a variable phenomenon. *Cognitive Neuropsychology*, 2: 347–384.

Kolk, H., Van Grunsven, M., and Keyser, A. (1985) On parallelism between production and comprehension in agrammatism. In M. L. Kean (ed.), *Agrammatism*, pp. 165–206. Academic Press, New York.

Laiacona, M., and Caramazza, A. (2004) The noun/verb dissociation in language production: varieties of causes. *Cognitive Neuropsychology*, 21: 103–123.

Linebarger, M. (1990) Neuropsychology of sentence parsing. In A. Caramazza (ed.), *Cognitive Neuropsychology and Neurolinguistics: Advances in Models of Cognitive Function and Impairment*, pp. 55–122. Erlbaum, Hillsdale NJ.

Linebarger, M., Schwartz, M., and Saffran, E. (1983) Sensitivity to grammatical structure in so-called agrammatic aphasics. *Cognition*, 13: 361–392.

Longoni, A. M., Richardson, J. T. E., and Aiello, A. (1993) Articulatory rehearsal and phonological storage in working memory. *Memory and Cognition*, 21: 11–22.

Lu, C.-C., Bates, E., Li, P., Tzeng, O., Hung, D., Tsai, C. H., Lee, S. E., and Chung, Y.M. (2000) Judgements of grammaticality in aphasia: the special case of Chinese. *Aphasiology*, 14: 1021–1054.

Lukatela, K., Crain, S., and Shankweiler, D. (1988) Sensitivity to inflectional morphology in agrammatism: investigation of a highly inflected language. *Brain and Language*, 33: 1–15.

MacDonald, M., Almor, A., Henderson, V., Kempler, D., and Andersen, E. (2001) Assessing working memory and language comprehension in Alzheimer's Disease. *Brain and Language*, 78: 17–42.

MacDonald, M. C., and Christiansen, M. H. (2002) Reassessing working memory: comment on Just and Carpenter and Waters and Caplan. *Psychological Review*, 109: 35–54.

Marslen-Wilson, W. D., and Tyler, L. K. (1980) The temporal structure of spoken language comprehension. *Cognition*, 8: 1–71.

Marslen-Wilson, W. D., and Tyler, L. K. (1997) Dissociating types of mental computation. *Nature*, 387: 592–594.

Marslen-Wilson, W. D., and Tyler, L. K. (1998) Rules, representations, and the English past tense. *Trends in Cognitive Science*, 2: 428–435.

Martin, N., and Saffran, E. M. (1997) Language and auditory-verbal short-term memory impairments: evidence for common underlying processes. *Cognitive Neuropsychology*, 14: 641–682.

Martin, R. C. (1987) Articulatory and phonological deficits in short-term memory and their relation to syntactic processing. *Brain and Language*, 32: 159–192.

25-Gaskell-Chap25 3/10/07 7:11 PM Page 438

Martin, R. (2000) Sentence comprehension deficits. In B. Rapp (ed.), *Handbook of Cognitive Neuropsychology*, pp. 349–74. Psychology Press, Philadelphia.

Martin, R., and Blossom-Stach, C. (1986) Evidence for syntactic deficits in a fluent aphasic. *Brain and Language*, 28: 196–234.

Martin, R. C., Blossom-Stach, C., Yaffee, L. S., and Wetzel, W. F. (1995) Consequences of a motor programming deficit for rehearsal and written sentence comprehension. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, 48A: 536–572.

Martin, R. C., and He, T. (2004) Semantic short-term memory and its role in sentence processing: a replication. *Brain and Language*, 89: 76–82.

Martin, R.C., and Romani, C. (1994) Verbal working memory and sentence processing: A multiple components view. *Neuropsychology*, 8: 506–523.

Martin, R. C., Shelton, J. R., and Yaffee, L. S. (1994) Language processing and working memory: neuropsychological evidence for separate phonological and semantic capacities. *Journal of Memory and Language*, 33: 83–111.

Martin, R. C., Wetzel, F., Blossom-Stach, C., and Feher, E. (1989) Syntactic loss versus processing deficit: an assessment of two theories of agrammatism and syntactic comprehension deficits. *Cognition*, 32: 157–191.

Mauner, G., Fromkin, V. A., and Gorell, T. L. (1993) Comprehension and acceptability judgements in agrammatism: disruptions in the syntax of referential dependency. *Brain and Language*, 45: 340–370.

Miceli, G., Mazzucchi, A., Menn, L., and Goodglass, H. (1983) Contrasting cases of Italian agrammatic aphasia without comprehension disorder. *Brain and Language*, 19: 65–97.

Miyake, A., Just, M., and Carpenter, P. (1994) A capacity approach to syntactic comprehension disorder: making normal adults perform like aphasic patients. *Cognitive Neuropsychology*, 11: 671–717.

Naeser, M., Mazurski, P., Goodglass, H., Peraino, M., Laughlin, S., and Leaper, W. C. (1987) Auditory syntactic comprehension in nine aphasia groups (with CT scans) and children: differences in degree but not order of difficulty observed. *Cortex*, 23: 359–380.

Natsopoulos, D., Katsarou, Z., Bostantzopoulou, S., Grouios, G., Mentenopoulos, G., and Logothetis, J. (1991) Strategies for comprehension of relative clauses by parkinsonian patients. *Cortex*, 27: 255–268.

Nespoulous, J. L., Dordain, M., Perron, C., Ska, B., Bub, D., Caplan, D., Mekler, J., and Lecours, A. R. (1988) Agrammatism in sentence production without comprehension deficits: reduced availability of syntactic structures or grammatical morphemes? A case study. *Brain and Language*, 33: 273–295.

Ostrin, R., and Tyler, L. (1995) Dissociations of lexical function: semantics, syntax, and morphology. *Cognitive Neuropsychology*, 12: 345–389.

Patterson, K., Lambon Ralph., M. A., Hodges, J. R., and McClelland, J. L. (2001) Deficits in irregular past-tense verb morphology associated with degraded semantic knowledge. *Neuropsychologia*, 39: 709–724.

Penke, M., Janssen, U., and Kraus, M. (1999) The representation of inflectional morphology: evidence from Broca's aphasia. *Brain and Language*, 68: 225–232.

Romani, C. (1994) The role of phonological short-term memory in syntactic parsing: a case study. *Language and Cognitive Processes*, 9: 29–67.

Rumelhart, D. E., and McClelland, J. L. (1986) On the learning the past tenses of English verbs. In J. L. McClelland and D. E. Rumelhart (eds.), *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, vol. 2: *Psychological and Biological Models*, pp. 216–71. MIT Press, Cambridge, Mass.

Saffran, E. M., and Marin, O. S. (1975) Immediate memory for word lists and sentences in a patient with deficient auditory short-term memory. *Brain and Language*, 2: 420–433.

Saffran, E., and Schwartz, M. (1988) "Agrammatic" comprehension it's not: alternatives and implications. *Aphasiology*, 2: 389–394.

Saffran, E., Schwartz, M., and Linebarger, M. (1998) Semantic influences on thematic role assignments: evidence from normals and aphasics. *Brain and Language*, 62: 255–297.

Schwartz, M., Saffran, E., and Marin, O. S. M. (1980) The word order problem in agrammatism, I: Comprehension. *Brain and Language*, 10: 249–262.

Shankweiler, D., Crain, S., Gorrell, P., and Tuller, B. (1989) Reception of language in Broca's aphasia. *Language and Cognitive Processes*, 4: 1–33.

Shapiro, K., and Caramazza, A. (2003) Grammatical processing of nouns and verbs in left frontal cortex? *Neuropsychologia*, 41: 1189–1198.

Spivey, M., and Tanenhaus, M. (1998) Syntactic ambiguity resolution in discourse: modeling the effects of referential context and lexical frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24: 1521–1543.

Sternberg, S. (1998) Discovering mental processing stages: the method of additive factors. In D. Scarborough and S. Sternberg (eds.), *Invitation to Cognitive Science*, vol. 4: *Methods, Models, and Conceptual Issues*, pp. 703–863. MIT Press, Cambridge, Mass.

Trueswell, J., Tanenhaus, M., and Garnsey, S. (1994) Semantic influences on parsing: use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language*, 33: 285–318.

Tyler, L. (1992) *Spoken Language Comprehension: An Experimental Approach to Disordered and Normal Processing*. MIT Press, Cambridge, Mass.

Tyler, L. K., Randall, B., and Marslen-Wilson, W. D. (2002) Phonology and neuropsychology of the English past tense. *Neuropsychologia*, 40: 1154–1166.

Ullman, M. T., Corkin, S., Coppola, M., Hickok, G., Growdeon, J. H., Koroshetz, W. J., and Pinker, S. (1997) A neural dissociation within language: evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience*, 9: 266–276.

Van Dyke, J. A., and Lewis, R. L. (2003) Distinguishing effects of structure and decay on attachment and repair: a cue-based parsing account of recovery from misanalyzed ambiguities. *Journal of Memory and Language*, 49: 285–316.

25-Gaskell-Chap25 3/10/07 7:11 PM Page 439

von Stockert, T. R., and Bader, L. (1976) Some relations of grammar and lexicon in aphasia. *Cortex*, 12: 49–60.

Waters, G., and Caplan, D. (1996) The capacity theory of sentence comprehension: critique of Just and Carpenter (1992). *Psychological Review*, 103: 761–772.

Waters, G., Caplan, D., and Hildebrandt, N. (1991) On the structure of verbal short-term memory and its functional role in sentence comprehension: evidence from neuropsychology. *Cognitive Neuropsychology*, 8: 81–126.

Waters, G., Caplan, D., and Rochon, E. (1995) Processing capacity and sentence comprehension in patients with Alzheimer's disease. *Cognitive Neuropsychology*, 12: 1–30.

Wilson, S. M., and Saygin, A. P. (2004) Grammaticality judgements in aphasia: deficits are not specific to syntactic structures, aphasic syndromes, or lesion sites. *Journal of Cognitive Neuroscience*, 16: 238–252.

Wulfeck, B. (1988) Grammaticality judgements and sentence comprehension in agrammatic aphasia. *Journal of Speech and Hearing Research,* 31: 72–81.

Zurif, E. (1996) Grammatical theory and study of sentence comprehension in aphasia: Comments on Druks and Marshall (1995). *Cognition*, 58: 271–279.

Zurif, E. (2001) More on sentence comprehension in Broca's aphasia: A response to Caplan. *Brain and Language*, 79: 321–328. *Cognition*, 79: 321–328.

Zurif, E., and Grodzinsky, Y. (1983) Sensitivity to grammatical structure in agrammatic aphasics: A reply to Linebarger, Schwartz, and Saffran. *Cognition*, 15: 207–213.

Zurif, E., and Pinango, M. (1999) The existence of comprehension patterns in Broca's aphasia. *Brain and Language*, 70: 133–138.

25-Gaskell-Chap25 3/10/07 7:11 PM Page 440