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# How verbs and non-verbal categories navigate the syntax/semantics interface: Insights from cognitive neuropsychology

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ABSTRACT

We report on two individuals with acquired language impairment who made thematic role confusion errors in both comprehension and production. Their confusions were remarkably specific, affecting the roles associated with spatial prepositions ("The box is in the bag" confused with *The bag is in the box*) and adjectival comparatives ("The glove is darker than the hat" confused with *The hat is darker than the glove*) but not the roles associated with verbs (e.g., in *The woman helps the man*). Additional results showed that the confusions did not arise from spatial deficits, deficits affecting the semantics of spatial terms and adjectives, or difficulties with spatial and comparative relationships. Interestingly, the selective deficits are well-explained by linguistic theories that propose that non-verbal lexical categories, when used as predicates, depend on special mechanisms and structures for linking their thematic roles to syntactic argument structures. These are the first neuropsychological results to show that thematic role assignment is supported by distinct brain mechanisms for verbal and non-verbal lexical categories. These findings have important implications for our understanding of the linguistic knowledge associated with verbal vs. non-verbal word classes and of the conditions under which these forms of knowledge support sentence processing.



## 1. Introduction

Sentence processing involves the transformation of concepts into acoustic forms in speech production, and follows the opposite trajectory – from acoustic forms to concepts – in speech comprehension. Psycholinguistic and linguistic research in the last twenty years has highlighted the key functions that verbs play in sentence processing and linguistic representations. The lexical entries of verbs contribute to specifying the concepts that fit a sentence, the morphological forms of words, and the order in which words should appear. We can say that verbs characterize events (or 'eventualities'; Bach, 1986) and provide a framework for mapping event representations into sentences. However, verbs/events are not the only category that can provide the main 'predicate' of a sentence – other words classes can as well. Indeed, sentences are not only structured around verbal predicates (*The traffic light turned red*) but also predicative nouns (*This is a traffic light*), adjectives (*The traffic light is red*) and prepositional phrases (*The traffic light is on the street*). When these other lexical categories appear in this central role of a sentence, they do not themselves have the structural properties of verbs.

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A range of linguistic accounts of predication (e.g., Baker, 2003; Croft, 1991) have proposed that non-verbal predicates that surface as the nuclei of sentences must rely on specialized semantic and syntactic mechanisms, unlike verbs. In the present investigation we explore how these differences between verbs and other word classes may affect sentence processing. We provide the first neurolinguistic evidence that specialized mechanisms are recruited to enable the construction of sentences around lexical categories other than verbs. Specifically, we report on individuals with acquired language impairment whose production and comprehension is remarkably intact with sentences involving verbal predicates, but impaired with sentences involving predicates based on other lexical categories. The striking selectivity of the sentence deficits provides a unique opportunity to examine the mechanisms underlying sentence processing and characterize how these mechanisms differ depending on lexical categories.

### 1.1. Verb lexical entries

It is generally agreed that at least two distinct representations of a sentence are computed – one semantic, another syntactic. The semantic representation specifies the thematic frame, that is, the grid of thematic roles performed by the various participants in an event (Fillmore, 1968; Gruber, 1976; Higginbotham, 1985; Jackendoff, 1972). To repeat the customary catchphrase, a verb and the major thematic roles describe *who did what to whom*, where *who* corresponds to the role of agent, *what* to the event described by the verb, and *to whom* to the role of the patient, theme, and possibly further roles such as goal. Concepts satisfying each of these roles have semantic characteristics that may vary from one event to the other. For example, concepts taking the role of agent in the event *running* are typically animate, not a requirement for the agents in the events of *standing* or *falling*. In contrast to the semantic representation, the syntactic representation specifies the types of phrases comprising a sentence and therefore encodes the positions and grammatical relationships (e.g., agreement) of the words in a sentence (Bresnan, 2001; Van Valin & LaPolla, 1997). A number of arguments have been proposed in support of the existence of distinct semantic and syntactic sentence representations. A primary argument is the lack of one-to-one correspondence between thematic frames and syntactic structures. In many instances a thematic frame can map onto more than one syntactic representation, as in the case of English transitive verbs. The same thematic roles appear in the sentence *Bob kicks the ball* and its passive counterpart *The ball is kicked by Bob* – in both cases, *Bob* is the agent and *ball* the theme. Disjunctions like these imply distinct representations encoding the semantic and syntactic features of sentences.

According to a number of theories, the lexical entries of verbs contain information that guides the computation of both semantic and syntactic representations of sentences (Bock & Levelt, 1994; Bornkessel & Schlesewsky, 2006; Collina, Marangolo & Tabossi, 2001; Kemmerer & Eggleston, 2010; Kim & Thompson, 2000; Pinker, 1989; Vigliocco, Vinson, Lewis, & Garrett, 2004). Part of the information stored at this level specifies the thematic roles corresponding to the event described by the verb (Grimshaw, 1990; Levin & Rappaport Hovav, 1995). The retrieval of the thematic frame dictates what concepts can satisfy particular roles and provides a grid for constructing semantic representations in which concepts are assigned their proper thematic roles. In terms of syntactic representation, verb lexical entries also specify the argument structure, which defines the number and types of phrases that must appear as complements of the verb in addition to the subject. Some verbs have no complements, only the subject (e.g., *smile*; *Bob smiles*), while other verbs take one or more complements (e.g., *lost*; *Bob lost the key*). Argument structure provides key information for building syntactic representations. There is a tight and systematic correspondence between the thematic frame and the argument structure of a verb, and the two-way mapping between semantic and syntactic representations taking place in sentence production and comprehension depends crucially on this correspondence.

Mounting evidence from psycholinguistic research supports this view that the lexical entries of verbs provide information critical for the mapping between thematic frames and syntactic argument structures, underscoring the pivotal role that verbs play in sentence processing. For example, studies comparing the response latencies of unimpaired participants to verbs varying in the number of arguments (and thematic roles) have reported that response latencies increase as a function of the number of arguments a verb requires, even in tasks that do not demand access to argument structure (e.g., when written words are presented in isolation for lexical decision) (Boland, Tanenhaus, & Garnsey, 1990; MacDonald, Pearlmutter, & Seidenberg, 1994; Shapiro, Brookins, Gordon, & Nagel, 1991; Trueswell & Kim, 1988). Effects of argument number were also observed in ERP (Rubin, Newhoff, Peach, & Shapiro, 1996). Further converging evidence was obtained in fMRI studies that examined BOLD response in processing one-, two-, and three-argument verbs. A graded BOLD response that varied according to argument number was reported, most typically in bilateral angular gyri but also in left inferior frontal cortex (Palti, Ben-Shachar, Hendler, & Hadar, 2007; Shetreet, Palti, Friedemann, & Hadar, 2007; Thompson et al., 2007). Sensitivity to argument number, so pervasive in normal participants, was lacking in aphasic individuals whose lesions extended over left posterior perisylvian cortex (Shapiro, Gordon, Hack, & Killackery, 1993; Shapiro & Levine, 1990). In verb naming, aphasic individuals with lesions in Broca's area showed increasing difficulty with increasing argument number (e.g., Jonkers & Bastiaanse, 1996; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004). Overall, the neuroimaging and neuropsychological data suggest that a brain network extending over 'classical' language areas and the angular gyrus underpins the computation of verb features critical for sentence processing.

### 1.2. Non-verbal categories

Verbs are not the only words that assign specific thematic roles. A case in point is that of *locatives*, describing spatial relations. Locatives take various forms in different languages. For example, in English, they surface as prepositions

(*in*, *on*, *beyond*, etc.), while in Finnish they are expressed by eight locative suffixes (e.g., *–ssa*, as in *talo + ssa*, literally house + in). Despite these differences, locatives are, cross-linguistically, consistently associated with the same binary, Figure-Ground thematic role configuration (Levinson, 2003; Talmy, 1983). The Figure refers to the entity to be located, whereas the Ground corresponds to the point or region of reference. Thus, locatives typically describe the position of the Figure with respect to the Ground. In the prepositional phrase *Tom is in the room*, *Tom* is the Figure and *the room* is the Ground. Just as for verbal thematic roles, the roles of Figure and Ground specify the features necessary in order to satisfy the spatial relation denoted by a particular locative preposition (Carlson & van der Zee, 2005; Coventry & Garrod, 2004; Herskovits, 1986; Landau & Jackendoff, 1993; Svorou, 1994). For example, only objects that can function as containers can fill the role of Ground with the locative *in*.

In English, locative prepositional phrases (PPs) cannot stand alone as the predicates of a sentence, but they require a copular verb like *be* (*Tom is in the room*; **Tom in room*). In this respect, locatives PPs are not unique; nouns and adjectives have similar constraints in English. The sentences **Tom rascal* or **Tom hungry*, are ill formed – the addition of the copular verb makes them grammatically acceptable. Adjectives and prepositions exhibit similar limitations in many languages, though there are languages where the supporting element is not a verb (Baker, 2003), or can be absent altogether. Across languages, non-verbal lexical categories (nouns, adjectives and prepositions) often overtly lack the predicative function that characterizes verbs (Baker, 2003; Croft, 1991; Koopman, 1984).

This basic difference in predicative function raises critical questions for theories of sentence processing: What mechanisms enable non-verbal lexical categories to link their thematic roles to the proper concepts and be interpreted with the correct mapping between the syntax and semantics? How do non-verbal lexical categories differ – semantically and syntactically – from verbs? There have been many attempts within linguistics to answer these questions (e.g., Adger & Ramchand, 2003; Baker, 2003; Bowers, 1993; Chomsky, 1995; Heggie, 1988; Hornstein & Lightfoot, 1987; Kratzer, 1996; Moro, 1997; Stowell, 1981; Williams, 1980, 1983). Baker (2003) has provided the most comprehensive recent account of the differing predicative functions of distinct lexical categories, one that will form our starting point. A more detailed description of Baker's account will be presented in Section 4. Here we highlight the major features of this account from which we have been able to derive testable predictions. While we will not be able to provide evidence for or against the precise details of Baker's proposal, instead we will argue that the broad outlines are confirmed, and the findings we report place restrictions on possible theories of predication.

What makes verbs unique under Baker's account is that "only verbs take subjects directly" (Baker, 2003, p. 32). Because of this feature, in a situation in which the (semantically-based) thematic role of agent has been assigned to *Tom*, the DP *Tom* is licensed in subject position in the sentence *Tom kicks the ball* directly by the verb *kick*. Baker defines this notion more formally within the framework of X' syntax arguing that only verbs can take a specifier and "assign a thematic role to the phrase that is their specifier" (Baker, 2003, p. 23). (We will not assume or argue for a particular theory of syntax here, rather we simply take it for granted that any theory of syntax characterizes the mapping between thematic roles and syntactic argument positions, and we assume that the broad outlines of Baker's proposal for predication can be translated to other theoretical approaches. For convenience of presentation we will, from now on, use the Government and Binding type theory that Baker adopts.) This claim not only implies that non-verbal lexical categories lack the linguistic/cognitive machinery of verbs, but also that, if they are to be used as predicates, they must depend on external grammatical machinery to assign thematic roles to their subject argument. The copular verb *be* provides an illustration of this point, as it is needed to generate sentences expressing predication for nouns (*Tom is a boy*), adjectives (*Tom is hungry*) and prepositions (*Tom is in the room*).

Baker, building most directly on Bowers (1993), Chomsky (1995), and Kratzer (1996), proposes that predicative uses of non-verbal categories behave in a fundamentally different way than predicative uses of verbal categories. On Baker's proposal, subjects of non-verbal predicates are licensed by a different mechanism than subjects of verbal predicates; the latter are licensed directly by the verb, but for non-verbal predication, there is a mediating mechanism. Crucially (for our purposes), this is also tied to a difference in thematic role licensing – verbs directly assign a thematic role to their subject, but non-verbal predicates do not. The broad outlines of this theory

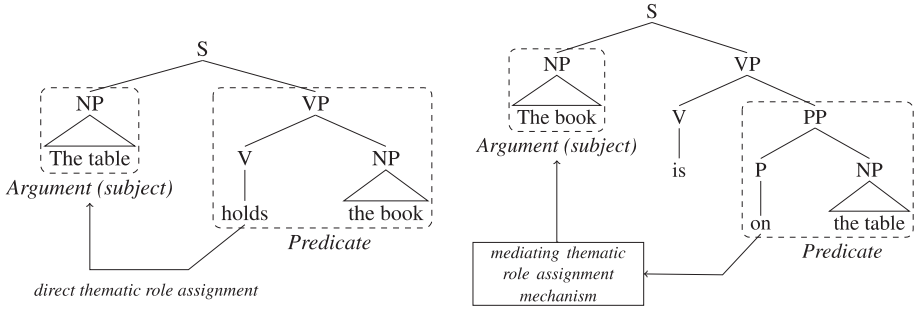


**Fig. 1.** Verbal vs. non-verbal predicates, under a theory-neutral version of Baker's (2003) analysis of predication. The sentence on the left is *The table hold the book*, the one of the right is *The book is on the table.*

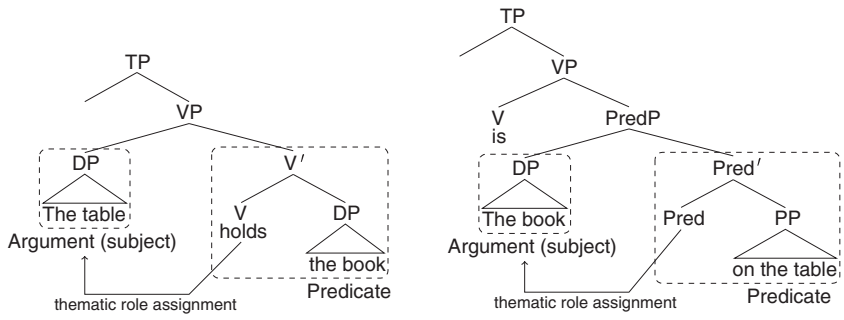


**Fig. 2.** Underlying structure of sentences predicated by a Verb (left) and a (spatial) Preposition (right). The sentence on the left is *The table hold the book*, the one of the right is *The book is on the table.* Note that Pred is needed to bind the Prepositional Phrase (PP) to the argument. (DP also moves to Spec TP for surface order.)

are sketched in Fig. 1, which depicts an example of this proposal that is neutral with regard to Baker's detailed syntactic assumptions, comparing a verbal sentence (*The table holds the book*) to a non-verbal sentence (*The book is on the table*). We will return to the details of Baker's theory in Section 4, but briefly, Baker's mechanism is centered around an abstract syntactic head above VP, called Pred (after Bowers, 1993). Following much syntactic literature, Baker treats Pred as a functional projection above VP. The linguistic characterization of Pred can be illustrated with the example of the preposition *on* in the sentence *The book is on the table*. The tree diagram in Fig. 2 illustrates the position of Pred in the sentence structure. *Book* is the Figure and the subject argument, while *table*, the Ground, is included in the prepositional phrase. The semantics of *on* determines which concepts function as Figure or Ground. Baker's proposal is that a PP like *on the table* is not inherently able to combine with a subject argument, either semantically or syntactically. It is only through the mediating mechanism of Pred that the Figure ends up as the thematic role that is linked to the subject argument. As also illustrated in Fig. 1, a verb does not need a mechanism like Pred to fulfill predication. In short, a Predicative Phrase (PredP) functions as a proxy for a verb phrase, making it possible to predicate of a subject even with lexical categories not inherently predisposed to take subjects directly. Pred amounts to a syntactic mechanism serving as the glue between the semantic and syntactic representations – a function that verbs are inherently capable of providing.

The fundamental aspect of Baker's account to underscore here, and what is illustrated in Fig. 1, is that specialized mechanisms are recruited to compensate for the lack of inherent predicative function of nouns, adjectives and locatives. This leads to the prediction, according to either the broad construal shown in Fig. 1, or Baker's specific proposal shown in Fig. 2, that non-verbal lexical categories are qualitatively different from verbs in terms of sentence processing. In the research we report on here we examined whether evidence of different verbal and non-verbal mechanisms can be observed in individuals suffering from acquired impairments in sentence processing. We did so by specifically investigating if verbal and non-verbal lexical categories can be differentially disrupted by neural damage.

### 1.3. Sentence processing impairments

Acquired language deficits often result in the impaired comprehension and production of sentences that are not explainable by single word processing difficulties. Sentence processing impairments are typically accompanied by a constellation of other language deficits varying considerably from case to case, although certain deficits appear more commonly than others (e.g., halting and effortful speech, under-utilization of closed class morphemes, simplification of phrase structures) (Kean, 1985; Martin, 2006; Menn & Obler, 1990). The brain lesion localization is also variable. Lesions often involve the left anterior inferior regions extending over Broca's area and the insula, but the specific components of these regions responsible for sentence processing impairments remain elusive (Dronkers, Wilkins, Van Valin, Redfern, & Jaeger, 2004; Kaan & Swaab, 2002; Newhart et al., 2012; Rogalsky & Hickock, 2011). Sentence processing impairments are most evident when the meaning of single words cannot support unambiguous interpretations of sentences, as with semantically reversible sentences such as *Tom greets Jeff* (Berndt, Mitchun, & Haendiges, 1996; Howard, 1985). The correct interpretation of this sentence requires understanding *who* greets *whom*, it is not sufficient to know the meaning of the single words since both *Tom* and *Jeff* can fulfill each role. Failures with reversible sentences are particularly evident with complex or non-canonical sentences (Caramazza & Zurif, 1976), although they can also appear with simpler constructions, such as active subject-verb-object (SVO) declarative sentences (*Tom greets Jeff*) (Schwartz, Saffran, & Marin, 1980).

The finding of role reversal errors in comprehension and production tasks is of clear relevance for theories of sentence processing. For example, presented with a sentence (*Tom greets Jeff*) individuals may point to a picture showing the reversed theme arrangement (Jeff greets Tom). Analogous role reversal errors may occur in a picture description task (*Tom greets Jeff* → "Jeff greets Tom"). Arguably, these types of errors may arise from impairment to syntactic or semantic processes or to the interface mechanisms responsible for mapping between the two. For example, the 'diagnosis' of a deficit specifically affecting the mechanisms responsible for mapping thematic roles onto syntactic ones

has been based on the finding of preserved grammaticality judgment ability in the face of role reversal errors in comprehension and production (Breedin & Martin, 1996; Caramazza & Miceli, 1991; Devescovi et al., 1997; Kim & Thompson, 2004; Linebarger, Schwartz, & Saffran, 1983; Miozzo, Fischer-Baum, & Postman, 2008). In these reports, individuals can distinguish ungrammatical from grammatical sentences fairly accurately but nevertheless fail in comprehending/producing reversible sentences. A dissociation such as this one, between (relatively) intact grammatical processing and impaired thematic role assignment, is important in providing evidence of the neural and computational separability of the key components of the sentence processing machinery.

In most cases reporting role reversal errors, testing has typically focused on comprehension and production of active and passive sentences involving verbs. Nonetheless, while reversible locative and adjectival contexts have been examined far less systematically, there are reports of individuals who also produce role reversal errors with locatives and adjectives (e.g., *The paper is on the book* or *The girl is fond of the boy)* (Black, Nickels, & Byng, 1991; Miozzo et al., 2008; Schwartz et al., 1980). Furthermore, Thothathiri, Schwartz, and Thompson-Schill (2010) reported problems in ordering words within Noun Phrases (e.g., *The eye and the pencil* was produced instead of *The pencil and the eye*) in patients with impairments affecting role assignment. The finding of similar difficulties in verbal and nonverbal contexts points to semantic or syntactic deficits affecting the various mechanisms that are shared by verbal and non-verbal lexical categories– e.g., those implicated in binding concepts to thematic roles or those determining word order. Damage to these shared mechanisms may generate reversal errors that cut across grammatical categories. However, as suggested by the discussion above, there are reasons to think that verbs might engage different mechanisms than locatives and adjectives. If so, one might expect there to be patterns of impairment that differentially affect these mechanisms, a possibility that was explored in the investigation reported on in this paper.

### 1.4. The present investigation

Two English-speaking participants (AES and GFE) exhibited sentence-processing impairments as a result of acquired brain lesions affecting left hemisphere inferior-frontal regions. They were able to distinguish grammatical from ungrammatical sentences but produced role reversal errors in comprehension and production that were not due to difficulties in single word comprehension/production. These characteristics, in addition to the fact that, as we will show, they did not have difficulties in computing thematic roles in general, point to a deficit affecting the semantics–syntactic interface. To examine the characteristics of role-reversal errors with verbal and non-verbal predicates and the possibility that verbal and non-verbal predication might recruit different mechanisms, we examined spoken comprehension and production of SVO sentences with (transitive) locatives (e.g., *Tom is behind Jeff*) as well as adjectival comparatives (e.g., *Tom is taller than Jeff*). Crucially, locatives and adjectival comparatives require the copular verb *be*, and therefore, under the account of predication reviewed above, they would depend on specialized mechanisms to serve as predicates. This testing allowed us to evaluate the claim that the mechanisms used by non-verbal categories are cognitive and neurally distinct from those used by verbs and can be selectively impaired by brain damage. In addition, we examined the possible domain of application of the mechanism under investigation. We did so by examining comprehension and production in complement encoding (e.g., *John put the book on the table*) which, following Pesetsky (1995), Harley (2003), among others on ditransitives in general, should also depend on a syntactic mechanism such as Pred in the embedded clause. In this way, the investigation represents a theoretically motivated neuropsychological study of highly detailed aspects of the cognitive machinery involved in sentence comprehension and production.

The presentation of the results is organized as follows. In Section 2, we describe the tests of cognitive abilities conducted with AES and GFE. Of particular relevance are those results highlighting the relative preservation of grammatical and visuo-spatial processes. Furthermore, the detailed assessment of deficits in spoken word production and verbal short-term memory (AES) was instrumental in designing experimental tasks best suited for examining sentence processing in our participants. The following section – Experimental Investigation – starts with the presentation of results showing the striking dissociation between preserved role assignment with verbs and impaired role assignment with locatives and adjectival comparatives. The rest of the Experimental Investigation section is devoted to examining several potential explanations of this dissociation.

## 2. Case descriptions

AES, an ambidextrous woman, held a Master's degree and worked as manager for a federal agency before suffering a stroke at the age of 42. The stroke resulted in a left hemisphere lesion affecting the inferior and middle frontal lobes, the superior temporal gyrus, supramarginal gyrus and extending posteriorly to the anterior portion of the angular gyrus. GFE, a left-handed man who worked as an attorney, suffered a left hemisphere stroke at the age of 51. The stroke resulted in cortical damage to the insula, and the posterior, medial frontal lobe, especially the orbitalis region of the inferior frontal gyrus, as well as subcortical damage to the putamen, internal capsule, caudate nucleus, pulvinar and thalamus. Both participants suffered left-sided hemiplegia affecting upper and lower limbs.

In terms of spontaneous speech, both AES and GFE exhibited frequent hesitations due to word-finding difficulties and occasional phoneme omissions and substitutions. A motor speech deficit also contributed to GFE's speech impairment, causing him to occasionally produce phonetically imprecise forms. By contrast to their moderate difficulties in spoken production, speech comprehension appeared to be largely preserved. AES and GFE were administered an extensive test battery to assess their language and cognitive skills. In this section, we report on the tests most relevant to the experimental language

and spatial tasks that were used in the present investigation. Results are summarized in Table 1. (Note: Only the first complete response was scored in all tasks.)

### 2.1. Spoken word comprehension

Phoneme perception was intact for both AES and GFE as demonstrated by scores within the normal range on Phoneme Discrimination (PALPA, Test 2; Kay, Lesser, & Coltheart, 1992). In this task, participants were asked to respond same/different to identical word pairs or word pairs differing by one phoneme (*bed-bet*). Scores were also within normal range on a spoken word comprehension task (PPVT, Form M; Dunn & Dunn, 1981) that requires matching a spoken word to a target picture presented with three semantically related picture foils. These normal scores indicate good auditory processing, preserved visual (picture) processing and generally intact lexical semantic knowledge.

### 2.2. Spoken word production

Performance on the Boston Naming Task (Goodglass & Kaplan, 1972) indicated moderate impairment, more severe for AES than GFE (correct responses: 40% ($z = -8.7$) vs. 70% ($z = -3.7$); age-matched control data from Tomaugh & Hubiey, 1997). Half of AES's errors (18/36; 50%) consisted of well-articulated words/nonwords phonologically similar to the target (*broom* → "boom"), suggesting difficulty in the retrieval and/or combination of phonemes (phonemic encoding). Semantic substitutions (*accordion* → "harmonica") and no-responses together accounted for 46% of AES's errors and for 78% of GFE's. While no-responses are the hallmark of lexical retrieval deficits, semantic substitutions in the context of intact semantic comprehension are also characteristic and, therefore, their overall pattern of performance indicates that lexical retrieval difficulties were a primary source of the naming errors. Nouns and verbs were named with comparable accuracy by both participants (see Table 1; materials from Zingeser & Berndt, 1990).

### 2.3. Grammatical processing

This ability was assessed with two grammaticality judgment tasks that required discriminating ungrammatical sentences from grammatical ones. Grammatical and ungrammatical sentences were spoken by the experimenter and were equally probable in the stimulus set. Materials for the first grammaticality judgment task were from Linebarger et al. (1983). Ungrammatical sentences violated one of ten grammatical rules, for example agreement (**I helped themselves to the birthday cake*) or reflexives (**I helped themselves to the birthday cake*). Each rule was tested with 7 or 8 sentences (Total $N = 80$). The scores obtained by AES (90%) and GFE (98%) were comparable to those of normal controls (96–99%; Miozzo et al., 2008). Materials for the second grammaticality judgment task were from Kim and Thompson (2004) and examined verb argument structure. Incorrect sentences either lacked an argument (**The boy is pulling to the house*) or included an extra one (**The boy is pulling the girl the cart*) (Total $N = 44$). AES and GFE were correct 98% and 93% of the time, respectively. Some of the sentences in the grammaticality judgment tasks tested prepositions and adjectives, the syntactic elements on which our investigation focused. Examples of ungrammatical sentences include **She went*

**Table 1**
Scores in language and spatial tasks.

| Tasks | AES | | GFE | |
|---|---|---|---|---|
| *Language tasks* | | | | |
| Phoneme Discrimination (PALPA 2) | | | | |
| Same | $z = .59$ | (36/36) | $z = -.69$ | (35/36) |
| Different | $z = .45$ | (36/36) | $z = -.32$ | (34/36) |
| Word Picture Matching (PPVT) | 39 | | 94 | |
| Boston Picture Naming (Goodglass & Kaplan, 1972) | 40% | (24/60) | 70% | (42/60) |
| | | $z = -8.7$ | | $z = -3.7$ |
| Picture Naming (Zingeser & Berndt, 1990) | | | | |
| Nouns | 85% | (51/60) | 86% | (52/60) |
| Verbs | 73% | (22/30) | 86% | (26/30) |
| Grammaticality Judgment Task | | | | |
| Linebarger et al. (1983) | 90% | (72/80) | 98% | (78/80) |
| Kim and Thompson (2004) | 98% | (43/44) | 93% | (41/44) |
| Verbal Short-term Memory | 3-digits | | 6-digits | |
| *Spatial tasks* | | | | |
| Differential Ability Scale (Elliott, 2007) | Normal Adult Score | Normal Adult Score | | |
| Rey–Osterrieth Figure | | | | |
| Copy | 41–59 | >99 | | |
| Immediate Reproduction | 29–40 | 41–59 | | |
| Delayed Reproduction | 29–40 | 41–59 | | |
| Face Memory (Warrington, 1984) | | >95 | | 75 |
| Recognition of Interior/Exterior Object Parts | 100% | (80/80) | 100% | (80/80) |
| Recognition of Top/Bottom/Front/Back of Objects | 88% | (141/160) | 99% | (158/190) |
| Rotation to Canonical Orientation (Turnbull et al., 1997) | 100% | (32/32) | 100% | (32/32) |
| Object-centered Position (Turnbull et al., 1997) | 95% | (49/50) | 100% | (50/50) |
| Viewer-centered Position (Miozzo et al., 2008) | 88% | (141/160) | 99% | (158/190) |

*the stairs up in a hurry* (incorrect preposition movement) and **The paper was full mistakes* (incorrect adjective phrase). Both participants accurately judged the grammaticality of these sentences (AES: 43/47, 91%; GFE: 46/47, 98%).

### 2.4. Verbal short-term memory

GFE exhibited normal performance in forward repetition of digit sequences, correctly repeating 6-digit sequences. AES, on the other hand was successful only with 3-digit sequences. Normal performance on this task is between 5and 6 digits.

### 2.5. Visuo-spatial tasks

Because of the importance of spatial language to the experimental investigation, AES and GFE were administered two standardized diagnostic tests of basic visuo-spatial abilities. In the Differential Ability Scales, Pattern Construction Subtest (Elliott, 2007), 2-D geometrical patterns are reproduced by arranging small blocks. In the Rey–Osterrieth (Stern et al., 1994) a complex figure is copied and also drawn from memory (immediate and delayed reproduction). In both tasks, GFE scored in the mid normal range, AES in the mid or low normal range (see Table 1). Both participants also performed within normal range in a forced-choice face recognition task (Warrington, 1984), a task in which individuals with spatial deficits are often impaired. Another set of tasks evaluated spatial skills necessary for accurate use of spatial language, namely: the ability to identify regions of space and objects with reference to frames centered on the object, the speaker or the listener (Landau & Jackendoff, 1993). Specifically, these tasks required participants to indicate the interior/exterior parts of objects shown in 2-D images, rotate objects to their canonical orientations, or compute orientation in object- or viewer-centered frames of reference. Object-centered frames were tested using a task developed by Turnbull, Beschin, and Della Sala (1997), in which participants indicated which of three identical objects had a different orientation. For viewer-centered frames (from Miozzo et al., 2008), an object drawing was shown in four positions on a page (front, bottom, right, and left) and participants identified the objects in specific locations (“Point to the left kite;” “Point to the top kite”). As the results in Table 1 show, the performance of AES and GFE ranged between 88% and 100% on all of these tasks. In sum, there were no signs of visuo-spatial deficits that could compromise spatial language processing.

### 2.6. Summary

A clear dissociation was observed with both participants between moderately impaired word production and spared word comprehension. The word production difficulties were primarily due to difficulties in accessing phonological word forms and, in the case of GFE, also from mild motor speech difficulties. There was no evidence of a selective naming deficit for verbs. Grammaticality judgments were extremely accurate, indicating generally well-preserved syntactic knowledge. Visuo-spatial abilities, tested extensively, for the most part were within normal range.

## 3. Experimental investigation

### 3.1. General procedure

Experiments included tests of both speech comprehension and speech production. The following features were shared by both of these tests: (a) materials from the different tests were tested separately, and the administration of most of the tests required multiple testing sessions; (b) each administration of a task started with practice trials; (c) the order of stimulus presentation was randomized within each test; (d) in the rare occasion that participants produced multiple responses, only the first response was included in the analyses; (e) control data were collected from sets of $n = 5$ college students if not available from previous publications.

#### 3.1.1. Comprehension tests

Most of the tasks used to assess comprehension required participants to indicate whether pictures correctly depicted the word, phrase, or sentence spoken by the experimenter. There were two variants of these comprehension tasks. One variant (Verification Task) involved sentences and was used to test role assignment with verbs, locatives, and comparatives. On each trial, participants saw a single picture and responded “Yes” or “No” depending on whether or not the picture matched the spoken sentence. Yes and No responses were each expected in 50% of the trials. Two pictures were prepared for each event/state by reversing the roles of the elements involved in the event/state. For example, a *man* and a *woman* took part in the event *helping* with reversed roles between pictures, so in one picture *the man helps the woman*, while in the other picture *the woman helps the man*. This procedure not only controlled for biases stemming from pragmatic knowledge, but it also ensured the reversibility of thematic roles. Both of the pictures prepared for each event were presented twice, accompanied by a sentence describing the roles depicted in the sentence either correctly or incorrectly. Therefore, crossing role assignment and response (Yes/No), each event/state was tested four times, each time in a separate block of the experiment.

The other variant (Picture Matching) was used to test the comprehension of words or phrases. Multiple pictures were presented and participants were instructed to point to the target picture corresponding to the word or phrase spoken by the experimenter. Target picture positions (e.g., left or right relative to the participant) were counterbalanced across trials.

In both variants of the comprehension task, the experimenter first showed a picture and immediately afterwards presented the verbal probe. Upon request, the experimenter repeated the verbal probe (an event that rarely occurred with either controls or participants with aphasia), and no time limits were imposed on participants’ responses.

*3.1.2. Production tests*

These tests required either producing words to complete a sentence or responding to specific questions. Because of their spoken production deficits (described above), AES and GFE occasionally produced phoneme errors (*rooster* → "wooster") and word substitutions ([male] *chef* → "man"), which were ignored because they did not affect the scoring of these tests. Responses were audio-taped for scoring purposes.

### 3.2. Experiment 1: Role reversal errors in verbal and non-verbal constructions

Evaluation of the integrity of thematic role assignment for verbs, locatives, and adjectival comparatives was carried out in tasks of spoken sentence comprehension (Sentence-Picture Verification Task) and production (Fill-in the-Blanks Task).

*3.2.1. Methods and materials*

*3.2.1.1. Task 1. Sentence-Picture Verification: role-reversible sentences.* The sentences spoken by the experimenter either matched the picture in terms of thematic role assignments or they were role reversed (foil sentences). Examples of pictures and foil sentences for verb, locatives, and adjectival comparatives are shown in Table 2.

Sentences were SVO, active declarative with verbs, copular with locatives and adjectival comparatives. We tested 46 distinct verbs and 46 distinct adjectives, fewer spatial prepositions (7; *around*, *behind*, *between*, *in*, *in front of*, *on*, *under*), due to the restricted number of categorical spatial relationships encoded by spatial prepositions. The picture pairs corresponding to each verb (from Miozzo et al., 2008) and adjective showed identical entities filling opposite roles. There were 10 distinct picture pairs for each spatial preposition. Each picture was presented with a matching sentence and a mismatching sentence such that the total number of trials in the Sentence-Picture Verification was equal to 184 with verbs and adjectives and 140 with locatives.

*3.2.1.2. Task 2. Fill-in-the-Blanks: role-reversible sentences.* The picture pairs used in the Sentence-Verification Task with verbs ($N = 46$), adjectival comparatives ($N = 46$), and spatial prepositions with the exclusion of *in*, were used again in the Fill-in-the-Blanks Task. Sentence fragments were printed beneath each picture with blank spaces in positions corresponding to both arguments. For example, the picture of a woman helping a man appeared with the following sentence fragment and blanks: ____ *helps* ____. Depending on the condition, the sentence fragment included a verb (*helps*), a copula + adjectival comparative (*is darker than*) or a copula + locative (*is below*). Participants were expected to provide nouns phrases to fill in the blanks, so that all sentences had SVO structure. The experimenter read the fragment out loud at the beginning of the trial and participants were asked to produce the complete sentence that matched the picture. The Fill-in-the-Blanks task comprised 92 trials with verbs and adjectival comparatives, and 120 with locatives.

**Table 2**
Examples of pictures, foil sentences (Sentence-Picture Verification) and sentence fragments (Fill-in-the-Blanks Task).

| Word category | Examples |
|---|---|
| *Verbs* | |
| Picture | The woman helps the man |
| Foil sentence | The *man* helps the *woman* |
| Sentence fragment | ____ helps ____ |
| *Adjectival comparatives* | |
| Picture | The hat is darker than the glove |
| Foil sentence | The *glove* is darker than the *hat* |
| Sentence fragment | ____ is darker ____ |
| *Locatives* | |
| Picture | The helicopter is below the UFO |
| Foil sentence | The *UFO* is below the *helicopter* |
| Sentence fragment | ____ is below ____ |

*3.2.2. Results*

As expected, controls performed at ceiling with mean accuracies in the 93–100% range across the various conditions in both tasks (see Table 3). AES and GFE performed very similarly to controls only with verbs, both in the Sentence-Picture Verification Task (AES = 97%; GFE = 96%) and the Fill-in-the-Blanks Task (AES = 96%; GFE = 89%). Responses in the Sentence-Picture Verification Task were more accurate with verbs than with either adjectival comparatives (AES 80%, $\chi^2 = 23.2$, $p < .001$; GFE 88%, $\chi^2 = 7.11$, $p = .007$) or locatives (AES 70%, $\chi^2 = 42.5$, $p < .001$; GFE 78%, $\chi^2 = 23.7$, $p < .001$). Superior performance with verbs was also apparent in *d'* scores (Table 3). A similar pattern was observed with the Fill-in-the-Blanks Task, on which both participants were significantly more accurate with verbs than adjectival comparatives (AES $\chi^2 = 14.5$, $p < .001$; GFE $\chi^2 = 3.1$, $p = .06$) or locatives (AES $\chi^2 = 41.3$, $p < .001$; GFE $\chi^2 = 8.8$, $p = .002$). All the errors in the Fill-in-the-Blanks Task consisted of role-reversals.

In both tasks, participants' responses were more accurate with adjectival comparatives than locatives; these differences were significant ($\chi^2$ $p < .05$) except for GFE's performance in the Fill-in-the-Blanks Task. The greater difficulties demonstrated with locatives could reflect systematic differences in the materials or in the syntactic structures; alternatively, they could have been due to specific difficulties with locatives. This second possibility was tested and results reported in a subsequent section.

*3.2.3. Interim discussion*

An identical pattern was observed in sentence comprehension and sentence production: AES and GFE made frequent role reversal errors with adjectival comparatives and locatives but almost never with verbs. This stark dissociation provides an important clue for determining the functional locus of the impairment causing role reversal errors. The absence of role reversal errors with verbs makes it unlikely the hypothesis of a semantic impairment affecting the processing of thematic roles in general. A general impairment of this type might make it difficult to associate the referent of an argument (*the woman*) with its appropriate thematic role (e.g., actor in *The woman helps the man*); furthermore, this type of deficit would be expected to affect all grammatical classes, including verbs.

**Table 3**
Responses in Sentence-Picture Verification and Fill-in the-Blanks Tasks (AES, GFE, Controls).

| Word class | *Sentence-Picture Verification Tasks/participants* | | | | | | |
|---|---|---|---|---|---|---|---|
| | AES correct responses | | *d'* | GFE correct responses | | *d'* | Controls correct responses total (range) |
| | Yes/no | Total | | Yes/no | Total | | |
| Verbs | 97/96% | 96% | 3.59 | 97/94% | 96% | 3.44 | 99%[a] (97–100%) |
| Adjectival comparatives | 71/89% | 80% | 1.78 | 93/83% | 88% | 2.44 | 98% (94–100%) |
| Locatives | 78/61% | 70% | 0.46 | 80/76% | 78% | 1.54 | 99% (98–100%) |
| | *Fill-in-the-Blanks Tasks/Participants* | | | | | | |
| | AES correct responses | | | GFE correct responses | | | Controls correct responses (range) |
| Verbs | 96% | | | 89% | | | 99%[a] (99–100%) |
| Adjectival comparatives | 76% | | | 79% | | | 97% (94–100%) |
| Locatives | 52% | | | 70% | | | 99% (98–100%) |

[a] Controls' data were from Miozzo et al. (2008).

The lack of role reversal errors with verbs indicates instead that syntactic arguments and thematic roles are correctly linked. Further, as reported above, the preserved ability to make grammaticality judgments across a wide range of structures makes it unlikely that the role reversal errors produced by AES and GFE stem from impaired syntactic processes. In light of the overall pattern of results, it seems more plausible to attribute the role reversal errors to deficits at the level at which thematic roles are mapped to their corresponding syntactic structures.

We should also point out that the response patterns produced by AES and GFE are unlikely to have resulted from deficits affecting verbal short-term memory or working memory. An association between these types of memory difficulties and sentence processing deficits has been proposed in prior neuropsychological studies (Stowe, 2000; Vallar & Baddley, 1984), and more recently in neuroimaging studies that showed activation in common posterior frontal and temporal–parietal areas in response to memory tasks and sentence processing tasks (Fiebach, Schlesewsky, Lohmann, von Cramon, & Friederici, 2005; Just, Carpenter, Keller, Eddy, & Thulborn, 1996; Kaan & Swaab, 2002; Rogalsky & Hickock, 2011; Rogalsky, Matchin, & Hickock, 2008; Santi & Grodzinsky, 2007). Although the significance of this association has been call into question (see e.g., Caplan & Waters, 1999), it is important to examine and rule out such a link in AES and GFE. The fact that comparably short sentences were used to evaluate verbs, locatives and comparatives cannot account for the differences in accuracy between the sentence types. In addition, the fact that, as described in Section 2, AES and GFE were quite discrepant in their verbal short-term memory performance is at odds with the remarkable similarities of their thematic role confusions.

We should also consider whether the discrepancies between verbal and non-verbal categories reflected strategies our participants used to circumvent (at least in part) language deficits. This is a legitimate concern in light of findings revealing the use of strategies especially to cope with problems in sentence processing (Caplan, & Hildebrandt, 1988; Kolk, & van Grunsven, 1985). A strategy assuming that *the subject noun is the agent* would explain the correct comprehension of verbal as compared to non-verbal forms. Such a strategy would ensure correct responses only with verbs, as we indeed found. Passive sentences provide a way to test as to whether a strategy of this kind was used. Because the agent does not correspond to the subject in passive sentences, the strategy "subject noun equals agent" would lead to incorrect role assignments with passive sentences. We assessed the comprehension of passive sentences using 32 of the verbs tested in the Sentence-Picture Verification Task (Exp. 1). AES and GFE indicated whether a passive sentence (*The man is helped by the woman*) matched the event depicted in the picture. GFE was correct 94% of the time; accuracy was similar when the same verbs were tested in active sentences (92%; $\chi^2 < 1$). By contrast, AEF was significantly less accurate with passive than active sentences (50% vs. 97%; $\chi^2 = 18.0$, $p < .001$). These data lend some support to the hypothesis that a strategy was used – at least by AES. However, the hypothesis falls short from providing a comprehensive explanation of the dissociation we found even with AES. The hypothesis holds for sentence comprehension, but it cannot account for the dissociation we found in sentence production.

Interestingly, the selectivity of the role reversal errors produced by AES and GFE is expected under the view that semantic–syntactic mapping is supported by different machinery for verbs and adjectival comparatives and locatives. Nevertheless, there are alternative accounts to examine.

First we considered that there could have been the fortuitous co-occurrence of two distinct deficits: one causing difficulties with comparative constructions, the other affecting the processing of spatial relationships. Second, we considered the possibility that a single deficit affected both adjectival comparatives and locatives because of certain shared semantic characteristics of the two categories. In this regard, we considered two possibilities, one relating to light verbs, the other to the sparseness of the semantic representations of adjectives and locatives. Each of these

three alternative hypotheses was tested and compared to the predictions of the hypothesis that the selective difficulties in comprehension and production with the adjectival comparatives and locatives originated in a deficit related to the different semantic–syntax mapping requirements of the verbal and non-verbal categories.

### 3.3. Experiment 2: Comparative constructions

In English, comparative constructions are not limited to adjectives but can also be used with adverbs, as in the sentence *The girl runs more quickly than the boy*. Adverbs typically qualify events and states expressed by verbs, and linguistic analyses have demonstrated that adverbial comparatives (just as non-comparative adverbs) are adjuncts under the syntactic projection of verbs (Bresnan, 1973; Rawlins, 2013; Rullman, 1994; von Stechow, 1984). In this respect adverbs differ considerably from adjectival comparatives, which most typically appear as predicates with semantically under-specified verbs (*be*, *seem*, *appear*). Crucially, some adverbial comparatives permit reversal errors, as with the sentence *The girl runs more quickly than the boy* where *girl* and *boy* could exchange their roles. This characteristic of adverbs provides an opportunity to investigate whether AES and GFE suffered from deficits with comparative construction that affected both adjectives and adverbs. Alternatively, under the hypothesis that the critical factor is the verbal/non-verbal distinction, the deficits should be limited to adjectival and not adverbial comparatives since the latter do not involve predication or binding of a thematic role the same way that predicative structures do.

#### 3.3.1. Methods and materials

*3.3.1.1. Task 3. Sentence-Picture Verification with adverbial comparatives.* Procedures and pictures were identical to those described above for the Sentence-Picture Verification Task with adjectival comparatives; the only changes involved the use of other verbs than the copular verb *be* and the substitution of adjectives (*energetic*) with the corresponding adverbs (*energetically*). For example, the sentence with the adjectival comparative *The woman is quicker than the man* was substituted by the sentence with the corresponding adverbial comparative *The woman skis more quickly than the man.*

#### 3.3.2. Results

Controls' accuracy with adverbial comparatives was close to or at ceiling (range: 93–100%). Accuracy was comparably high for both AES (93%) and GFE (97%). Adverbial and adjectival comparatives can be compared directly since they were tested with identical procedures and comparable stimulus materials. Both participants responded more accurately to adverbial than adjectival comparatives (AES: $\chi^2 = 7.8$, $p = .005$; GFE: $\chi^2 = 8.8$, $p = .002$; Fig. 3). By contrast, accuracy was strikingly similar between adverbial comparatives and verbs (AES: $\chi^2 = 1.6$, n.s.; GFE: $\chi^2 < 1$). Comparisons of *d'* values support the same pattern of results.

The intactness of performance with adverbial comparatives is at odds with the hypothesis of a deficit generally affecting comparatives. Instead, the dissociation observed with comparatives between (impaired) adjectival constructions and (spared) adverbial constructions is expected under the account that the lexical category and, therefore, the nature of the thematic role machinery at the syntax–semantics interface determines which comparative constructions are impaired.[1]

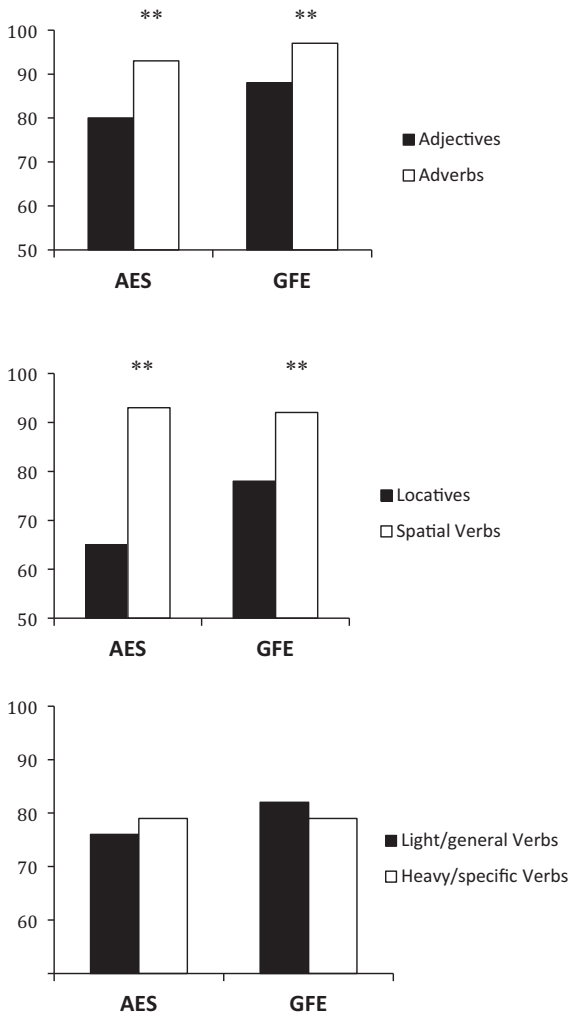


**Fig. 3.** % Correct responses produced by AES and GFE in the Sentence-Picture Verification Task with adjectival and adverbial comparatives (Top), in the Acting-out Task with locatives and spatial verbs (Middle), and in the production of light/general and heavy/specific verbs (Bottom). Both participants responded more accurately with adverbs (than adjectives) and with spatial verbs (than locatives). No differences were observed in the production of the different types of verbs. ** indicates differences significant at $p = .05$.

### 3.4. Experiment 3: Understanding of spatial relationships

Deficits affecting spatial relationships have been documented in individuals who suffered from left inferior

[1] Alternatives test cases that we did not investigate, but would also be predicted to not lead to reversal errors, include numerical comparatives (*John bought more books than Sue*) and attributive comparatives (*John read a longer book than Mary*).

**Table 4**
Examples of sentences tested with spatial verbs and locatives in the Acting-out Task.

| Locatives | | Spatial verbs | |
|---|---|---|---|
| *around* | The dogs are around the sheep | *surround* | The dogs surround the sheep |
| *behind* | The tractor is behind the cow | *follow* | The tractor follows the cow |
| *under* | The shaker is under the can | *support* | The can supports the shaker |
| *in* | The box is in the bag | *contain* | The bag contains the box |
| *in front of* | The car is in front of the truck | *lead* | The car leads the truck |
| *on* | The plate is on the napkin | *cover* | The plate covers the napkin |

frontal lesions and whose errors on sentences with spatial prepositions resemble those of AES and GFE (Friederici, Schönle, & Garrett, 1982; Parisi & Pizzamiglio, 1970; Seron & Deloche, 1981; Tranel & Kemmerer, 2004). While the results reported earlier in Section 2 rule out general spatial deficits, there is the possibility of a more specific deficit affecting the spatial relationships that are encoded in spatial language. We examined this possibility by testing English verbs of rest and motion that denote spatial relationships – which we will refer to as spatial verbs. Crucially, the spatial verbs used in the testing describe exactly the same spatial relationships as locatives, as illustrated by the sentences *The car follows the truck* and *The car is behind the truck.* Spatial verbs and locatives, however, map into markedly different syntactic structures. Thus, by testing spatial verbs and locatives we can decouple spatial from syntactic deficits.

#### 3.4.1. Methods and materials

*3.4.1.1. Task 4. Acting-out with spatial verbs and locatives.* On each trial, participants were presented with a pair of small, manipulable objects (*bag*, *box)* or a pair of toy replicas of large objects (*car*, *truck).* The task consisted of arranging the objects in accordance with a sentence spoken by the experimenter. The spatial verbs and locatives used in this task are listed in Table 4 and were each tested 12 times, each time using a different object pair. Only objects with intrinsic front-back and up-down axes were chosen in order to avoid ambiguous spatial arrays. Replicating the procedure of the previous tasks, an object pair (*car, truck*) was used to test opposite thematic role assignment (*car behind truck*; *truck behind car*). Upon request, the experimenter repeated the verbal probe. No time limits were imposed on participants' responses. Responses were video-taped for scoring purposes.

#### 3.4.2. Results

Control participants' accuracy was again at ceiling (99%) and AES and GFE performed very similarly to control participants with spatial verbs but much less accurately than control participants with locatives PPs. In fact, both AES and GFE were significantly less accurate with locatives than with spatial verbs (AES: 93% vs. 65%; $\chi^2 = 7.2$, $p = .007$; GFE: 92% vs. 78%; $\chi^2 = 5.3$, $p = .02$; Fig. 2). All errors involved role reversals, with the exception of one locative confusion made by AES (*below* → in front).

We draw two conclusions from the clear contrast in performance with locatives PPs and spatial prepositions. First, while the contrast confirms difficulties with locatives, it also rules out that these difficulties originated from a deficit affecting the processing of spatial relationships or spatial language more generally. Second, the apparent intactness of their comprehension of spatial relationships is especially important when considered together with the results ruling out a general deficit with comparatives that was reported above. The coincidental co-occurrence of deficits to comparatives and to the processing of spatial relationships could have explained the dissociation between relatively normal accuracy with verbs and poor performance with adjectival comparatives and locatives. This hypothesis, however, was not supported by the evidence, and we therefore must look for a unified explanation of the role reversal pattern exhibited by AES and GFE.

### 3.5. Experiment 4: Light and heavy verbs

It has long been recognized that verbs vary along a light/heavy continuum (Jasperson, 1965). Semantically, light verbs are relatively underspecified, a feature that allows their use in a variety of contexts, making them frequently occurring words. Heavy verbs have more specific meanings and thus are used in a more limited set of contexts. The verbs *go* and *run* exemplify this distinction: the light verb *go* is used to describe a wide range of motions, unlike the heavy verb *run* that is appropriate only with specific forms of motion. The light/heavy distinction has proven relevant in neuropsychology, as there have been reports of aphasic individuals demonstrating more severe impairments with light verbs (Barde, Schwartz, & Boronat, 2006; Breedin, Saffran & Schwartz, 1998; Kim & Thompson, 2004) or with heavy verbs (Berndt, Mitchum, Haendiges, & Sandson, 1997; Kohn, Lorch, & Pearson, 1989). These noteworthy precedents raise the possibility that difficulties with light verbs underlie with copular constructions demonstrated by AES and GFE. Arguably, the verb *be* is the lightest of light verbs (Breedin et al., 1998) and therefore a general difficulty with light verbs would especially affect predicative copular constructions.

What would explain a deficit correlated with the heavy/light scale? The light/heavy distinction has typically been viewed as reflecting the richness of semantic representations that are, supposedly, more detailed and complex for heavy verbs. A more formal account has been advanced under compositional semantic theories that regard verb meanings as emerging from the composition of some subset of predicate terms, conceptual constituents and appropriately defined functions/relations (Jackendoff, 1990; Pinker, 1989). The semantic representations of light verbs on these accounts include core predicates that are also shared with (some) heavy verbs, but heavier verbs involve

additional components that contribute to their rather specific meanings. Thus, while *go* and *run* have a common core predicate specifying motion/change of location, the semantic representation of *run* is richer and more complex because it bears a specification of manner (form of motion) as well as a path. These semantic proposals also provide a framework for explaining deficits that more severely affect light verbs. Breedin et al. (1998) proposed that while impairments that reduce the number of available semantic features severely impact light verbs, the remaining features might be sufficient to support heavy verbs. This kind of account has received support from a connectionist model implemented by Gordon and Dell (2003) to simulate the production of light and heavy verbs in sentential contexts and picture naming. Light verbs were represented in the model by fewer semantic units than heavy verbs. Simulated lesions that randomly destroyed some of the semantic features produced more severe 'deficits' for light than heavy verbs. This computational result is consistent with accounts that view the light/heavy verb distinction as stemming from the sparseness/richness of semantic representations.

### 3.5.1. Methods and materials

*3.5.1.1. Task 5. Production of light/heavy and general/specific verbs.* Evidence of light verb deficits has typically been obtained from spontaneous or directed speech and has taken the form of fewer occurrences of light verbs than observed in the speech of neurologically intact individuals. Breedin et al. (1998) pursued a different approach comparing the production of heavy and light verbs in an experimentally controlled task. The same task was administered to AES and GFE.

The task designed by Breedin et al. (1998) is a combination of story completion and delayed repetition. The experimenter reads a short story that contains a critical verb and then presents a question to elicit the critical verb. Two versions of each story were prepared differing only in the critical verb (light vs. heavy). Examples of the stories and the questions are presented in Table 5. Breedin et al. (1998) also tested *general* and *specific* verbs, of which *clean* and *wipe* are an example. Both of these verbs refer to similar actions, although the specific verb (*wipe*) defines the actions more precisely than the general verb (*clean*).

**Table 5**
Examples of materials (from Breedin et al., 1998) used to elicit verbs varying for richness of semantic representations.

| | |
|---|---|
| *Light vs. heavy verbs* | |
| Jane loves antiques | The convention starts today |
| Tom *gave/bought* her an oak chest | Mr. Wilson, the main speaker, *came/arrived* yesterday |
| Jane took very good care of it | A big turnout is expected |
| Q: What did Tom do for Jane? | Q: What did Mr. Wilson do yesterday? |
| *General vs. specific verbs* | |
| The class was boring | It was Roger and Tanya's first date |
| Jill *looked/stared* out the window | They *ate/dined* at a French restaurant |
| Finally the bell rang | The food was expensive |
| Q: What did Jill do during the class? | Q: What did Roger and Tanya do on their first date? |

General/specific verb pairs differ from light/heavy verb pairs in that they do not necessarily share core meanings (Breedin et al., 1998). However, they resemble light/heavy verbs because of differences in number of semantic features. Problems with light verbs went hand-in-hand with problems with general verbs in the group of aphasic individuals tested by Breedin et al. (1998), likely because the conceptual representations of both of these verbs are relatively little detailed. Given these similarities, we also tested general/specific verbs, again using the materials of Breedin et al. (1998). An example of the sentences used to test general/specific verbs is presented in Table 5. Breedin et al. (1998) provide various measures that showed that pairs of matched verbs were equally suited to the story context. The task was administered in two sessions held at least a week apart and included 19 light-heavy pairs and 14 general-specific pairs that were presented in random order. Only one version of a story was presented in each session. Instructions were those used by Breedin et al. (1998). Specifically, participants were informed that they would hear short stories and then be asked a question about the story. They were explicitly instructed to attempt to include words from the story in their answers and were encouraged to try to produce complete sentences. Practice trials and feedback during practice helped participants to fully understand the task requirements. Responses were audio-taped for scoring purposes.

### 3.5.2. Results

All responses were identified that included the target verb mentioned in the short story, regardless of whether it occurred in a complete sentence. Morphological errors (donated → *donate*) and minor phonological/phonetic errors were ignored in response scoring. To increase power, light/general verbs were analyzed together with heavy/specific verbs. Normal control participants produced both types of verbs equally often (light/general verbs = 91%; heavy/specific verbs = 94%). AES and GFE scored more poorly, not surprisingly given their word finding difficulties. When not produced, target verbs were substituted by other verbs fitting the context (AES = 89%; GFE = 86%), and these responses probably represented attempts to circumvent word-finding difficulties. Importantly, their scores were comparable for light/general verbs and heavy/specific verbs (AES = 76% vs. 79%, $\chi^2 < 1$; GFE = 82% vs. 79%, $\chi^2 < 1$; Fig. 2). To the extent that these results rule out a deficit for light/general verbs, they also rule out that adjectival comparatives and locatives were impaired because they were tested with sentences including the copular verb *be*, allegedly the lightest of verbs.

## 3.6. Experiment 5: The role of sparse semantic representations

The logic underlying the accounts of light-verb deficits – more sparse representations are more susceptible to damage – has also been applied to other neuropsychological deficits, including those selectively affecting abstract words or living things (Saffran & Schwartz, 1994). One could entertain the possibility of extending this logic to deficits involving locatives and adjectives. Both classes of

words appear in a wide range of contexts, a feature that only light semantic representations can satisfy. If this analysis is correct, then the deficits of AES and GFE could be associated with the sparseness of the semantic representations of locatives and adjectives. Although this account is similar in logic to the one analyzed above with light verbs, it differs critically in referring to the semantics of adjectives and locatives rather than the semantics of verbs. To assess this possibility, four tasks were administered to assess the integrity of the AES and GFE's comprehension of the meanings of adjectives and locatives. If sparse semantic representations in general were impaired, AES and GFE should have exhibited difficulties in understanding adjectives and prepositions themselves, and not only in role reversal contexts.

#### 3.6.1. Materials and methods

*3.6.1.1. Task 6. Word-picture matching: superlative adjectives.* On each trial, participants saw three pictures, each showing the same object varying with respect to a specific property. For example, three *buildings* of different height were showed (*tall*, *taller*, *tallest*). The experimenter orally presented a superlative adjective (*tallest*) and participants pointed to the corresponding object (*the tallest building*). A different adjective was tested in each of the 34 trials comprising this task. A subset of adjectives tested in Task 6 (15/34) was also tested in Tasks 1 and 2 with comparative forms.

*3.6.1.2. Task 7. Word-matching: adjectives.* Participants chose which of two adjectives was more similar in meaning to a third adjective (the probe). Because the probe (*youthful*) was related to both alternatives (*juvenile* and *immature*), the task demanded subtle distinctions. The probe adjectives differed from those tested in Tasks 1 and 2 with adjectival comparatives and were, on average, less frequent (counts per million words: 25 vs. 115; $t(71) = -4.06$, $p < .0001$; norms from Balota, Yap, et al., 2007), thus providing a stringent test of adjective knowledge. Correct and incorrect adjective alternatives were matched for frequency (mean counts per million words: 35 vs. 32; $t(73) = 1.37$, $p > .15$). On each of trial ($N = 38$), three printed words were shown – the probe and the two alternatives beneath it. The experimenter read the words aloud and participants responded by pointing.

*3.6.1.3. Task 8. Word-picture matching: locative choice.* In this task (Miozzo et al., 2008) the experimenter showed a picture (e.g., of a photo leaning against the wall) and asked about the location of a specific object (*Where is the photo?*) orally presenting a choice between two spatial prepositions (*Against the wall* or *on the wall?*). Care was taken to choose the most plausible foils. To minimize thematic role confusions, stimuli included only objects for which pragmatic knowledge disallowed exchanges of Figure/Ground roles. In the 45 trials comprising this task, 8 spatial prepositions were tested multiple times.

*3.6.1.4. Tasks 9 Word-picture matching: spatial preposition matching.* On each trial (total = 42), the experimenter presented two drawings, each showing identical geometrical shapes in different spatial arrangements (e.g., *triangle on/in square*). Participants indicated which drawing corresponded to the sentence spoken by the experimenter. We should note that because it is the spatial preposition that is manipulated in the alternatives (e.g., *in* vs. *on*) there is no possibility of role reversal confusions to influence performance on this task. Each of seven spatial prepositions was tested six times. The spatial prepositions of Tasks 7 and 8 comprised those tested in Tasks 1 and 2 with copular sentences, thus providing a direct control of the materials used in these tasks.

#### 3.6.2. Results

Results are summarized in Table 6. Across tasks, controls' accuracy was 87–100% correct. On the two tasks testing adjectives, AES and GFE always responded correctly in the Superlative Adjectives Task, and comparably to controls in the Word-matching Task. They responded accurately also in the two tasks testing locatives: on the Locative Choice Task, response accuracy for AES (93%) and GFE (96%) were very good and just outside control range (97–100%), while on the Spatial Preposition Matching Task, AES and GFE performed identically (95%) scoring close to control range (97–100%). The highly accurate performance of AES and GFE in these four tasks gives no indication of impairments affecting the comprehension of the meanings of locatives and adjectives. Thus, the possibility that poor performance with locatives and adjectives in reversible sentences is due to the sparseness of the semantic representations of adjectives and locatives received no support.

#### 3.6.3. Interim summary

We were able to rule out several alternative accounts on which the thematic confusions of AES and GFE stem from difficulties with the processing of comparatives, with the comprehension of spatial language terms or the semantics of certain word classes (adjectives, locatives, light verbs).

### 3.7. Experiment 7: Complement encoding

In some sentences, the properties of embedded structures under a verbal projection overlap with those we have been investigating, for example in embedded prepositional structures. Thus, in the sentence *The mover put the chair behind the box*, *chair* is at the same time the object of the (spatial) ditransitive verb *put* and the Figure of the preposition *behind*. Sentences involving spatial ditransitive verbs raise the interesting question of whether AES and GFE would make role reverse errors in these structures. Thematic confusions are expected if *chair*, along with *box*, receive their thematic roles from the preposition and the

**Table 6**
Scores in tasks used to evaluate the semantics of adjectives and locatives.

| Task | % Correct responses/participants | | |
|---|---|---|---|
| | AES (%) | GFE (%) | Controls mean (range) |
| Superlative Adjectives | 100 | 100 | 100% |
| Adjective Matching | 92 | 84 | 95% (87–97%) |
| Locative Choice | 93 | 96 | 98% (97–100%) |
| Spatial Preposition Matching | 95 | 95 | 98% (97–100%) |

whole PP is then incorporated into the VP (as we would expect from recent accounts of ditransitive verbs; e.g. Harley, 2003; Pesetsky, 1995). However, if *chair* is directly encoded as an argument of the V and not the PP (as in e.g. the classic analysis of ditransitives in Larson, 1988), role assignment would be unproblematic just as it has been with any of the other verbs. An empirical answer to this question could have several implications for understanding both sentence processing and the grammar of ditransitives. Although we defer a detailed discussion of these implications to Section 4, it is sufficient to say here that if we find reversal errors in this context, this provides strong support for the notion of Pred (as well as the particular referenced theory of ditransitives). The mechanism of Pred is, according to this literature, quite general, and appears in a number of embedded constructions involving non-verbal predicates, spatial ditransitives being a particularly relevant case.

#### 3.7.1. Methods and materials

*3.7.1.1. Task 10. Ditransitive verbs in Sentence-Picture Verification.* The experimental stimuli consisted of sentences like *The mover put the chair behind the box* that contains an adjunct formed by a locative and terms corresponding to Figure and Ground. We created 35 sentence pairs in which the elements involved in the spatial relationship were reversed, as in the example *The mover put the chair behind the box/the box behind the chair*. Five verbs and seven locatives were used in these sentences. Each verb and locative was presented an equal number of times. Pictures were created representing the action described by the sentences. Each picture was presented either with a matching sentence correctly describing the action shown in the picture or with a mismatching sentence in which the elements involved in the spatial relationship were reversed. For example, in a mismatch trial the sentence *The mover put the box behind the chair* was paired to the picture showing *the chair behind the box*. A total of 140 Sentence-Picture Verification trials were used to test the comprehension of Figures and Grounds embedded in the adjuncts.

For 20 of the pictures, we created 20 additional sentence pairs that were presented in filler trials excluded from analysis. These sentences were made by changing the subject, the locative, the Figure or the Ground. To illustrate this with an example, the following changes could have been made: *The mover/policeman put the chair/toy behind/on the box/book*. Filler sentences were introduced to direct participants' attention to every component of the sentence instead of having them focusing exclusively on Figures and Grounds.

#### 3.7.2. Results

Results indicate that while controls performed at ceiling in this task (95–100%), AES and GFE had clear difficulties with Figure/Ground role reversals, with AES making only 72% of correct choices and GFE 69%. Their *d'* values (AES = 1.24; GFE = 1.33) further illustrate the degree of their difficulty with these structures. These results help us to better characterize the mechanisms under the control of Pred, a point we examine in detail in Section 4.

## 4. General discussion

The impairments found in AES and GFE span a range of linguistic phenomena: spatial predication, comparative predication, and inner arguments of ditransitive predicates. We first considered the possibility that the error patterns in each empirical domain might be, to some degree, independently explained, and thus coincidental. A number of factors might lead to errors with spatial predication, including difficulties with (transitive) spatial relations, difficulties with preposition meanings, or perhaps problems with spatial cognition more generally. However, we tested the possible alternative explanations that we are aware of, and ruled them out. Strikingly, both participants failed to exhibit errors when processing sentences involving spatial verbs (Section 3.4) that were closely matched in meaning to the relevant preposition (e.g., *follows* vs. *behind*). We also tested both participants' understanding of the relations involved in the prepositions (e.g., that *on* signals some kind of gravitational support but *in* signals containment), and found that they understood the prepositional meanings (Section 3.6). A number of tests ruled out general impairments with spatial cognition as well (Section 2). This line of investigation narrows down the field of explanations of the errors produced by AES and GFE with prepositional examples substantially – the errors involve the binding of arguments/thematic roles (e.g., Figure and Ground) to transitive spatial prepositions in predicative sentences, but not the spatial content of those prepositions *per se*.[2]

This last point is supported by the fact that both individuals made similar reversal errors with (non-spatial) comparative adjectives in predicative structure (Section 3.2). This error pattern also might have independent explanation, and so we attempted to rule out the possible explanations we were aware of. AES and GFE might make errors with comparative structures more generally, might have difficulty with the adjectival meanings themselves, or might have some difficulty with comparisons, either linguistic or more generally. The lack of reversal errors with adverbial comparatives (e.g., *The girl runs more quickly than the boy*; Section 3.3) rules out impairments with comparative structures or comparisons more generally, as such impairments would lead to difficulty with adverbial comparatives. In diagnostics aimed at explaining the errors via a light/heavy distinction (Section 3.5) or in terms of adjective meaning (Section 3.6), AES and GFE performed highly accurately. Thus, the alternative explanations that we are aware of were ruled out.

This line of argumentation suggests that the two error patterns do not have independent explanations that conspire to produce a similar set of errors, but rather have the same explanation. What is in common between the two cases is that they involve copular predicative structures, which in English involve the verb *to be* followed by

[2] In fact, this suggests that the apparent localization of this initial error pattern to spatial meanings might be an accident of the lexicon – there are very few transitive prepositions (or non-verbal predicates) that are not spatial, especially when the preconditions for a reversal error must be met (similar size, no functional asymmetries provided by world knowledge, etc.).

a non-verbal predicate of some kind. It happens that most non-verbal predicates are intransitive, and so do not lead to reversal errors. But with those non-verbal predicates that do allow role exchanges, both AES and GFE demonstrated difficulty binding syntactic arguments (e.g., subject and object) to semantic/thematic arguments (e.g., Figure and Ground, in the relevant predicates). Consequently, it is in theories of how this binding happens that we must look for explanations for the error patterns observed.[3]

AES and GFE performed surprisingly well with transitive verbs and thus seemed capable of binding syntactic arguments to semantic arguments. This is, of course, most striking in the matched preposition/spatial verb cases (Section 3.4), but in general (as noted earlier) it is not a pattern much reported in previous literature – the cases we are aware of involve patients who do in fact make reversal errors with verbs. A dissociation between (impaired) non-verbal predicates and (spared) verbal predicates is the remaining explanation once the alternatives hypotheses were tested and ruled out. This is illustrated in Fig. 4. It should be noted that this dissociation was only partial in both of our participants, as they both showed residual abilities in processing the problematic nonverbal predicates.

### 4.1. Implications for theories of predication in sentence processing and the grammar

The finding of evidence from comprehension and production that there is distinct machinery at the syntax/semantic interface for verbal and non-verbal categories has a number of implications for our understanding of sentence processing in general, as well as for linguistic theories of predication and any cognitively plausible theory of the processing and production of predication. We first address general implications, and then turn to predication in particular.

First, the dissociation in performance between verbal and non-verbal categories and the specific manifestation of the difficulties with non-verbal categories provides novel information regarding the semantic–syntax interface mechanisms that speakers must acquire for non-verbal word categories. As proposed within the linguistic theories we reviewed in the Introduction, non-verbal categories appear to lack a predicative function, and to compensate for this, non-verbal categories depend on specific syntactic-semantic mechanisms (discussed further below). This conclusion raises intriguing questions for future research that concern the acquisition of these mechanisms and their implementation in adult language systems.

Second, the dissociation in performance between verbal and non-verbal categories, with intact performance with verbs only, converges with a wide range of results from psycholinguistic and neuropsychological investigations that have revealed the richness and complexity of the lexical representations of verbs. Among other things, the evidence indicates that verb representations specify the number of syntactic arguments that the verb can take (Boland et al., 1990; Jonkers & Bastiaanse, 1996; Kemmerer & Tranel, 2000; Kim & Thompson, 2000, 2004; MacDonald et al., 1994; Palti et al., 2007; Rubin et al., 1996; Shapiro et al., 1991, 1993; Shetreet et al., 2007; Thompson et al., 2007; Trueswell & Kim, 1988) as well as the semantic and pragmatic features by which these arguments are associated to words. The results from this investigation contribute to this literature by indicating that information instrumental for mapping thematic roles onto arguments is also an integral component of acquired knowledge about verbs.

Third, the fact that AES and GFE experienced identical difficulties with non-verbal categories in comprehension and production strongly suggests that the semantic–syntax interface mechanisms operate upon representations that are abstract, in the sense that they are implemented irrespective of variations in input/output formats. The similarity of performance in comprehension and production has not always been reported (e.g., Berndt et al., 1996; Cupples & Inglis, 1993). Whether or not deficits affect both comprehension and production provides important information regarding the level of processing at which the deficits occur, with the modality-specific deficits arising at the more peripheral levels of processing or in the communication from the periphery to central, while abstract processes are insensitive to acoustic or articulatory details. These results have implications for future behavioral and neuroimaging investigations of the syntax/semantics interface in that similarity in performance or activation patterns for comprehension and production will be 'diagnostic' of interface mechanisms. Interestingly, recent behavioral findings (Kempen, Olsthoorn, & Sprenger, 2012) and fMRI finding (Segaert, Menenti, Weber, Petersson & Hagoort, 2012) converge with our results in suggesting that language comprehension and language production share core processes that specify the syntactic relations between words in the sentence.

Fourth, these findings add to the broader understanding of the sentence processing system as a highly complex, internally structured system with multiple dissociable components. The pattern reported in this investigation reveals distinct processes at the syntax/semantics interface that can be considered in conjunction with other patterns that affect other components of this complex process. Just above we discussed patterns affecting only comprehension or production and which, therefore, are likely to originate in the modality-specific mechanisms that provide input to the amodal syntactic, semantic and interface processes. In addition, in the Introduction we referred to cases that exhibit difficulties with both verbal and nonverbal categories. These cases highlight the fact that many (most) of the machinery for sentence comprehension and production is likely shared across categories. For example, for patient JP (Miozzo, Fisher-Baum, & Postman, 2010; Miozzo et al., 2008) thematic role confusions appeared not only with locatives and adjectival comparatives, but also with verbs.

[3] An alternative potential unifying theme of much of the data we have considered is that it involves transitive stative examples. Could the difficulty be with binding syntactic arguments in states? In general, most non-verbal predicates are stative, and consequently stativity is highly confounded with predicative sentences. However, the confound does not work the other way, and we have considered a number of stative transitive spatial (e.g., *support*, *contain*, *cover*). AES and GFE's good performance with these verbs is difficult to reconcile with an explanation in terms of processing states.

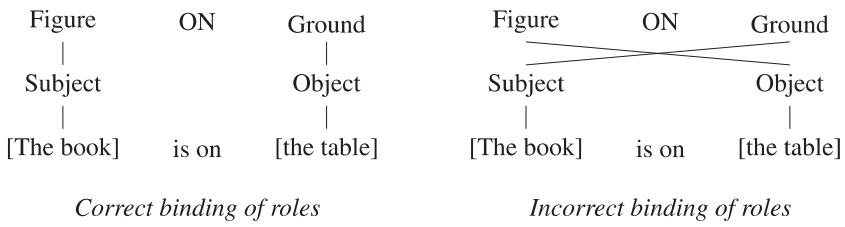


**Fig. 4.** Schematic illustration showing a correct binding (left) and an incorrect binding (right) of the thematic roles onto the syntactic arguments corresponding to the Preposition *on*.

JP's intact ability to recognize syntactic anomalies ruled out major syntactic deficits, whereas different lines of evidence indicate preserved semantic knowledge, including for verbs. Based on these results, a fundamental deficit in thematic role assignment was posited as the most probable cause of the difficulties experienced by JP.

Finally, we should comment on the finding that the responses of both AES and GFE in the Verification Task were less accurate with locatives than adjectival comparatives (Section 3.2). We already pointed out that these differences in accuracy could reflect systematic differences in the materials, a likely possibility especially given that materials were not equated for variables affecting task difficulties. Nevertheless, these differences in accuracy could stem from differences in the processing supporting the binding of syntactic arguments and thematic roles. Under this view, comparatives and locatives not only share processing features that make them more vulnerable to damage than verbs, but they are also supported by partially distinct mechanisms that can be differently affected by damage, thus leading to the accuracy asymmetries that were observed. Our data do not allow us to determine the correctness of this account. However, this hypothesis predicts that there should be individuals with the reverse pattern, exhibiting more severe deficits with comparatives than locatives.

In the remainder of this section we discuss in more detail the ways in which our findings bear on the theory of predication and the interface between syntax and semantics in cognition.

This work converges with a long line of research examining the nature of predication in linguistics. A null hypothesis about predication (instantiated in many textbook treatments of compositional semantics (e.g., Heim & Kratzer, 1998), and in fact long implicit in e.g., classical predicate logic) is that at the level of meaning representation, there is not a fundamental difference between predicates corresponding to syntactic category. In modern linguistic semantics and philosophy, this idea originates with Frege (1997/1892), who argued that verb phrases and non-verbal constituents (NPs, APs) in copular sentences are uniformly predicates. For example, *on the table* is a predicate that, when combined with its subject, returns True just in case that the referent of the subject is supported by the table. A parallel VP such as *supported by the table* would return True in very similar circumstances, and apply to the same kind of subjects. In terms of the kinds of situations they describe in the world, there is very little inherent difference between these cases of verbal and non-verbal predicates. In fact, across languages, we might expect some relations that in English involve a preposition to be only describable using a verb, and vice versa (such an example involving English and Korean is discussed by Choi and Bowerman (1991) and Kawachi (2007)). On this null hypothesis, there does not need to be any grammatical machinery in the syntax or at the syntax/semantics interface corresponding to 'predication' – the notion can be a purely semantic one.

A competing hypothesis emerging from the linguistic literature on the syntax/semantics interface is that (i) predication is a grammatical, and not purely semantic notion and (ii) there is a fundamental grammatical distinction between certain types of predicates (see Fig. 1). This hypothesis has taken a range of forms and is compatible with many general approaches to the syntax of natural languages; we focus on Baker's (2003) proposal as it represents the most comprehensive version in the linguistics literature. This idea corresponds to what we have so far labeled as the Pred hypothesis – that there is some syntactic node in a tree structure corresponding to a grammatical mechanism for the binding of syntactic to semantic roles. Further instantiations of this idea exist beyond Baker's (cf. Bowers's (1993) "Pred," Chomsky's (1995) "v," Kratzer's (1995,1996) "Voice;" see also, among others, Adger & Ramchand, 2003; Heggie, 1988; Hornstein & Lightfoot, 1987; Moro, 1997; Stowell, 1981; Williams, 1980, 1983). Though some of these proposals have treated all predicates uniformly, for the most part, there is agreement that not all predicates involve a grammatical element like Pred in their role binding.[4] This holds true for Backer (2008) hypothesis on which we focus here: the lexical category Verb is characterized by the (unique) ability of verbs to license a determiner phrase (DP) in their specifier at an underlying level of representation. Other classes of lexical items, in order to be used as predicates, require grammatical support in the form of the functional projection headed by Pred, which can license specifiers. The semantic consequence of this is that verbs alone can bind their external argument to subject position without grammatical support. Non-verbal predicates require Pred for this to happen, as illustrated in Fig. 1.

Baker provides a range of linguistic arguments for his precise proposal, focusing mainly on cross-linguistic data

[4] For example, Kratzer (1995) suggests that only eventive predicates, not stative predicates, involve a grammatical mechanism. As noted above, this is not the distinction that our data leads us to, though we leave open the question as to whether a Baker-style Pred is compatible with some version of the Kratzerian eventive/stative distinction.

that we will not review in detail here. The key theme throughout his arguments is that across all languages non-verbal predicates (e.g., adjectival phrases, noun phrases) pattern together in various ways that are distinct from how verbal predicates pattern. We discuss two main linguistic diagnostics, one cross-linguistic, and one in English.

One of the most important cross-linguistic patterns Baker observes is that in some languages a particular overt, non-verbal morpheme co-occurs (only) with non-verbal predicates. When there is such a grammatical marker, and it makes a distinction between predicates, it always respects this major V vs. non-V distinction. This supports the general hypothesis that verbal and non-verbal predication behave distinctly. In short, Baker argues that such morphemes are the overt exponent of Pred, providing evidence that this syntactic category is not as abstract as it might seem, and leading to the particular syntactic analysis we have sketched here (see Fig. 2). However, since English does not have any overt exponent (beyond the copular verb itself), this diagnostic cannot apply directly to English.

Within particular languages, a key diagnostic used by Baker is what we will term the conjunction test. Baker shows that in predicative constructions, non-verbal predicates of different categories (PP, NP, AP) can be conjoined using *and* with each other, but not with verbs or verb phrases. This amounts to an argument that the syntactic category of these predicates is the same across non-verbal predicate types, but distinct from the category of verbal predicates. This diagnostic, in contrast, can be applied directly to English. For example, Bowers (1993) pointed out that examples like *John is crazy and a fool* were acceptable, despite the fact that an adjective phrase is conjoined with a noun phrase. Bowers also discussed embedded examples like *I consider Liz crazy and a fool*, where he (and following a range of literature) argues that there is an embedded predicational structure that in English simply is not realized with an overt verb at all (i.e., there is still predicational syntax, but no copular verb). In English, Baker extends Bowers' diagnostic to the observation that examples like **Eating poisoned food made John [sick and die]* are not acceptable. (This example, on Baker's proposal, involves an embedded predicative structure as well; it is not possible to test this case in a root clause.) Consequently, Baker concludes that at least some non-verbal predicative phrases in English (and a number of other languages) pattern together on the conjunction test, and therefore have the same syntactic category.

Baker does not discuss conjunctions of PPs in English, but as much of our data rests on spatial PPs, these are a key case here. To extend the conjunction argument, we collected a range of attested examples of conjunctions of APs and PPs from the *Corpus of Contemporary American English* (Davies, 2008), a large mixed-genre corpus of American English. In regular (copular) predicational structures, we readily find examples like *Once the barrel is clean and at its chosen site, it is ready to be lined*, as well as *He believes Hussein is alive and on the run within Iraq*. These conjunctions also productively appear in embedded predicational structures parallel to Baker's example: *. . .he seems serene and out of the reach of critics,* and *They consider themselves special and above the law.* In contrast, examples like **Doing well on the exam made John pass and at the top of the class* are judged not acceptable by native speakers, and we were unable to find attested examples of a verb or VP conjoined with a PP. This gap parallels Baker's above 'poison' example and completes the paradigm. In summary, in conjunction, predicative PPs, APs, and NPs group together and can be conjoined, where as verbal predicates stand apart. At some level of representation, non-verbal predicates do share a syntactic category with each other, but not with regular VPs.[5] What is conjoined in these examples, on Baker's proposal is a (surface) PredP.

This line of linguistic argumentation, where non-verbal predicates pattern together and are distinct from verbal predicates on linguistic criteria, converges with the error patterns exhibited by AES and GFE. These individuals made errors when binding syntactic arguments to semantic roles in the case of non-verbal predicates, but did not make similar errors when performing such binding in the case of verbal predicates. In terms of Baker's theory, what this suggests is that the grammatical or processing mechanism that supports this binding (i.e., Pred on Baker's specific proposal) is impaired. The general line of Baker's proposal provides some explanation for why AES and GFE exhibited the error patterns that they did: non-verbal predicates do not inherently support the necessary role-binding, but lean on an extra mechanism; verbal predicates, on the other hand, can inherently support the role-binding. AES and GFE were capable of binding syntactic arguments to semantic roles in general (a procedure that is pervasive throughout compositional interpretation, including the simple SVO case), but only when the predicate itself supports the binding of roles. In turn, the error patterns we have reported here provide strong support for a key component of Baker's analysis – which potentially predicts just such an error pattern. The error pattern is not compatible with the null (Fregean) hypothesis about predication, where all predicates are semantically alike, nor is it compatible with proposals like Bowers' (1993) that invoke a grammatical Pred uniformly across all categories (including verbs). It is, however, generally compatible with proposals that differentiate non-verbal from verbal predicates, and in particular, differentiates the mechanism by which thematic roles are mapped to syntactic arguments in these two cases. Baker's (2003) theory of predication is the best match to this that we are aware of in the linguistics literature.

Further support for this idea is provided by the errors that AES and GFE produced with the objects of (spatial) ditransitives (Section 3.7). For example, with the sentence

[5] It is worth pointing out that Baker himself treated PPs across languages as involving yet a third class of predicative structures; the evidence for this does not come from English (and is not available in English). In many languages that have an overt but non-verbal morpheme corresponding to Pred (e.g., Ede) Baker observes that PPs do not take this verb, but require a light spatial verb. Given the conjunction test data, which Baker does not discuss for English, we conclude that English PPs do not pattern with prepositional constructions in these other languages. Our assumption, outside of Baker's work, is what we take to be the standard one (see e.g., Adger & Ramchand, 2003; Bowers, 1993). Note also that comparative APs pattern with regular APs.

*The mover put the chair behind the box,* they could have erroneously identified *box* as the Theme or Patient of the putting event. In some parts of the linguistic literature on predication, cases such as those of the objects of spatial ditransitives have been treated as actually involving an underlying predication relation between the direct object and a predicate indicated by the prepositionally marked indirect argument (see e.g., Harley, 2003).[6] This is illustrated in the tree shown in Fig. 5. A prediction stemming from this independently motivated analysis is that AES and GFE would make role exchange errors with spatial ditransitive verbs, among the objects (but not the subject). This is exactly what we found, providing support both for the overall approach to non-verbal predication, and this treatment of ditransitives.

In summary, the error patterns exhibited by AES and GFE are compatible with a grammatical explanation on the basis of Baker's particular analysis of predication at the syntax/semantics interface. Non-verbal predicates do not have the lexically-based ability to assign a thematic role to their external arguments, but must rely on a general (i.e., not specific to any particular lexical item) grammatical mechanism in the form of the functional projection Pred. Verbal predicates do have this ability, and thus can remain intact even if there is impairment to the general mechanism. Independently of Baker's particular linguistic theory, the error patterns exhibited by AES and GFE lend support to the claim that there must be a fundamental distinction in how predicates work for verbs compared to other types of predicates. A cognitively plausible theory of the processing and production of thematic roles must respect this distinction.

### 4.2. Conclusions

This investigation was motivated by the desire to further our understanding of the processes supporting predication, as we were aware that, as aptly put by Davidson (2005), "if we do not understand predication, we do not understand how any sentence works, nor can we account for the structure of the simplest thought that is expressible in language" (p. 77). Our results indicate that predication involves partially distinct neurocognitive processes for verbs and other word categories, such that deficits subsequent to brain damage may selectively affect predication with non-verbal categories. Although future research is needed to precisely characterize how processes supporting predication vary across word categories, that speakers acquire linguistic knowledge about predication as well as the interface between semantics and syntax through which predication arises. In the end, it is this type of knowledge that enables speakers to talk not only about events, which are typically related to verbs, but also about identity, properties, comparison and analogy, concepts that are expressed by other word categories – from nouns, to adjectives and prepositions. That verbal and non-verbal word-categories differ with respect to predication, a notion that has been recognized by linguistic theories, has provided the theoretical framework for the present investigation. In sum, this investigation illustrates the productivity of the interaction between linguistic and cognitive neuroscience research.

[6] Harley (2003) focuses on more abstract ditransitives, such as *give*. Our treatment of predication is somewhat different than hers, but we take it the natural extension of her proposal in Baker's system.

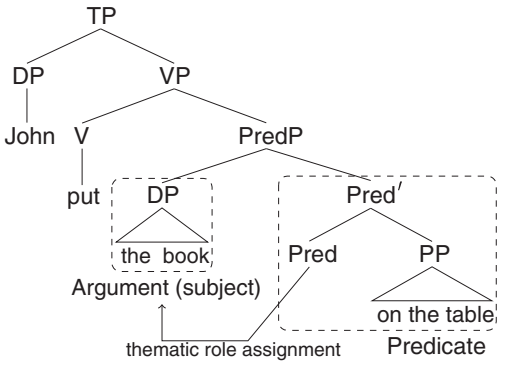


**Fig. 5.** Underlying structure of a sentence embedding a (spatial) ditransitive verb (*put*), its object (*book*) and a PP (*on the table*), assuming Baker's syntax. Pred is needed to bind the PP to its argument.

## Acknowledgments

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## References

Adger, D., & Ramchand, G. (2003). Predication and equation. *Linguistic Inquiry, 34*, 325–359.
Bach, E. (1986). The algebra of events. *Linguistics and Philosophy, 9*, 5–16.
Baker, M. C. (2003). *Lexical categories*. Cambridge: Cambridge University Press.
Balota, D. A., Yap, M. J., et al. (2007). The English Lexicon Project. *Behavior Research Methods, 39*, 445–459.
Barde, L. H. F., Schwartz, M., & Boronat, C. B. (2006). Semantic weight and verb retrieval in aphasia. *Brain and Language, 97*, 266–278.
Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997). Verb retrieval in aphasia: 1. Characterizing single word impairments. *Brain and Language, 56*, 68–106.
Berndt, R. S., Mitchun, C. C., & Haendiges, A. N. (1996). Comprehension of reversible sentences in "agrammatism": A meta-analysis. *Cognition, 58*, 289–308.
Black, M., Nickels, L., & Byng, S. (1991). Patterns of sentence processing deficit: Processing simple sentences can be a complex matter. *Journal of Neurolinguistics, 6*, 79–101.
Bock, J. K., & Levelt, W. J. M. (1994). Language production: Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). New York, NY: Academic Press.
Boland, J. E., Tanenhaus, M. K., & Garnsey, S. M. (1990). Evidence for the immediate use of verb control information in sentence processing. *Journal of Memory and Language, 29*, 413–432.
Bornkessel, I., & Schlesewsky, M. (2006). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review, 113*, 787–821.
Bowers, J. (1993). The syntax of predication. *Linguistic Inquiry, 24*, 591–656.
Breedin, S. D., & Martin, R. C. (1996). Patterns of verb impairment in aphasia: An analysis of four cases. *Cognitive Neuropsychology, 13*, 51–91.
Breedin, S. D., Saffran, E. M., & Schwartz, M. F. (1998). Semantic factors in verb retrieval: An effect of complexity. *Brain and Language, 63*, 1–31.
Bresnan, J. (1973). Syntax of the comparative clause construction in English. *Linguistic Inquiry, 4*, 275–343.

Bresnan, J. W. (2001). *Lexical-functional syntax*. Oxford: Balckwell.

Caplan, D., & Hildebrandt, N. (1988). *Disorders of syntactic comprehension*. Cambridge, MA: MIT Press.

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

Caramazza, A., & Miceli, G. (1991). Selective impairment of thematic role assignment in sentence processing. *Brain and Language, 41*, 402–436.

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

Carlson, L., & van der Zee, E. (Eds.). (2005). *Functional features in language and space*. New York: Oxford University Press.

Choi, S., & Bowerman, M. (1991). Learning to express events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition, 41*, 83–121.

Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA: The MIT Press.

Collina, S., Marangolo, P., & Tabossi, P. (2001). The role of argument structure in the production of nouns and verbs. *Neuropsychologia, 39*, 1125–1137.

Coventry, K. R., & Garrod, S. C. (2004). *Saying, seeing, and acting: The psychological semantics of spatial prepositions*. New York: Psychology Press.

Croft, W. (1991). *Syntactic categories and grammatical relations: The cognitive organization of information*. Chicago: University of Chicago Press.

Cupples, L., & Inglis, A. L. (1993). When task demands induce "asyntactic" comprehension: A study of sentence interpretation in aphasia. *Cognitive Neuropsychology, 10*, 201–234.

Davidson, D. (2005). *Truth and predication*. Cambridge, MA: Harvard University Press.

Davies, M. (2008). Corpus of American English: 360 million words, 1990-present. <http://www.americancorpus.org>.

Devescovi, A., Bates, E., D'Amico, S., Hernandez, A., Marangolo, P., Pizzamiglio, L., et al. (1997). An on-line study of grammaticality judgments in normal and aphasic speakers of Italian. *Aphasiology, 11*, 543–579.

Dronkers, N. F., Wilkins, D. P., Van Valin, R. D., Redfern, B. B., Jr., & Jaeger, J. J. (2004). Lesion analysis of the brain area involved in language comprehension. *Cognition, 92*, 145–177.

Dunn, L. M., & Dunn, L. M. (1981). *PPVT: Peabody picture vocabulary test-revised*. Circle Pines, MN: American Guidance Services.

Elliott, C. D. (2007). *Differential ability scales* (2nd ed.). San Antonio, TX: Harcourt Assessment.

Fiebach, C. J., Schlesewsky, M., Lohmann, G., von Cramon, D. Y., & Friederici, A. D. (2005). Revisiting the role of Broca's area in sentence processing: Syntactic integration versus syntactic working memory. *Human Brain Mapping, 24*, 79–91.

Fillmore, C. J. (1968). *Lexical entries for verbs*. Dordrecht: D. Reidel.

Frege, G. (1997/1892). On concept and object. In M. Beaney (Ed.) *The Frege Reader* (pp. 181–193). Cambridge, MA: Blackwell.

Friederici, A. D., Schönle, P. W., & Garrett, M. F. (1982). Syntactically and semantically based computations: Processing prepositions in agrammatism. *Cortex, 18*, 525–534.

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

Gordon, J. K., & Dell, G. S. (2003). Learning to divide the labor: An account of deficits in light and heavy verb production. *Cognitive Science, 27*, 1–40.

Grimshaw, J. (1990). *Argument structure*. Cambridge: Cambridge University Press.

Gruber, J. S. (1976). *Studies in lexical relations*. Amsterdam: North Holland.

Harley, H. (2003). Possession and the double object construction. In P. Pica & J. Rooryck (Eds.), *Linguistic variation yearbook* (2nd ed., pp. 31–70). Philadelphia: John Benjamins.

Heggie, L. (1988). *The syntax of copular sentences*. Doctoral dissertation, University of South California.

Heim, I., & Kratzer, A. (1998). *Semantics in generative grammar*. Cambridge, MA: Blackwell.

Herskovits, A. (1986). *Language and spatial cognition: An interdisciplinary study of the prepositions in English*. Cambridge: Cambridge University Press.

Higginbotham, J. (1985). On semantics. *Linguistic Inquiry, 16*, 547–593.

Hornstein, N., & Lightfoot, D. (1987). Predication and PRO. *Language, 63*, 23–52.

Howard, D. (1985). Agrammatism. In S. Newman & R. Epstein (Eds.), *Current perspectives in dysphasia*. London: Churchill Livingston.

Jackendoff, R. (1972). *Semantic interpretation in generative grammar*. Cambridge, MA: The MIT Press.

Jackendoff, R. (1990). *Semantic structures*. Cambridge, MA: The MIT Press.

Jasperson, O. (1965). *A modern English grammar on historical principles*. London: Allen & Unwin.

Jonkers, R., & Bastiaanse, R. (1996). The influence of instrumentality and transitivity on action naming in Broca's and anomic aphasia. *Brain and Language, 55*, 50–53.

Just, M. A., Carpenter, P. A., Keller, T. A., Eddy, W. F., & Thulborn, K. R. (1996). Brain activation modulated by sentence comprehension. *Science, 274*, 114–116.

Kaan, E., & Swaab, T. Y. (2002). The brain circuit of syntactic comprehension. *Trends in Cognitive Sciences, 6*, 350–356.

Kawachi, K. (2007). Korean putting verbs do not categorize space contrastively in terms of "Tightness of Fit". *Lingua, 117*, 1801–1820.

Kay, J., Lesser, R., & Coltheart, M. (1992). *Psycholinguistic assessments of language processing in aphasia (PALPA)*. Philadelphia, PA: Psychology Press.

Kean, M. L. (1985). *Agrammatism*. New York: Academic Press.

Kemmerer, D., & Eggleston, A. (2010). Nouns and verbs in the brain: Implications of linguistic typology for cognitive neuroscience. *Lingua, 120*, 2686–2690.

Kemmerer, D., & Tranel, D. (2000). Verb retrieval in brain-damaged subjects: Analysis of stimulus, lexical, and conceptual factors. *Brain and Language, 73*, 347–392.

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.

Kim, M., & Thompson, C. K. (2000). Patterns of comprehension and production of nouns and verbs in agrammatism: Implications for lexical organization. *Brain and Language, 74*, 1–25.

Kim, M., & Thompson, C. K. (2004). Verb deficits in Alzheimer's disease and agrammatism: Implications for lexical organization. *Brain and Language, 88*, 1–20.

Kohn, S. E., Lorch, M. P., & Pearson, D. M. (1989). Verb finding in aphasia. *Cortex, 25*, 57–69.

Kolk, H. H. J., & van Grunsven, M. M. F. (1985). Agrammatism as a variable phenomenon. *Cognitive Neuropsychology, 2*, 347–384.

Koopman, H. (1984). *The syntax of verbs: from verb movement rules in the Kru languages to universal grammar*. Dordrecht: Floris.

Kratzer, A. (1995). Stage-level/individual-level predicates. In G. N. Carlson & F. J. Pelletier (Eds.), *The generic book* (pp. 125–175). Chicago: University of Chicago Press.

Kratzer, A. (1996). Severing the external argument from its verb. In J. Rooryck & L. Zaring (Eds.), *Phrase structure and the lexicon* (pp. 109–137). Kluwer: Dordrecht.

Landau, B., & Jackendoff, R. (1993). "What" and "where" in spatial language and spatial cognition. *Behavioral and Brain Sciences, 16*, 217–265.

Larson, R. K. (1988). On the double object construction. *Linguistic Inquiry, 19*, 335–391.

Levin, B., & Rappaport Hovav, M. (1995). *Unaccusativity: At the syntax–lexical semantics interface*. Cambridge: Cambridge University Press.

Levinson, S. C. (2003). *Space in language and cognition*. Cambridge: Cambridge University Press.

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

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). Lexical nature of syntactic ambiguity resolution. *Psychological Review, 101*, 676–703.

Martin, R. C. (2006). The neuropsychology of sentence processing: Where do we stand? *Cognitive Neuropsychology, 23*, 74–95.

Menn, L., & Obler, L. K. (1990). *Agrammatic aphasia: A cross-language narrative sourcebook*. Amsterdam: Benjamins.

Miozzo, M., Fischer-Baum, S., & Postman, J. (2008). Knowing what but not where. Impaired thematic roles and spatial language. *Cognitive Neuropsychology, 25*, 853–873.

Miozzo, M., Fisher-Baum, S., & Postman, J. (2010). A selective deficit for inflection production. *Neuropsychologia, 48*, 2427–2436.

Moro, A. (1997). *The raising of predicates: Predicative noun phrases and the theory of clause structure*. Cambridge: Cambridge University Press.

Newhart, M., Trupe, M. A., Gomez, Y., Cloutman, L., Molitoris, J. J., Davis, C., Leigh, R., Gottesman, R., Race, D., & Hillis, A. E. (2012). Asyntactic comprehension, working memory, and acute ischemia in Broca's area versus angular gyrus. *Cortex, 48*, 1288–1297.

Palti, D., Ben-Shachar, M., Hendler, T., & Hadar, U. (2007). The cortical correlates of grammatical category differences: An fMRI study of nouns and verbs. *Human Brain Mapping, 28*, 303–314.

Parisi, D., & Pizzamiglio, L. (1970). Syntactic comprehension in aphasia. *Cortex, 6*, 204–215.
Pesetsky, D. (1995). *Zero syntax: Experiencers and cascades*. Cambridge, MA: The MIT Press.
Pinker, S. (1989). *Learnability and cognition: The acquisition of argument structure*. Cambridge, MA: The MIT Press.
Rawlins, K. (2013). Adverbs of (space and) time. In B. Arsenijević, B. Gehrke, & R. Marín (Eds.), *Studies in the Composition and Decomposition of Event Predicates*. Dordrecht: Springer.
Rogalsky, C., & Hickock, G. (2011). The role of Broca's area in sentence comprehension. *Journal of Cognitive Neuroscience, 23*, 1664–1680.
Rogalsky, C., Matchin, W., & Hickock, G. (2008). Broca's area, sentence comprehension, and working memory: An fMRI study. *Frontiers in Human Neuroscience, 2*, 14.
Rubin, S. S., Newhoff, M., Peach, R. K., & Shapiro, L. P. (1996). Electrophysiological indices of lexical processing: The effects of verb complexity and age. *Journal of Speech and Hearing Research, 39*, 1071–1080.
Rullman, H. (1994). De ambiguïteit van comparatieven met minder [the ambiguity of comparatives with less]. *TABU: Bulletin voor Taalwetenschap, 24*, 79–101.
Saffran, E. M., & Schwartz, M. F. (1994). Of cabbages and things: Semantic memory from a neuropsychological perspective. In C. Umilta' & M. Moscovitch (Eds.), *Attention and performance 15: Conscious and non-conscious information processing* (pp. 507–536). Cambridge, MA: MIT Press.
Santi, A., & Grodzinsky, Y. (2007). Working memory and syntax interact in Broca's area. *Neuroimage, 37*, 8–17.
Schwartz, M. F., Saffran, E. M., & Marin, O. M. (1980). The word order problem in agrammatism. I. Comprehension. *Brain and Language, 10*, 249–262.
Segaert, K., Menenti, L., Weber, K., Petersson, K. L., & Hagoort, P. (2012). Shared syntax in language production and language comprehension – An fMRI study. *Cerebral Cortex, 22*, 1662–1670.
Seron, X., & Deloche, G. (1981). Processing of locatives "in", "on", and "under" by aphasic patients: An analysis of the regression hypothesis. *Brain and Language, 14*, 70–80.
Shapiro, L. P., Brookins, B., Gordon, B., & Nagel, N. (1991). Verb effects during sentence processing. *Journal of Experimental Psychology, 17*, 983–996.
Shapiro, L. P., Gordon, B., Hack, N., & Killackery, J. (1993). Verb argument processing in complex sentences in Broca's and Wernicke's aphasia. *Brain and Language, 45*, 423–447.
Shapiro, L. P., & Levine, B. A. (1990). Verb processing during sentence comprehension in aphasia. *Brain and Language, 38*, 21–47.
Shetreet, E., Palti, D., Friedemann, N., & Hadar, U. (2007). Cortical representation of verb processing in sentence comprehension: Number of complements, subcategorization, and thematic frames. *Cerebral Cortex, 17*, 1958–1969.
Stern, R., Javorsky, D., Singer, E., Harris, N., Somerville, J., et al. (1994). *The Boston qualitative scoring system for the Rey–Osterrieth Complex Figure*. Odessa, FL: Psychological Assessment Resources Inc.
Stowe, L. A. (2000). Sentence comprehension and the left inferior frontal gyrus: Storage, non computation. *Behavioral and Brain Sciences, 23*, 51.
Stowell, T. (1981). *Origins of phrase structure*. Doctoral dissertation, MIT, Cambridge (Mass).
Svorou, S. (1994). *The grammar of space*. Amsterdam: John Benjamins.
Talmy, L. (1983). How language structures space. In H. Pick & L. Acredolo (Eds.), *Spatial orientation: Theory, research, and application* (pp. 225–282). New York: Plenum.
Thompson, C. K., Bonakdarpour, B., Fix, S. C., Blumenfeld, H. K., Parrish, T. B., Gitelman, D. R., et al. (2007). Neural correlates of verb argument structure processing. *Journal of Cognitive Neuroscience, 19*, 1753–1767.
Thothathiri, M., Schwartz, M. F., & Thompson-Schill, S. L. (2010). Selection for position: The role of left ventrolateral prefrontal cortex in sequencing language. *Brain & Language, 113*, 28–38.
Tomaugh, T. N., & Hubiey, A. M. (1997). The 60-item Boston naming test: Norms for cognitively intact adults aged 25 to 88 years. *Journal of Clinical and Experimental Neuropsychology, 19*, 922–932.
Tranel, D., & Kemmerer, D. (2004). Neuroanatomical correlates of locative prepositions. *Cognitive Neuropsychology, 21*, 719–749.
Trueswell, J. C., & Kim, A. E. (1988). How to prune a garden-path by nipping it in the bud: Fast priming of verb argument structure. *Journal of Memory and Language, 39*, 102–123.
Turnbull, O. H., Beschin, N., & Della Sala, S. (1997). Agnosia for object orientation: Implications for theories of object recognition. *Neuropsychologia, 35*, 153–163.
Vallar, G., & Baddley, A. D. (1984). Fractionation of working memory: Neuropsychological evidence for a phonological short-term store. *Journal of Verbal Learning and Verbal Behavior, 23*, 151–162.
Van Valin, R., & LaPolla, R. (1997). *Syntax, structure, meaning and function*. Cambridge: Cambridge University Press.
Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M. F. (2004). Representing the meaning of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology, 48*, 422–488.
von Stechow, A. (1984). Comparing semantic theories of comparison. *Journal of Semantics, 3*, 1–77.
Warrington, E. K. (1984). *Recognition memory test*. Windsor, Berkshire: NFER-Nelson.
Williams, E. (1980). Predication. *Linguistic Inquiry, 11*, 203–238.
Williams, E. (1983). Semantic vs. syntactic categories. *Linguistics and Philosophy, 6*, 423–446.
Zingeser, L., & Berndt, R. (1990). Retrieval of nouns and verbs in agrammatism and anomia. *Brain and Language, 39*, 14–32.