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Verb deficits in Alzheimer's disease and agrammatism: Implications for lexical organization☆

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Abstract

This study examined the nature of verb deficits in 14 individuals with probable Alzheimer's Disease (PrAD) and nine with agrammatic aphasia. Production was tested, controlling both semantic and syntactic features of verbs, using noun and verb naming, sentence completion, and narrative tasks. Noun and verb comprehension and a grammaticality judgment task also were administered. Results showed that while both PrAD and agrammatic subjects showed impaired verb naming, the syntactic features of verbs (i.e., argument structure) influenced agrammatic, but not Alzheimer's disease patients' verb production ability. That is, agrammatic patients showed progressively greater difficulty with verbs associated with more arguments, as has been shown in previous studies (e.g., Kim & Thompson, 2000; Thompson, 2003; Thompson, Lange, Schneider, & Shapiro, 1997), and suggest a syntactic basis for verb production deficits in agrammatism. Conversely, the semantic complexity of verbs affected PrAD, but not agrammatic, patients' performance, suggesting "bottom-up" breakdown in their verb lexicon, paralleling that of nouns, resulting from the degradation or loss of semantic features of verbs.

Keywords: Verb production in aphasia; Verb production in Alzheimer's Disease; Verb impairment in aphasia; Verb impairment in Alzheimer's Disease; Agrammatism; Language in Alzheimer's Disease; Lexical organization in aphasia; Lexical organization in Alzheimer's Disease

1. Introduction

Verb retrieval difficulty in aphasic patients has been studied extensively (e.g., Berndt, Mitchum, Haendiges, & Sandson, 1997; Kohn, Lorch, & Pearson, 1989; Marshall, Pring, & Chiat, 1998; Miceli, Silveri, Villa, & Caramazza, 1984; Thompson et al., 1997; Williams & Canter, 1987). A number of recent studies have investigated factors influencing aphasic patients' verb retrieval, in order to elucidate the nature of their verb deficit. Several studies have examined the influence of syntactic, argument structure properties of verbs, and others have examined semantic features (e.g., Breedin, Saffran, & Schwartz, 1998; Kim & Thompson, 2000; Thompson et al., 1997). Results have shown that both syntactic and semantic attributes of verbs influence their production in aphasia.

Kim and Thompson (2000) and Thompson et al. (1997) examined the effects of the syntactic representation of verbs, that is, the number of arguments associated with a verb, on verb retrieval in agrammatism. The agrammatic aphasic subjects in Kim and Thompson (2000) showed difficulty in naming and categorizing verbs in line with previous observations of Thompson and colleagues. Moreover, they observed a hierarchy of verb difficulty in both naming and categorization

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conditions. The agrammatic subjects were more accurate in naming and categorizing one-place verbs than two-place verbs, and more accurate with two-place verbs than three-place verbs. That is, their agrammatic subjects appeared to have more difficulty retrieving verbs associated with more arguments. They hypothesized that this hierarchy may occur because the additional argument(s), and therefore, more associated syntactic information, render the verbs more complex. Retrieval of such verbs, in turn, may require greater processing resources, as proposed in the Argument Structure Complexity Hypothesis (Thompson, 2003).

On the other hand, Breedin et al. (1998) examined verb production based on the semantic complexity of verbs. Based on a decompositional view of verb representation, adopted by Jackendoff (1976, 1983) and Schank (1973), Breedin et al. categorized verbs as semantically simple or complex. This approach assumes that, at some level of semantic representation, rather than being indivisible units, verbs are composed of a number of primitive elements.

For example, Fig. 1 illustrates the contrast between the verbs *go* and *run* (Pinker, 1989). In this representation, each verb's meaning is decomposed into smaller related elements. Notice that the representation for *run* naturally includes that of *go* and further specifies the manner of the movement. Therefore, one could say that the verb *run* is semantically more complex than the verb *go*. Breedin et al. found that their aphasic subjects were better at retrieving more complex verbs than simpler verbs. Based on this finding, the authors argued that aphasic patients with verb retrieval difficulties benefit from the elaborate semantic representation of more complex verbs.

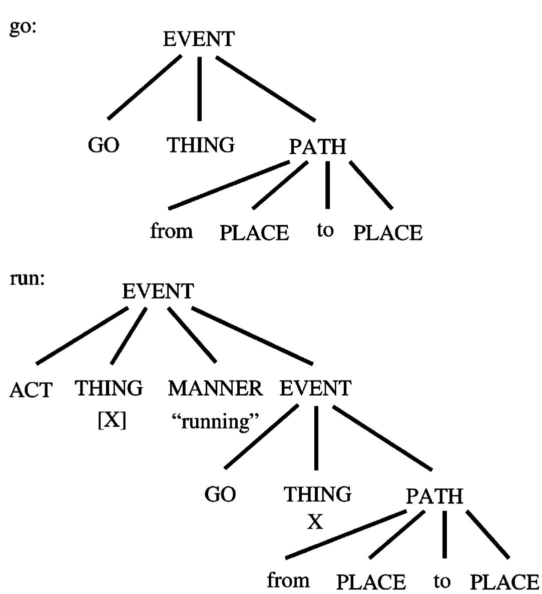

Fig. 1. Tree structure notation of the decomposition of verbs *go* and *run* (Pinker, 1989).

Verb production has also recently been examined in individuals with Alzheimer's Disease (AD). Because these patients putatively show impaired semantic knowledge of nouns (e.g., Chan, Butters, & Salmon, 1997; Hodges, Salmon, & Butters, 1991, 1992; Martin & Fedio, 1983; Monsch et al., 1994; Smith, Murdoch, & Chenery, 1989), in the face of spared grammatical ability (e.g., Blanken, Dittman, Haas, & Wallesch, 1987; Croisile et al., 1996; Kemper et al., 1993; Kempler, Curtiss, & Jackson, 1987; Schwartz, Marin, & Saffran, 1979), verb impairments in this group has not been suspected. However, a series of recent studies have shown a "verb deficit" in AD patients, i.e., impaired verb naming and comprehension of verb-related information at the sentence level (Grossman, Mickanin, Onishi, Robinson, & D'Esposito, 1997; Koenig et al., 1999; Robinson, Grossman, White-Devine, & D'Esposito, 1996; White-Devine et al., 1996). These findings suggest that the language deficits in AD may extend beyond impairments relating to nouns and that syntactic as well as semantic aspects of production may be vulnerable.

Close inspection of the Grossman et al. paper, however, suggests a need for further study of verb production in AD before any conclusions can be drawn. For example, the verbs examined were not controlled for length, word category ambiguity, or argument structure properties. Verbs such as *weightlifting* and *brushing* (i.e., zero-derived) were included. In addition, semantic and syntactic properties of verbs tested were not completely controlled. For example, their verbs were controlled for the number of possible argument structure arrangements, but not for the number of arguments. Therefore, the nature of AD patients' verb deficit is uncertain in that the potential cause of breakdown in their verb retrieval could not be clearly identified. It is possible that the semantic and syntactic factors that are known to influence aphasic patients' verb retrieval may affect AD patients' verb processing as well. Therefore, further research is warranted to investigate the mechanism underlying verb deficits in AD, in order to arrive at a coherent explanation for such impairments.

The present study was designed to investigate the presence and nature of verb deficits in AD by examining factors influencing their verb retrieval and their use of verb knowledge in sentence processing. In particular, building on previous work with aphasic patients (Breedin et al., 1998; Kim & Thompson, 2000; Thompson et al., 1997), the influence of both syntactic (i.e., verb argument structure) and semantic properties of verbs was examined. By comparing AD subjects' performance to that of agrammatic aphasic and normal subjects, the study sought to test the hypothesis that AD patients' verb deficit involves the semantic aspect of the verb's representation while agrammatic aphasic patients' verb deficit is influenced by the syntactic argument structure properties of the verb.

Naming and comprehension tasks involving verbs and nouns were used to examine single word retrieval in the two groups. The effect of syntactic and semantic features on verb retrieval was tested using a verb naming and a sentence completion task. Narrative language samples also were analyzed to examine verb usage with regard to their syntactic and semantic nature. Finally, the two groups' processing of syntactic information associated with verbs at the sentence level was tested using a grammaticality judgment task. Findings from these tasks were expected to either support or challenge the view that different components of language can be selectively impaired in different neuropathologies.

2. Method

2.1. Subjects

Fourteen individuals with the diagnosis of probable Alzheimer's disease (PrAD), nine agrammatic aphasic patients, and two groups of 10 normal subjects participated in the study. All subjects were native speakers of English with a minimum of 10 years of formal education. All except one aphasic subject, who wore a hearing aid (resulting in corrected to normal acuity), passed a pure tone audiometric screening at 500, 1000, and 2000 Hz at 40 dB HL ANSI:1969, in at least one ear. All except one PrAD subject demonstrated visual acuity of at least 20/40 on the Snellen's chart. The subject who failed the Snellen test was able to describe pictures and name objects correctly.

2.1.1. Patients with probable Alzheimer's disease

Fourteen PrAD subjects with mild-moderate cognitive impairment were recruited from the subject pool of the Clinical Core of the NIA-funded Northwestern Cognitive Neurology and Alzheimer's Disease Center and the NIA-funded Rush Alzheimer's Disease Center. All subjects met NINCDS-ADRDA criteria (McKhann et al., 1984) for a primary diagnosis of probable Alzheimer's disease. Subjects' demographic and selected neuropsychological data are presented in Table 1. Results of testing using Mini-Mental State Exam (MMSE) (Folstein et al., 1975) and the Boston Naming Test (BNT) (Kaplan, Goodglass, Weintraub, 1983) indicated that all patients show mild to moderately severe dementia, with most of them also presenting with impaired noun naming. Some subjects demonstrated mild-moderately impaired attention as measured by the letter fluency (i.e., FAS test) and the category fluency test (i.e., animal fluency test). Most subjects were able to perceive gross visual distinctions as indicated by their performance on the CERAD Constructional Praxis test. All subjects were community-dwelling at the time of testing.

2.1.2. Agrammatic aphasic subjects

Table 2 presents the demographic data of the agrammatic aphasic subjects. All but one subject were right-handed. All subjects had suffered a single, left hemisphere thromboembolic stroke involving Broca's area and adjacent white matter. Some patients' lesion also included the left parietal region. None of the subjects had a history of drug or alcohol abuse, hospitalization for psychiatric disorder, developmental speech/language disorders, prior neurological disease, or any other progressive neuro-degenerative disease.

The diagnosis of aphasia was based on the administration of the Western Aphasia Battery (WAB;

Table 1
Demographic and selected neuropsychological data of the PrAD subjects

Subject	Sex	Age	Education	MMSE*	BNT	Category fluency	Letter fluency	Construction[a]
SG	M	84	13	26	59	17	59	10
AB	F	67	12	24	43*	8*	30	8*
NT	F	77	14	23	58	15	26	8
BM	M	53	13	23	52	11	14*	10
RM	F	75	12	20	28*	5*	14	10
EN	F	84	10	19	39	11	24	7
ABj	F	85	12	19	33*	8*	20	7
AR	F	85	12	19	21*	9	15	9
MD	F	87	10	19	35*	8	22	8
JS	F	78	14	18	15*	7*	14	9
MB	F	83	16	17	15*	9*	32	10
DS	M	75	14	16	40*	6*	15*	9
MH	M	64	14	15	20*	2*	26	9*
JW	F	81	12	13	14*	0*	4*	9
Mean		77	12.7					

* Indicates impaired performance (all subjects were impaired on the MMSE).
[a] Total possible score is 11.

Table 2
Demographic information on agrammatic aphasic subjects

Subject	Sex	Age	Education	Post-onset[a]	Etiology
CH	M	48	14	118	LCVA
MD	M	51	20	114	LCVA
BH	M	56	16	128	LCVA
JOC	M	64	16	79	LCVA
BW	F	58	18	76	LCVA[b]
MR	F	55	14	59	LCVA
MK	M	54	18	16	LCVA
JP	M	62	20	32	LCVA
RT	M	54	16	65	LCVA
Mean		55.7	16.8		

[a] Months.
[b] BW had a stroke during surgery for an aneurysm.

Kertesz, 1982), as well as narrative discourse analysis. Aphasic subjects' scores on selected language subtests and the results of the narrative analysis are presented in Table 3. All subjects were initially classified as Broca's aphasic patients on the WAB. All but one subject demonstrated the ability to read aloud and comprehend single words. One subject showed the symptoms of deep dyslexia, and thus, the examiner read the word choices for the subject in the single-word comprehension tasks.

As shown in Table 3, analysis of narrative samples indicated production patterns consistent with a diagnosis of agrammatic aphasia (Saffran, Berndt, & Schwartz, 1989), such as a low proportion of grammatical sentences, high open:closed class ratio, and high noun:verb ratio, when compared to data from normal control subjects (Thompson, Shapiro, Li, & Schendel, 1995). Two exceptions were the noun:verb ratios of CH and MR. CH's sentence structure demonstrated the agrammatic pattern, even though his noun:verb ratio was in the normal range. MR's noun:verb ratio was outside the agrammatic range, because she had difficulty retrieving both nouns and verbs, in single word tasks and sentence production.

2.1.3. Normal subjects

Ten cognitively normal subjects (9 female and 1 male) were recruited from the subject pool of the Clinical Core of the Northwestern Cognitive Neurology and Alzheimer's Disease Center. All normal subjects scored 27 and above on MMSE and within 2.0 standard deviations on all CERAD neuropsychological tests, when compared with the means for age and education peer groups. Their mean age was 69.7 (range: 64–77 years) and mean years of education was 15.9 (range: 13–20 years). All normal subjects showed a negative history of disease or disorder which might have affected their cognitive and/or language function. These subjects participated in the development of stimuli for all the tasks used in the study. In addition, they were administered the sentence completion task in order to compare normal performance with that of the neurologically damaged, experimental subjects.

2.1.4. Normal narrative subjects

Narratives were collected from an additional group of 10 normal individuals (normal narrative group) using procedures identical to that used with aphasic and PrAD patients. These participants evinced no history of

Table 3
Aphasic subjects' performance on selected language subtests and values of linguistic variables

Variables	Aphasic subjects									NC mean[a]
	CH	MD	BH	JOC	BW	MR	MK	JP	RT	
WAB AQ	81.6	78.3	75.3	78	76.8	59	79.9	67	70.3	
WAB fluency	6	6	5	5	4	5	4	4	5	
WAB naming	8.9	8.4	6.5	8.7	8.5	6	7.6	7.5	6.9	
Proportion grammatical sentence	0.49	0.07	0.16	0.14	0	0	0	0	0	0.88
Open:closed ratio	1.47	2.91	1.32	2.78	6.75	1.45	16.5	1.69	2.1	0.98
Noun:verb ratio	1.02	1.31	1.87	4.71	2.12	0.85	30	5.27	2	1.19
Proportion correct verb morphology	0.91	0.74	0.7	0.57	0.28	0.76	1[b]	0.45	0.23	0.99

[a] Normal control subjects: $N = 10$.
[b] MK produced only one verb with correct morphology in his narrative.

neuropathology or other speech and language problems. They were closely matched with agrammatic aphasic subjects on age ($M = 55.1$; aphasic $M = 56$) and education ($M = 15.5$; aphasic education = 16.75), and therefore, were younger in age and higher in educational level than the PrAD group.

2.1.5. Demographic characteristics of subject groups

One-way ANOVAs were performed on the age and education of the aphasic, PrAD, and the two normal subject groups. Post hoc tests were performed when there were significant differences. The mean age of the aphasic group was significantly lower than the PrAD ($p < .000$) and the normal subjects ($p = .001$), but not the normal narrative group ($p = .76$). The normal group's mean age also was lower than that of the PrAD group, however, the difference only approached statistical significance ($p = .057$). The PrAD group's mean years of education was significantly lower than that of the aphasic group ($p < .000$), however, neither the normal group's ($p = .577$) nor the normal narrative group's ($p = .273$) differed from that of the aphasic group. These differences were expected since individuals with Alzheimer's Disease tend to be much older than aphasic patients and consequently tend to have a lower level of education than many aphasic patients. Therefore, in analysis of the data, whenever an ANOVA was used, a separate ANCOVA was performed using age and education as co-variates.

2.2. Materials and procedures

2.2.1. Materials

2.2.1.1. Stimuli

Naming and comprehension. For naming tasks, 36 noun and 36 verb targets, matched for cumulative frequency (Francis & Kucera, 1982) and number of syllables, were used. Each selected verb occurred as a noun less than 25% of its total frequency. The corresponding rule was applied to noun stimuli. The mean frequency of the verb targets was 156 per million (range: 1–1264) and the noun targets was 147.4 (range: 1–717). All except two verbs and three nouns were composed of one syllable. Single word targets, with frequency data, are listed in Appendix A.

Verbs were classified according to the number of argument(s) associated with the verb (12 one-place, two-place, and three-place verbs, respectively) in order to examine the effect of the number of arguments on verb naming. One-place verbs need only an external argument which is the subject of the sentence. Only unergative verbs, which theoretically do not have an internal argument (Perlmutter, 1978), were selected. Two- and three-place verbs included verbs taking one and two internal argument(s), regardless of the optionality of the argument(s). This decision was made because the optionality of a verb's argument did not influence agrammatic aphasic patients' verb retrieval in a previous study (Kim & Thompson, 2000). Despite the effort to match the frequency of verbs between types, the mean frequency of the three-place verbs was higher than that of the other two verb types, due to the limited number of picturable three-place verbs which matched the cumulative frequency of the noun targets. Based on Francis and Kucera's (1982) word frequency norm, the frequencies of verbs were as follows: one-place verbs, $M = 92$; two-place verbs, $M = 84.5$; three-place verbs, $M = 291.5$.

Picture stimuli (5×7 in. black and white line drawings) were developed for each stimulus. Normed pictures from Snodgrass and Vanderwart (1980) were used for all nouns. Verb pictures were artist-drawn. The picture stimuli elicited correct responses from all normal subjects, and most of the targets were the first response to the corresponding picture.

The comprehension tasks were picture—written word matching tasks. They used the same 36 noun and verb targets as the corresponding naming tasks, and involved presentation of a picture target and written labels of the target and three distractors—semantic, phonological, and unrelated—on a sheet of paper. The position of the target word was randomized on each comprehension trial.

Sentence completion task. A sentence completion task was developed to examine the effect of semantic complexity on verb retrieval. Verbs were categorized as simple or complex based on the level of elaboration in their semantic representations (e.g., Pinker, 1989). Simple verbs included both light verbs such as *go* and general verbs such as *clean*, whereas complex verbs included heavy verbs such as *run* and specific verbs such as *scrub*, thereby allowing contrasts between light vs. heavy verbs (e.g., *go* vs. *run*) and general vs. specific verbs (e.g., *clean* vs. *scrub*), as in Breedin et al.'s study (1998). While both pairs contrast simpler with more complex verbs, a pre-determined listing of light verbs (e.g., *come*, *do*, *get*, *give*, *go*, *have*, *make*, *move*, *put*, and *take* in this study), agreed upon by theorists (e.g., Jespersen, 1965; Pinker, 1989), was used. Light verbs are distinguished in that they are thought to be transitional cases between open and closed class words (Pinker, 1989) and often serve as the core primitive in more complex verbs' semantic representations. On the other hand, the general vs. specific contrast is a relative judgment between two given verbs, and general verbs do not have the characteristics of light verbs.

Thirty-four simple vs. complex verb pairs were selected. Ten well-educated ($M = 18$ years) native English speakers from the Northwestern University Department of Communication Sciences and Disorders and North Park University (8 females and 2 males with a mean age of 40.8 years) participated in developing the verb stimuli. These individuals were provided a test booklet in which 34 verb pairs were listed (e.g., *take–grab*). A computer program randomized the order of presentation for all verb pairs, while guaranteeing that in half of the pairs the simple verb preceded the complex one (with the reverse order for the remaining pairs). The first two pages of the test booklet briefly explained the concept of semantic complexity, with two examples of contrasts between simple and complex verbs, along with the corresponding tree structure diagrams. Subjects were required to decide which verb of the pair was more complex and which was simpler and write their response below each verb.

Analysis of the data showed high agreement among subjects. Four verb pairs were deleted from the stimulus set, leaving 15 light–heavy verb pairs and 15 general-specific verb pairs, all of which had at least 90% agreement among these subjects. Some simple verbs appeared in more than one pair of contrasts, but items were limited to a maximum of three appearances in the entire stimulus set. All but six verbs (two simple and four complex) were composed of one syllable.

The frequency of usage of verbs in each pair appears in Appendix B. Eighty percent of the target verbs had a noun usage less than 25% of the total (noun + verb) usage. Although every effort was made to do so, the frequencies between the simple and complex verbs could not be closely matched because light verbs in the simple verb category (e.g., *make*, *do*, *get*) are the most frequently occurring verbs in English. The effect of frequency on both groups' performance is considered in Section 4.

Sixty sentence stimuli were created, using the 30 pairs of simple–complex verbs. Two sentences with the same subject-argument, but a different object-argument or locative PP, were paired with each member of the verb pair (e.g., The mother is making/baking *cookies*. – The mother is making/baking *a cake*.) The noun arguments were selected to provide a plausible context for both members of the contrastive pair. Verb pairs were chosen so that both verbs fit in the sentence frame equally well and required the same number of arguments in the given context. The first sentence was used as a model, while the second sentence was used to elicit the verb and the object–noun, locative PP, or both. A list of sentence stimuli is included in Appendix C.

Picture stimuli (8 in. × 11.5 in. black and white line drawings) depicting the action/event described in each sentence, were developed. An example of a picture/sentence pair used in the task is included in Appendix D. Ratings for picture stimuli were obtained from the normal subjects at the end of their participation in the study. They rated how well each verb fit into the sentence and picture context, on a 0–10 point scale: 0 indicated that the verb 'did not fit into the context at all,' and 10 indicated that the verb 'fit the context perfectly well.' The overall mean rating of all picture stimuli was 9.26 ($SD = 0.89$), indicating that the verbs used in the task corresponded with the linguistic and pictorial contexts well.

Grammaticality judgment. A grammaticality judgment task was constructed to investigate subjects' abilities to parse sentence stimuli and detect grammatical violations involving verb argument structure requirements. All the sentence stimuli were simple, canonical sentences, and the only type of grammatical violation was that of subcategorization. Forty-four sentences, which showed 100% accuracy in correct judgment by the normal group, were selected. Sentences contained verbs with different numbers of obligatory arguments: obligatory one-place (Ob1), obligatory two-place (Ob2), and obligatory three-place (Ob3) verbs. Half of the sentences were grammatical and the remaining half were ungrammatical. Of 22 grammatical sentences, 11 sentences were constructed using the basic argument structure for each type of verbs (i.e., Ob1: agent + verb; Ob2: agent + verb + theme; Ob3: agent + verb + theme + goal). The remaining 11 grammatical sentences were constructed using the basic argument structure + an adjunct (e.g., Ob1: agent + verb + locative adjunct phrase such as *The dog is barking in the house*.)

Twelve ungrammatical sentences were constructed by deleting one or two obligatory arguments (e.g., Ob3: agent + verb + theme such as in **The man is putting the dollar.*). Ten ungrammatical sentences were constructed by adding an illegal argument (e.g., Ob1: agent + verb + theme such as in **The dog is barking the girl.*). A listing of sentence stimuli by grammaticality and verb type is included in Appendix E. All sentence stimuli were recorded by a native English speaker (with standard American dialect).

Narrative elicitation. Narrative samples were collected by asking subjects to tell the story of Cinderella after reviewing a picture book detailing the story. All the words in the book were deleted. A standard script was developed for the examiner to give subjects a brief synopsis of the story, while the subject looked at the picture book. This was because pilot PrAD subjects either did not remember the story or claimed that they had not previously heard the story. This script was used for both aphasic and PrAD groups.

2.2.2. Procedures

Testing was completed in two to three sessions for all subjects except one agrammatic subject, who required five sessions due to his expressive impairment and fatigue. Testing sessions were held at least a week apart. The order of presentation of target items within a task was randomized and held the same for all subjects.

Since both comprehension and production tests employed the same targets, task blocking was used, to ensure that no stimulus was elicited more than once in a single session, using split-halves (odd vs. even numbered items) of the noun or verb list. Similarly, because the same pictures were used for both verbs in a simple–complex pair (e.g., The mother is making/baking a cake.), the stimuli for the sentence completion task were divided into two sets. Only one of the sentences was elicited in a single session. The order of presentation of the tasks was counterbalanced between the two sets of sentence completion stimuli, between the noun and verb classes, between the odd and even numbered items, and between the naming and comprehension tasks. Narratives were always collected at the end of the first session.

For all tasks, at least two practice items were used to establish that subjects understood the task. No feedback on the accuracy of their responses was provided during testing. Self-correction occurring within the given time frame was accepted.

2.2.2.1. Naming and comprehension. For the naming tests, pictures were randomized within word class blocks, with the nouns presented separately from the verbs. For verb naming, pictures of the verb target were presented one at a time and the subject was instructed to "tell me what action that is." If the subject did not appear to understand the instruction, it was rephrased as "tell me what he/she does." No attempt was made to elicit a particular form of the verb. For noun naming, the subject was instructed to "tell me what object this is." For both verb and noun naming, the subject was given 20 s to respond. If the subject produced a plausible but non-target response (e.g., *take the pie out of the oven* for *bake*), they were cued to "tell me another word for the picture," and were allowed two more attempts. If the subject produced a sequence of more than one response, the response indicated by the subject as the final response or given following the prompt ("Give me only one word for it.") was used for scoring. Semantically appropriate responses for the target verb (e.g., production of *hand* instead of *give*) and responses that were approximate synonyms of the target noun (e.g., *stove* for *oven*) were accepted as correct responses.

For comprehension, subjects were instructed to "show me the word that matches the picture." When a subject pointed to more than one word choice without indicating which was their final choice, the examiner cued the subject to "read all four words and point to one of the words that matches the picture." Subjects were given 10 s to respond.

2.2.2.2. Sentence completion. Subjects' production of simple vs. complex verbs was tested in a sentence completion task using a delayed model procedure and picture stimuli. This procedure was chosen so as to constrain production of the novel sentence (i.e., not repetition), and also to keep PrAD subjects' responses as coherent as possible.

The test was administered in the following manner. The first picture (e.g., a picture showing the maid cleaning/scrubbing the bathtub) of a pair was presented and the examiner described the picture using one of the target verbs, such as *clean*, in a sentence. The examiner then covered the first picture and presented a 15 s standard script, saying, "Now I'm going to show you another picture in which the same person is doing exactly the same action. I want you to make a sentence which is similar to the one I gave you in terms of its length and complexity. Here's the picture." The examiner then presented the second picture (e.g., a picture showing the maid cleaning/scrubbing the sink), while providing the subject-argument as a prompt (e.g., "In this picture, the maid is _."). The subject was expected to complete the sentence (e.g., "cleaning the sink."). Only one of the given verb pair was elicited in a single session. That is, if a complex verb of the pair was elicited in one session, the simple verb of the pair was elicited in another session, using the same picture stimuli. A computer program randomized the order of presentation, while maintaining an equal number of simple and complex verbs for each set of verb stimuli used in each session.

Subjects were not specifically instructed to use the same verb provided by the examiner for the first picture of the pair. This decision was made because pilot testing in which subjects were instructed to use the same verb resulted in aphasic subjects rehearsing the verb until the second picture was presented. However, the use of the target verb was covertly encouraged in two ways: by modeling the use of the target verb in feedback during practice trials, and by stating that the person is 'doing exactly the same action' in the second picture. The fact that normal subjects produced the target verb 89.3% of the time, although they were not specifically instructed to do so, was thought to validate the procedure. After completing the practice trials, the test began. During testing, whenever a subject failed to follow the instructions or did not appear to understand the task, the examiner again presented the two practice items and demonstrated the appropriate response required of the subject.

Responses were tape-recorded and transcribed verbatim for scoring. The number of the target verbs produced was counted, regardless of the completeness of the utterance. For PrAD subjects, the first response containing a verb relevant to the context of the target was used for scoring. This decision was made because some PrAD subjects produced a series of sentences, despite the instructions. For example, for the target verb *sell*, a PrAD subject said, "He is smiling, I guess he's happy. He must have sold that woman something." In this case, the verb *sell* was used for scoring.

Errors made by each subject were classified into four different categories. Responses that contained no verb was put into the 'No verb' category. A verb that was semantically richer than the target verb was put into the 'Complex substitution' category (e.g., *to sip* for *to drink*). A verb that was semantically simpler than the target verb was classified as a 'Simple substitution' (e.g., *to clean* for *to scrub*). Some verbs were unrelated to the target semantically or related but thought to be equivalent to the target in terms of semantic complexity (e.g., *to slice* for *to chop*). These responses were put into the 'Alternative' category. Subjects' error responses were independently classified by the examiner and by a linguist who was blind to the design of the study. The item-to-item agreement on error classification between the two judges was 96.4%.

2.2.2.3. Grammaticality judgment. Sentence stimuli were presented auditorily. Instructions accompanying the task were read by the examiner at the beginning: "You are going to listen to some sentences. I want you to tell me if each sentence is grammatical or not by pointing to one of the cards. As you can see, the card with the smiling face says 'good' meaning 'good grammar' and the one with the frowning face says 'bad' meaning 'bad grammar'." After listening to each sentence, the subject indicated whether it was a good or a bad sentence. Four practice items—two grammatical and two ungrammatical—were presented. Feedback on the accuracy of subject's response was provided during the practice trials. When requested by the subject, the recorded sentence was repeated up to two times. Subjects were given 10 s to respond.

2.2.2.4. Narrative task. During the narrative task, the subject was allowed to look at the picture book. For agramatic aphasic subjects, this helped to insure the production of a sample of adequate length. For PrAD subjects, this was expected to improve the relevance and coherence of their narratives. The normal narrative subjects were allowed to look at the picture book before and during their telling of the story, but the examiner did not provide any part of the story for these subjects. Otherwise, the procedure for collecting and analyzing the narratives were the same for all three groups.

The language samples were tape-recorded, transcribed, and analyzed by the examiner, using a method developed by Thompson et al. (1995). In this method, the entire sample was used for analysis. False starts, revisions, perseverations, repetitions, meaningless fillers were mazed and excluded from the analysis. Verbs were coded by type (i.e., one-place, two-place, three-place, copula, and complement verbs). The percentage of one-, two-, and three-place verbs produced with correct argument structure as well as the overall proportion of verbs produced with correct argument structure were computed.

For lexical-semantic analysis, the proportion of light vs. heavy verbs in the subjects' narratives was computed. All lexical verbs were included, except verbs used as auxiliaries (e.g., the verb *is* and *do* as in *She is cleaning* and *don't*), semi-auxiliary elements (e.g., *gonna*, *wanna*, *got to*), and formulaic uses (e.g., *Excuse me*, *Thank you*). In the present study, the verbs *be*, *come*, *do*, *get*, *give*, *go*, *have*, *make*, *move*, *put*, and *take* were coded as light verbs, based on the discussion in Pinker (1989), Jespersen (1965), and Breedin et al. (1998). All other lexical verbs were coded as heavy verbs.

2.2.3. Reliability

An independent judge, a graduate student in Communication Sciences and Disorders, scored subject responses on-line for 30% of all experimental tasks. Point-to-point agreement between the scores of the primary examiner and the independent judge was 99.6%. An independent transcriber transcribed 20% of the narrative samples. The transcription agreement, calculated between the examiner and the independent transcriber, showed 98.2% agreement. An independent coder also coded 20% of the narrative samples. The overall agreement between the examiner and the independent coder was 96.3%. Both the transcriber and the coder were graduate students in Communication Sciences and Disorders, with training in transcribing and coding narratives using Thompson et al.'s method.

2.2.4. Data analysis

In the following analyses, the raw data consisted of scores expressed in percentages (i.e.,% accuracy, % error). Prior to statistical analysis, each variable was tested for normality of the distribution of scores by performing the Lilliefors test (Lilliefors, 1967). When the scores were determined not to be normally distributed, an appropriate non-parametric test was used for analysis. Otherwise, a t test or an ANOVA was used. For all statistical tests, the α level was set at $p < .05$.

3. Results

3.1. Naming and comprehension of nouns and verbs

Data from single word naming and comprehension tasks were analyzed using Wilcoxon signed ranks tests, in order to verify the presence of a verb deficit in the subject groups. As shown in Table 4, both aphasic and PrAD subjects named nouns significantly better than verbs (aphasic, $T^+(N = 9) = 43.5$, $p = .009$; PrAD, $T^+(N = 14) = 101$, $p = .0008$). While aphasic subjects also comprehended nouns significantly better than verbs ($T^+(N = 6) = 21$, $p = .03$), the difference was not significant in the PrAD group ($T^+(N = 8) = 25.5$, $p = .34$). Within the verb class, both groups' comprehension was significantly better than their naming (aphasic, $T^+(N = 9) = 45$, $p = .004$; PrAD, $T^+(N = 14) = 93.5$,

Table 4
The mean percentage correct naming and comprehension of nouns and verbs for aphasic and PrAD groups

	Group			
	Aphasic ($N = 9$)		PrAD ($N = 14$)	
	Noun	Verb	Noun	Verb
Naming	89.8	76.5	96.6	87.1
Comprehension	97.2	93.8	97.8	94.8

$p = .007$). In both groups, noun comprehension was not different from noun naming (aphasic, $T^{+}(N = 7) = 22.5$, $p = .18$; PrAD, $T^{+}(N = 12) = 52$, $p = .33$). Thus, verb naming was the most impaired among the four tasks in both the aphasic and PrAD groups.

The naming abilities of the two groups were compared using Kolmogorov–Smirnov two-sample tests. Although the aphasic group's performance appeared to be more impaired than that of the PrAD group, the difference in their verb naming failed to reach statistical significance ($D_{9,14} = .38$, $p = .34$). Neither did the two groups differ in their noun naming ($D_{9,14} = .22$, $p = .91$), their noun comprehension ($D_{9.14} = .33$, $p = .53$) nor their verb comprehension ($D_{9,14} = .20$, $p = .95$).

3.2. Verb production by argument structure feature

Data from the verb naming and narrative tasks were analyzed to examine the effect of the number of arguments entailed within the verbs' representation on verb retrieval and processing in the two groups.

3.2.1. Verb naming by type

Fig. 2 shows the effects of verb type (one-place vs. two-place vs. three-place) on verb naming. Aphasic subjects' verb naming was increasingly worse as the number of arguments associated with the verb increased. The results of the Wilcoxon signed ranks tests revealed that the difference between the one-place and the three-place verbs was significant ($T^{+}(N = 7) = 28$, $p = .015$) while the difference between the one-place and two-place verbs ($T^{+}(N = 6) = 9.5$, $p = .078$) and between the two-place and the three-place verbs ($T^{+}(N = 7) = 16$, $p = .81$) did not reach significance. On the other hand, PrAD subjects showed more difficulty naming two-place verbs than other verb types. In this group, the difference between the one-place and two-place verbs was significant ($T^{+}(N = 11) = 60$, $p = .013$) whereas the differences between the one-place and three-place verbs ($T^{+}(N = 10) = 44$, $p = .10$) and two-place and three-pace verbs ($T^{-}(N = 12) = 61$, $p = .09$) was not.

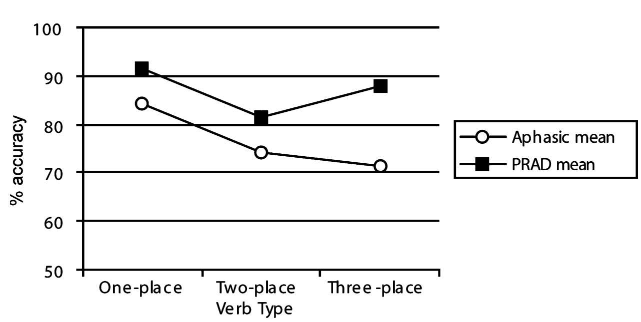

Fig. 2. Mean percent accuracy of verb naming by syntactic type.

3.2.2. Verb production by type in narratives

The proportion of verbs produced with correct argument structure for aphasic, PrAD, and normal subjects is shown in Fig. 3. Aphasic subject MK's data were deleted from all the narrative data analyses, because he produced only one verb, which did not allow for meaningful comparison of the proportion of different verb types. Since the data met the normality requirements, differences between verb types were analyzed using a series of repeated-measure analyses of variance (ANOVA) calculations.[1]

Results of the analysis showed no significant differences between the percentage of correctly produced one-, two-, and three-place verbs in the normal group. However, both aphasic and PrAD groups showed significant differences between the percent correct use of the three types of verbs ([$F(2, 14) = 5.92$, $p = .014$] for the aphasic group; [$F(2, 26) = 4.88$, $p = .016$] for the PrAD group). Results of the pairwise comparisons of mean differences showed that the aphasic group produced one-place verbs with correct argument structure significantly more often than the other verb types ($p = .041$ for comparison between one- and two-place verbs; $p = .009$ for comparison between one- and three-place verbs). The difference between the two- and three-place verbs was not significant. For the PrAD group, the difference was significant only between the one- and three-place verbs ($p = .007$).

3.3. Grammaticality judgment

Both aphasic and PrAD subjects performed relatively well on the grammaticality judgment task (aphasic group, $M = 92.1\%$; PrAD group, $M = 94.3\%$). Wilcoxon signed ranks tests were performed to determine whether the type of sentence (grammatical vs. ungrammatical) influenced subjects' performance. In both groups, sentence type did not influence subjects' performance on the task (aphasic, $T^{-}(N = 6) = 15$, $p = .43$; PrAD, $T^{-}(N = 9) = 31.5$, $p = .33$).

[1] To examine the effect of age and education on subjects' performance, both an ANOVA and an ANCOVA were performed on the data. Since the results of the ANOVA and ANCOVA were identical, it was determined that the differences in the age and education level of the groups did not influence the findings of the study.

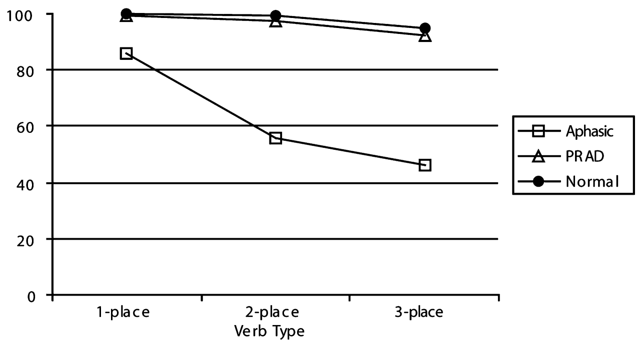

Fig. 3. Mean percent correct production of verbs by syntactic type in the narrative task.

3.4. Production of semantically simple and complex verbs

Data from the sentence completion and narrative tasks were analyzed in order to examine the effect of semantic complexity on verb production.

3.4.1. Verb production in sentence completion

As shown in Table 5, normal subjects produced the target verbs nearly 90% of the time, while aphasic and PrAD groups produced the target verbs only about half of the time. For the light vs. heavy verb contrast, all three groups showed a numerical advantage for producing heavy verbs (e.g., *bake*) as compared to light verbs (e.g., *make*). The difference was significant in the normal group ($T^{-}(N = 8) = 34$, $p = .02$). For the general (e.g., *clean*) vs. specific (e.g., *scrub*) verb contrast, the PrAD group produced general verbs significantly better than specific verbs ($T^{+}(N = 13) = 87$, $p = .0018$). On the contrary, both the aphasic and the normal groups showed a numerical advantage for producing specific verbs as compared to general verbs. This difference was significant in the aphasic group ($T^{-}(N = 7) = 27$, $p = .031$).

Table 5
Mean percentage correct production of verbs in the sentence completion task

Verb type	Group		
	Aphasic	PrAD	Normal
Light ($N = 15$)	42.9	39.5	84
Heavy ($N = 15$)	49.6	41.9	92.6
General ($N = 15$)	45.9	53.8	89.3
Specific ($N = 15$)	63.7	32.8	91.3
Total simple[a] ($N = 30$)	44.4	46.4	86.6
Total complex[a] ($N = 30$)	60.3	37.6	92
Overall total ($N = 60$)	52.4	42.0	89.3

[a] Simple verb = light + general verbs; complex verb = heavy + specific verbs.

3.4.1.1. Error data analysis: Substitution patterns.

The types of errors subjects made, when they failed to produce the target verb, were examined. As indicated by Table 6, 22% of aphasic subjects' errors consisted of the lack of a verb in their sentences ('No verb'), while normal and PrAD subjects did not make such errors. Both aphasic and PrAD subjects produced a greater proportion of 'Alternative' verb errors (e.g., production of *to leave* for *to give*) than the normal group.

Only looking at 'Simple' and 'Complex' errors, the three groups showed different patterns. Both the aphasic and normal groups produced more Complex substitution errors (e.g., *bake* for *make*), although the differences did not reach statistical significance ($T^{-}(N = 7) = 23.5$, $p = .13$ for the aphasic group; $T^{-}(N = 7) = 21$, $p = .29$ for the normal group). On the other hand, the PrAD group produced significantly more Simple substitution errors (e.g., *make* for *bake*) than Complex substitution errors ($T^{+}(N = 14) = 87$, $p = .02$).

3.4.1.2. Semantic complexity and extraneous variables.

To be able to conclude that semantic complexity accounts for the observed differences in the subjects' verb retrieval, the potential influence of other variables was examined. The frequency of verbs was one such variable, since the frequency of verbs between different semantic types could not be matched. In addition, it was possible that both verbs in each pair may not have fit the sentence and pictorial context equally well. Thus, subjects' verb retrieval was correlated with these two measures: lemma frequency (per million obtained using the Celex Lexical Database, 1993) of each verb and the ratings of the verb (i.e., how well each verb fits into the sentence and picture context) obtained from the normal subjects.

Twenty-eight out of 33 subjects (i.e., 9 aphasic, 10 normal, and 14 PrAD subjects) showed a negative correlation between correct responses and verb frequency, i.e., better naming of low frequency verbs and poorer naming of high frequency verbs. Five of these correlations were statistically significant ($p < .05$), with the correlation coefficient r ranging from $-.26$ to $-.41$ (correspondingly, coefficient of determination r^2 ranging from .06 to .16). The remaining subjects showed a nonsignificant positive correlation between correct responses and verb frequency.

Table 6
Mean percentage of errors by type produced in the sentence completion task

Group	Error type			
	Simple	Complex	Alternative	No verb
Aphasic	14.37	21.70	42.14	21.79
Normal	26.5	40.6	32.8	0
PrAD	30.78	20.97	48.25	0

Correlational analysis between ratings received for the picture stimuli and verb naming showed that 26 out of 33 subjects showed a non-significant correlation between verb rating and correct responses. Seven subjects showed a significant correlation. The correlation coefficient r for these significant correlations ranged from .26 to .30 (correspondingly, coefficient of determination r^2 ranged from .06 to .09). The correlation coefficient of one PrAD subject was .50 (i.e., $r^2 = .25$).[2] These data indicate that neither verb frequency or picture context had any measurable influence on most subjects' performance in sentence completion.

3.5. Heavy vs. light verb production in narratives

The proportion of light and heavy verbs in each subject's narrative was computed and the group mean was calculated. Percentages were used for comparison, because groups differed in the number of total verbs produced (agrammatic total = 275; PrAD total = 658; normal narrative total = 909). A 2×3 ANOVA was performed with the Group as the between-subject factor.

As shown in Fig. 4, overall, a significantly greater proportion of heavy verbs were produced than light verbs (main effect for Verb Type [$F(1,58) = 38.47$, $p < .000$]). However, the groups differed in the relative proportion of light and heavy verbs produced in their narratives (interaction effect for Group × Verb Type [$F(2,58) = 8.875$, $p < .000$]). A Tukey HSD test was performed to determine the source of the differences.

Results showed that both aphasic and normal narrative groups produced a significantly greater proportion of heavy verbs than light verbs ($p < .000$ for the aphasic group; $p = .031$ for the normal narrative group). However, there was no significant difference between the proportion of heavy and light verbs in the PrAD group ($p = .924$). In addition, the aphasic group produced a significantly greater proportion of heavy verbs than the PrAD group ($p = .046$). Although the proportion of heavy verbs in the aphasic group was greater than that in the normal group, the difference was not significant ($p = .54$).

[2] In both sets of correlation analyses, the value of r^2 should be noted, since it is "not the correlation coefficient per se but the *square* of the correlation coefficient that informs us the 'goodness' of the linear rule for prediction" (Hays, 1994, p. 614). That is, the proportion of Y variance (i.e., correct response) accounted for by X (i.e., verb frequency and verb rating, respectively) is given by r^2, the coefficient of determination. Thus, if the value of a correlation coefficient is .30, only 9% of the variance in subjects' correct response is accounted for by the linear association between verb rating or verb frequency and correct response. Only the correlation coefficient of one subject in each analysis indicated that the extraneous variable under examination accounted for more than 10% of the variance in their correct responses.

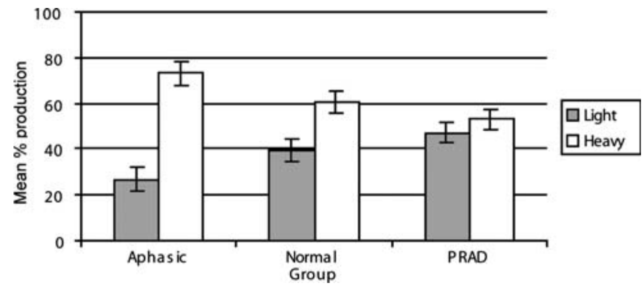

Fig. 4. Mean percent production (+SE) of light and heavy verbs in the narrative task.

Some researchers (e.g., Breedin et al., 1998) suggest that the copula could be a special case of a light verb ("the lightest of the light verbs"). A separate 2×3 ANOVA was performed, in which the copula *be* was excluded from the light verb count. When copulas were excluded, the proportion of heavy verbs was significantly greater than light verbs in all groups ($p < .000$ in all three groups). This suggests that copulas comprised a significant proportion of the light verbs in the PrAD group. However, the proportion of heavy verbs in the narrative of PrAD subjects was still significantly smaller than that of the agrammatic aphasic group ($p < .006$).

4. Discussion

Both PrAD and agrammatic aphasic subjects were impaired in verb production and, to a degree, processing of information associated with verbs. However, their overall performance patterns suggest that the underlying mechanism for the two groups' verb impairment differs.

Consistent with the results of previous studies (Kim & Thompson, 2000; Miceli, Silveri, Nocentini, & Caramazza, 1988; Zingeser & Berndt, 1990), our agrammatic aphasic subjects showed more difficulties naming verbs than nouns. In addition, their naming of verbs was worse than their comprehension. The dissociation between noun and verb classes was also observed in comprehension, even though comprehension of both classes was quite good. This pattern in comprehension was consistent with Miceli et al.'s results (1988), although it was at odds with the results of Berndt et al. (1997) and Kim and Thompson (2000). These conflicting findings point to the need for further research on this issue.

PrAD subjects' pattern of performance partially converged with the results of past studies. As reported by some recent studies (Robinson et al., 1996; White-Devine et al., 1996), PrAD subjects' verb naming was impaired. However, unlike the results of previous studies, PrAD subjects did not show impairment in noun naming. This result is likely due to the nouns utilized in the present study. Our nouns, unlike those used in previous naming studies with PrAD patients or the Boston Naming Test (BNT), consisted mainly of single syllable words with high familiarity (e.g., *grapes*). White-Devine et al. (1996) included multi-syllabic words with varying degrees of familiarity (e.g., *alligator*) and the Boston Naming Test includes both high (e.g., *bed*) and low frequency items (e.g., *abacus*). Because 11 out of 14 of our patients evinced naming deficit on the BNT, we interpret their noun naming data with caution.

Within the class of verbs, qualitative differences were noted between the two patient groups. Whereas the number of arguments associated with the verb influenced aphasic subjects' verb retrieval in a systematic way, PrAD subjects' verb naming did not show this hierarchy in production. Aphasic subjects retrieved one-place verbs better than two-place verbs, and two-place verbs better than three-place verbs. Thus, the more arguments associated with the verb, the more difficulties aphasic subjects appeared to have in producing the verb. Although some of the differences did not reach statistical significance possibly due to the small number of items, the hierarchy of verb difficulty noted replicated previous findings of Kim and Thompson (2000), Thompson (2003), and Thompson et al. (1997). This replication of previous findings provides further evidence to their claim that the number of arguments associated with verbs influences verb production in agrammatism.

Interestingly, the same pattern emerged in their narrative production as previously noted in Thompson et al. (1997). Examination of subjects' production of verbs with correct argument structure indicated that agrammatic aphasic subjects' argument structure production in narratives revealed the same pattern seen in their verb naming. As the number of arguments associated with a verb increased, agrammatic aphasic subjects showed more difficulty producing the correct argument structure associated with the verb.

On the other hand, PrAD subjects' verb naming did not show a hierarchy based on the number of arguments. As in the aphasic group, they named one-place verbs better than the other verb types. However, their pattern diverged from that of aphasic subjects in that they named three-place verbs better than two-place verbs. A frequency effect does not explain this pattern because the three-place verbs were higher in frequency than the one-place verbs. These data suggest that PrAD subjects' performance is consistent with the general prediction of the present study—i.e., that the syntactic feature of verbs does not have a systematic influence on their verb naming.

The PrAD patients also did not show a strong hierarchy effect in their narratives. Whereas aphasic subjects' performance decreased from 86% correct for one-place verbs to 46% correct production of arguments for three-place verbs, both the normal and the PrAD groups' production of correct arguments was above 90% for all types of verbs. Thus, while it is possible that verbs with more arguments pose a greater challenge for both normal and neurologically damaged individuals when constructing sentences, the data suggest that this difficulty is exacerbated in agrammatism.

In contrast to verb production, both agrammatic aphasic and PrAD subjects performed above the 90% level in the grammaticality judgment task, indicating generally well-preserved ability to detect syntactic errors associated with verb argument structure. The agrammatic performance pattern was consistent with the predictions generated based on Kim and Thompson (2000)'s study. PrAD subjects were also expected to perform well, since they were assumed to have no syntactic deficit.

To summarize, the number of syntactic arguments in the verb entry consistently influenced aphasic subjects', but not PrAD subjects' verb retrieval, as predicted. In contrast, the findings of the present study show that PrAD patients' verb deficits can be accounted for based on the semantic complexity of verbs. Unlike the aphasic and normal subjects who produced more complex verbs as compared to simple verbs, PrAD subjects showed superior production of general over specific verbs. Furthermore, examination of the error data showed that the aphasic and normal groups tended to substitute semantically complex verbs for their simpler targets more frequently than vice versa. On the contrary, PrAD subjects substituted semantically simple verbs for their complex targets significantly more often than the reverse. In addition, each group's production of light and heavy verbs in their narratives agreed with the retrieval pattern observed in the sentence completion task.[3] Therefore, PrAD subjects' verb retrieval was abnormal, in that they seem to have difficulty in retrieving semantically more complex verbs in the sentence completion (i.e., specific verbs) and narrative tasks (i.e., heavy verbs). It is surprising, then, that their retrieval did not differ significantly between the light and heavy verbs in the sentence completion task. A satisfactory accounting of PrAD subjects' verb retrieval in these tasks should be able to explain this somewhat inconsistent pattern.

[3] One should note that the term 'heavy' verb was used in both the sentence completion and narrative tasks, even though the term referred to different sets of verbs in different tasks. While the heavy verbs in the sentence completion task were constrained to a set of verbs, each of which was contrasted to a light verb, the heavy verbs in the narratives included any verb that was not light, allowing for a wide range of semantic complexity among the heavy verbs. Despite the broad classification of heavy verbs in narratives, the PrAD group's production of light and heavy verbs was comparable, while aphasic and normal narrative groups produced more heavy verbs than light verbs.

These data partially replicated Breedin et al.'s (1998) results with the aphasic subjects. Although the magnitude of the effect was slightly different in different pairs contrasted (i.e., light vs. heavy, general vs. specific) between the two studies, the direction of retrieval advantage and the substitution patterns were similar in the two studies. The present findings affirm the robustness of the semantic complexity effect in verb retrieval in non-fluent aphasic patients, in that the two studies obtained the same results, despite the differences in stimuli, nature of tasks, and the severity and specific type of aphasic subjects' language impairment. However, our normal subjects also showed the same pattern of performance. The implication of this finding will be discussed later.

To arrive at the most likely explanation for this pattern, several different possibilities were considered. The potential effect of the word frequency was ruled out since 85% of the subjects showed a negative correlation between word frequency and correct responses, and the strength of association between the two variables was non-significant for most subjects. Another possibility relates to the context-specificity of the targets. Simple verbs (e.g., light verbs) can occur in many different contexts (e.g., *make a cake*, *make a pie*, *make a mess*, *make a dress*, *make headlines*, *make ready*, and *make trouble*). On the other hand, more complex verbs tend to be constrained in terms of the contexts in which they can occur (e.g., *bake a cake*, *bake a pie*, **bake a mess*, **bake a dress*, and **bake headlines*). The difference in context-specificity can be problematic in two ways. First, the stimuli could be biased in how well the context accommodates simple vs. complex verbs. However, our data showing no correlation between context ratings (provided by normal subjects) and correct responses suggest that context did not play a role. The strong one-to-few association between a specific verb and its arguments as compared to the weak, one-to-many associations between a simple verb and its arguments also could have made it easier to reactivate the more complex, specific verb than the simpler, more general verb, when a specific NP (e.g., such as *cake* for *make* vs. *bake*) was provided. This is especially a problem if the task relies heavily on short-term memory function. The present study attempted to circumvent this second problem by reinforcing the production aspect of the task, using a delayed model and introducing a new NP argument in the target sentences. In addition, the fact that our subjects' performance pattern was consistent even in their substitution errors and narratives, in which short-term memory would have played no significant role, indicates that this factor could be ruled out.

An alternative explanation involves the potential advantage of activation for verbs with richer semantic representations. In a connectionist network developed for simulating deep dyslexic reading difficulties, Plaut and Shallice (1993) examined the reading of concrete vs. abstract nouns. In their model, the semantic representations of concrete nouns were richer than those of abstract nouns. The network's learning behavior indicated that a greater number of active semantic features for a noun leads to stronger activation of the target word. A similar effect could be expected when retrieving a verb with a richer semantic representation. In such a network, the activation for lexical retrieval may be greater for verbs associated with more semantic features than for verbs with fewer semantic features in their representations. This account is speculative, since the present study was not designed to explore retrieval patterns in relation to the connectionist model. However, it is a plausible hypothesis and further research is warranted to investigate this possibility.

To summarize, the verb retrieval pattern of our aphasic subjects is consistent with a decompositional view of verb representation, along with Breedin et al.'s results. However, our interpretation differs from Breedin et al. to a degree. While Breedin et al. attributed this complexity effect to the aphasic subjects' verb deficit, we believe that this is a normal pattern, since normal subjects in the present study showed a similar performance pattern to the aphasic group in both the sentence completion and the narrative task. Verbs with more elaborate semantic representation may be easier to retrieve, from a connectionist point of view, than simple verbs. In turn, both agrammatic aphasic and normal subjects with relatively preserved semantic systems may benefit from the enriched semantic representation of such verbs.

A different explanation is offered to account for the PrAD subjects' notable semantic complexity effect. We postulate a 'bottom-up breakdown of verb lexicon' hypothesis, in order to explain the somewhat inconsistent performance pattern of these subjects across tasks examining the semantic complexity effect.

Fig. 5 shows a tree diagram which schematically represents a hypothetical taxonomic organization around the target verb *clean*. In keeping with Miller and Fellbaum's analysis (1991), verb taxonomies tend to form a rather shallow, bushy structure with a hierarchy of only three levels, like that in the figure. The verb on the top level of the diagram is analogous to a superordinate category in a noun taxonomy. In the same manner, the verbs in the middle level are analogous to basic level items, and the bottom level to subordinate level items. Some potential semantic features associated with the subordinate level verb *scrub* are given at the bottom of the diagram. The top level contains light verbs, such as *do*. The sets of heavy and general verbs, such as *wash* and *clean*, used in the sentence completion task are represented at the intermediate level, indicating

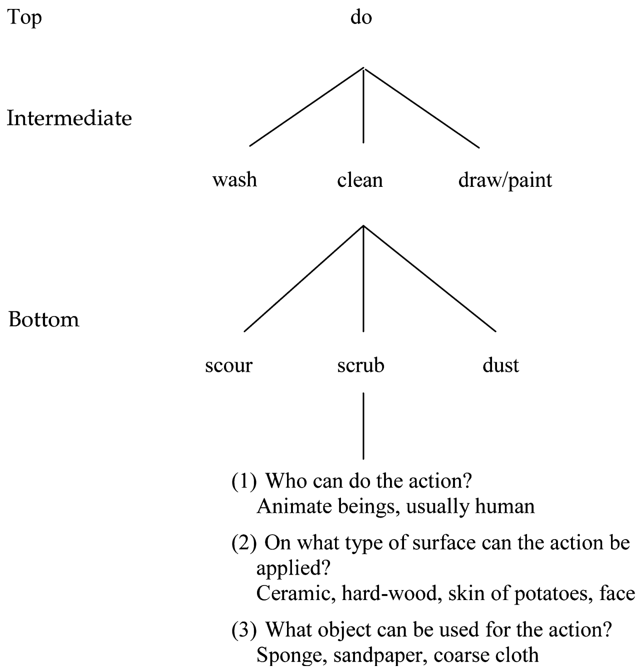

Fig. 5. A tree diagram showing the semantic representation of the verb *clean* and its superordinate and subordinate level.

a similar level of semantic elaboration. Verbs which are semantically most complex, such as the specific verb *scrub*, appear at the lowest level. A verb at the lowest level has many associated semantic features, some of which may be shared with verbs above or adjacent to it

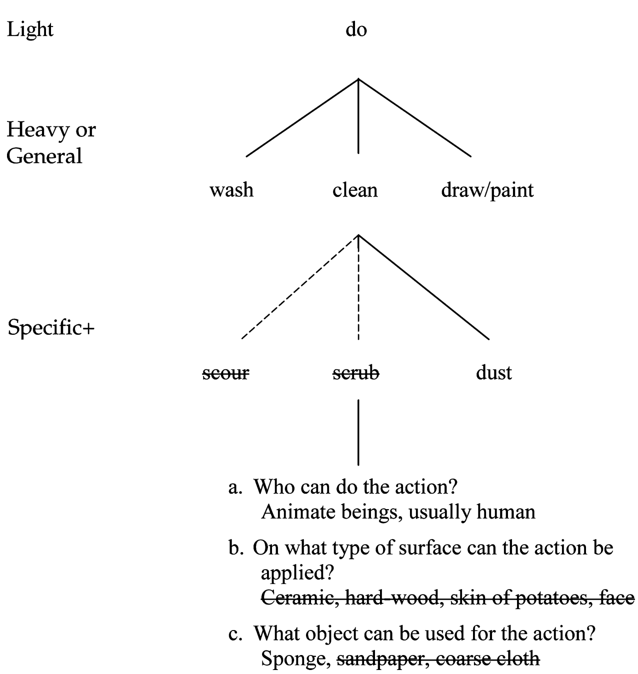

Fig. 6. A tree diagram showing the loss of semantic features associated with the verb *scrub* and hypothesized retrieval failure of the verb and its coordinates.

in the diagram. One should remember that with regard to the narrative task, everything below the top level would have been classified as heavy verbs.

Now, Fig. 6 displays a 'bottom-up breakdown of verb lexicon,' where we imagine that some of the semantic features associated with the verb *scrub* are degraded or lost. This might make it difficult for PrAD subjects to retrieve the verb during lexical access. If the activation over the target verb *scrub* does not reach the threshold level, another verb, which is associated in meaning to the target verb, such as *scour* or *clean*, and is therefore connected in the semantic network, may be activated instead. If *scour* is activated, the pattern is similar to the de-differentiation of exemplars within the superordinate category as reported in their breakdown of noun lexicon. If *clean* is retrieved, the pattern will look like the complexity effect observed in the present study.

This account of PrAD subjects' verb retrieval is economical in that it accommodates the entire pattern of retrieval in both the narrative and sentence completion tasks well. The 'bottom-up breakdown of verb lexicon' hypothesis predicts that PrAD subjects will show difficulties retrieving complex verbs. In general, when a more complex target verb is not available, they may retrieve a verb at a higher node with intact semantic features. This hypothesis can explain why PrAD subjects showed a strong retrieval advantage for general verbs over specific verbs in the sentence completion task. However, they would not necessarily show a retrieval advantage for light over heavy verbs, since a significant percentage of heavy verbs could still be available. This is what we found in their sentence completion data. Finally, this also explains why, in their narratives, they produced a greater proportion of light verbs than the other groups. If many verbs at the lower levels were not available, they would be forced to rely on verbs at the higher node with intact representations.

Some support for this hypothesis may be found in the verb use of children with specific language impairment (SLI). For example, Rice and Bode (1993) reported that children with SLI relied heavily on General All Purpose (GAP) verbs to fill the verb functions in their spontaneous speech. Verbs in this category tended to overlap significantly with the light verbs used in the present study. Rice and Bode also observed that children with SLI inappropriately used GAP verbs in place of a more specific verb required to fully convey the intended message (e.g., **Now put my name with it* when the target verb was *write*). The preponderance of these errors, as well as the heavy use of the GAP verbs in these children's speech, appears to suggest that the children with SLI may rely on GAP verbs to fill in when a more appropriate, specific verb is not available to them.

Even more relevant to the population under consideration, Breedin, Saffran, and Coslett (1994) reported that a patient with semantic dementia showed a disproportionate loss of perceptual features, not only for nouns but also for verbs. These findings from other language-impaired populations support the plausibility of the 'bottom-up breakdown of the verb lexicon' hypothesis proposed here. One should note that not only does this hypothesis explain the PrAD subjects' performance pattern with economy, but it also is consistent with the well-supported breakdown pattern of their noun lexicon (Hodges et al., 1992; Martin & Fedio, 1983; Schwartz et al., 1979; Smith et al., 1989). Although it is only speculative at this stage, the explanatory power of this hypothesis makes it an attractive alternative, and it may advance understanding of PrAD subjects' verb deficits.

5. Conclusions

The present study examined the presence and nature of a verb deficit in PrAD patients by investigating factors influencing their verb retrieval and their use of verb knowledge in sentence processing, by comparing their performance to agrammatic aphasic and normal subjects. Results of the study showed that both agrammatic and PrAD subjects evinced clear patterns of performance, corresponding with our predictions. As expected, agrammatic aphasic subjects' pattern of performance suggested that their verb deficits are largely restricted to the lexical-syntactic aspects of their verb lexicon. Conversely, PrAD subjects' overall performance pattern was consistent with the prediction that their verb deficit results from a breakdown in the lexical-semantic representation of the verb lexicon.

The present study makes several important contributions to our understanding of lexical organization and processing, in general, and PrAD and agrammatic aphasic patients' language, in particular. First, the study directly compared two different patient groups, providing methodologically sound evidence for a verb deficit in both groups. Moreover, it shows how a verb deficit can arise from disruption in different language components in the two groups, respectively. Although the selective impairment of semantic and syntactic abilities in patients with different neurological disorders has been used as a basis to argue for a modular view of the language (e.g., Kempler et al., 1987), these studies rarely involved both agrammatic aphasic and PrAD groups.

Second, the results of the present study have theoretical implications for aphasic subjects' language processing. The findings provide additional evidence supporting the claim of Kim and Thompson (2000) and Thompson et al. (1997) that the number of arguments associated with a verb systematically influences verb retrieval in agrammatism (i.e., the Argument Structure Complexity Hypothesis proposed by Thompson, 2003). This effect has also been shown in other languages such as Hungarian and German (De Bleser & Kauschke, 2000; Kiss, 2000).

Third, the findings are consistent with a decompositional view of verb representation. While previous studies (e.g., Roelofs, 1993) sought evidence by comparing the speed of processing semantically simple vs. complex verbs, the present study compared the rate of successful access. Since the decompositional view was developed to address issues of lexical organization/representation, not processing of such information, the latter is a more appropriate approach than the former. Whereas the previous studies failed, the present study successfully detected a complexity effect in aphasic subjects, first observed by Breedin et al. (1998), which extended to normal and PrAD subjects, as well. Because of the differences in stimuli, nature of the task, procedure, and population, this replication of results provides strong evidence for the robustness of the effect.

Finally, the discussion of PrAD subjects' lexical impairment has been limited to that of the noun class until recently. However, as reported in some recent studies (e.g., White-Devine et al., 1996), their lexical impairment appears to extend to that of the verb class. In addition, our findings suggest a 'bottom-up breakdown in PrAD subjects' verb lexicon,' paralleling the pattern of loss of semantic information in their noun lexicon. Degradation progresses from the specific features at the bottom of taxonomic hierarchies, to the basic level, and possibly to the superordinate level, at the top of the hierarchies.

The possibility that nouns and verbs may share the same process of degradation in the semantic system of a single patient group has not previously been suspected. It is likely that the difference in the lexical organization of nouns and verbs, and the different roles they play in sentences could have contributed to the way in which many researchers have conceptualized nouns and verbs separately, when investigating the preservation or disruption of different word classes. However, the findings of the present study point to the need to modify this framework and to explore word class effects from a language component or linguistic process-based point of view. That is, focusing on the language component involved in the processing of a given word class (e.g., semantics) instead of attempting to find a localized anatomical substrate for the word class may reveal important principles of lexical organization. The fact that PrAD subjects with primary posterior damage show a verb deficit, which often has been associated with anterior damage, lends further support for such approach.

Appendix A. Verb–noun stimuli

Verb	Frequency	% Noun usage	Noun	Frequency	% Verb usage
Ob1 ($n=12$)					
bark*	1	92.9	kite	1	0
crawl	37	9.8	belt	36	7.7
cry*	64	35.4	hat	71	0
jump	58	14.7	moon	63	1.6
laugh	89	19.8	box	82	4.7
pray	30	0	shirt	29	0
run	431	17.9	church	451	0
sit	314	0	door	348	0
sneeze	3	0	pear	8	0
snore	4	0	vest	4	0
swim	55	1.8	shoe	58	3.3
wink	18	18.2	axe	19	0
Ob2 ($n=7$)					
carry	304	0	foot	361	0.6
erase	5	0	carrot	5	0
pull	145	8.2	gun	142	1.4
spill	9	0	stool	8	0
stir	39	0	corn	38	0
weigh	33	0	boot	30	11.8
zip	2	0	goat	8	0
Op2 ($n=5$)					
climb	65	3.0	nose	65	3.0
ride	126	14.3	window	172	0
shave	23	0	bell	23	0
sweep	54	12.9	star	58	6.5
watch	209	12.9	arm*	217	21.9
Ob3 ($n=2$)					
give	1264	0.15	hand	717	6.8
put	513	0	house	662	7.4
Op3 ($n=10$)					
bake	15	0	rabbit	16	0
build	249	0.8	table	242	0.4
cut	245	14	heart	199	0
fry	143	3.4	glass	128	0
knit	18	11	grapes	10	0
pour	48	0	bus	42	0
read	274	0	book	292	2.3
sew	18	0	pie	19	0
throw	150	4.5	tree	160	0
write	561	0	eye	524	2.4
Mean (*SD*)	165.4 (264.5)			147.7 (181.1)	

Note. Two verb (bark, cry) targets and one noun (arm) target were used in the study, although their % usage for the other form class was >25%, because the meaning of the word is different when used as a noun and as a verb.

Appendix B. Verb pairs used in the sentence completion task

	Light	Frequency	Heavy	Frequency
Light vs. heavy verbs				
1.	come	1960	hurry	40
2.	do	4499	wash	93
3.	get	2381	buy	256
4.	give	1278	donate	4
5.	give	1278	sell	145
6.	go	2889	walk	309
7.	have	13,494	cherish	9
8.	make	2332	bake	24
9.	make	2332	build	242
10.	make	2332	mix	51
11.	move	427	roll	72
12.	put	804	drop	142
13.	put	804	throw	159
14.	take	1913	choose	179
15.	take	1913	grab	33
Mean		2709		117
	General	Frequency	Specific	Frequency
General vs. specific verbs				
1.	clean	60	dust	8
2.	clean	60	scrub	10
3.	cut	190	chop	19
4.	damage	37	smash	24
5.	drink	129	sip	16
6.	eat	289	lick	11
7.	fill	137	stuff	21
8.	follow	296	chase	20
9.	look	1347	glance	48
10.	look	1347	stare	121
11.	pull	186	drag	48
12.	say	4267	shout	84
13.	speak	371	whisper	14
14.	stitch	4	hem	0
15.	talk	510	argue	119
Mean		615		37

Appendix C. Sentence stimuli used in the sentence completion task light vs. heavy verbs

Light vs. heavy verbs

1. The policeman is coming/hurrying to the crime scene.
   The policeman is coming/hurrying to the accident scene.
2. The woman is doing/washing the laundry.
   The woman is doing/washing the dishes.
3. The man got/bought his wife a new car.
   The man got/bought his wife a present.

Appendix C. (*continued*)

4. The man is giving/donating the picture to the church.
   The man is giving/donating the money to the church.
5. The man gave/sold the ring to the woman.
   The man gave/sold the watch to the woman.
6. The girl is going/walking to the store.
   The girl is going/walking to the bus stop.
7. The lady has/cherishes her family photo.
   The lady has/cherishes her necklace.
8. The mother made/baked a cake.
   The mother made/baked cookies.
9. The boy is making/building a sandcastle.
   The boy is making/building a birdhouse.
10. The cook is making/mixing some lemonade.
    The cook is making/mixing some cakebatter.
11. The man is moving/rolling the rock.
    The man is moving/rolling the log.
12. The man is putting/dropping the letter in the mail chute.
    The man is putting/dropping the letter in the mailbox.
13. The man is putting/throwing the shirt in the hamper.
    The man is putting/throwing the sock in the hamper.
14. The boy is taking/choosing the red balloon.
    The boy is taking/choosing the blue balloon.
15. The boy is taking/grabbing the doll away from the girl.
    The boy is taking/grabbing the ball away from the girl.

General vs. specific verbs

16. The maid is cleaning/dusting the mantle.
    The maid is cleaning/dusting the coffee table.
17. The maid is cleaning/scrubbing the bathtub.
    The maid is cleaning/scrubbing the sink.
18. The chef is cutting/chopping the green pepper.
    The chef is cutting/chopping the onion.
19. The man damaged/smashed the radio.
    The man damaged/smashed the vase.
20. The man is drinking/sipping his coffee.
    The man is drinking/sipping his wine.
21. The girl is eating/licking the popsicle.
    The girl is eating/licking the ice cream.
22. The woman is filling/stuffing the peppers with meat.
    The woman is filling/stuffing the doll with cotton.
23. The dog is following/chasing the cat.
    The dog is following/chasing the boy.
24. The woman is looking/glancing at her watch.
    The woman is looking/glancing at the clock.
25. The policeman is looking/staring at the beggar.
    The policeman is looking/staring at the door.

Appendix C. (*continued*)

26. The man is pulling/dragging the duffel.
    The man is pulling/dragging the suitcase.
27. The boy is saying/shouting his name.
    The boy is saying/shouting the alphabet.
28. The girl is speaking/whispering to her mother.
    The girl is speaking/whispering to the doctor.
29. The lady is stitching/hemming the dress.
    The lady is stitching/hemming the pants.
30. The man is talking/arguing with his neighbor.
    The man is talking/arguing with the policeman.

Appendix D. Examples of picture-sentence pairs used in the sentence completion task

See Pictures 7 and 8.

Picture 7. The maid is cleaning/scrubbing the bathtub.

Picture 8. The maid is cleaning/scrubbing the sink.

Appendix E. Sentence stimuli used in grammaticality judgment task

Number of sentence stimuli by type of verbs: 13 Ob1, 17 Ob2, 14 Ob3 verbs

Number of different types of verbs used: 7 Ob1, 8 Ob2, 4 Ob3 verbs (total 19 verbs)

A. Grammatical sentences with basic argument structure

Obligatory one-place verb (Ob1)

1. The dog is barking.
2. The girl is sitting.
3. The man is snoring.
4. The boy is swimming.

Obligatory two-place verb (Ob2)

5. The boy is catching the ball.
6. The girl is drying the dishes.
7. The boy is sharpening the pencil.
8. The woman is weighing the package.

Obligatory three-place verb (Ob3)

9. The woman is giving the money to the girl.
10. The boy is leaning the ladder against the wall.
11. The man is putting the book on the table.

B. Grammatical sentences with an additional adjunct

Obligatory one-place verb (Ob1)

1. The dog is barking in the house. (+ locative)
2. The lady is praying in her room. (+ locative)
3. The man is snoring at night. (+ temporal)
4. The boy is swimming toward the girl. (+ goal/locative)

Obligatory two-place verb (Ob2)

5. The man is carrying the box to the car. (+ locative)
6. The girl is drying the dishes in the kitchen. (+ locative)
7. The man is erasing the name from the book. (+ locative)
8. The boy is pushing the cart in the yard. (+ locative)

Obligatory three-place verb (Ob3)

9. The woman is giving the money to the girl in the car. (+ locative)
10. The boy is leaning the ladder against the tree in the garden. (+ locative)
11. The man is putting the book on the table in the bedroom. (+ locative)

C. Ungrammatical sentences with deletion of argument(s)

a. Without an additional adjunct

Obligatory two-place verb (Ob2)

1. *The boy is carrying. (−NP)
2. *The boy is sharpening. (−NP)

*Obligatory three-place verb (Ob3)

3. *The woman is giving to the driver. (−NP)
4. *The man is putting. (−NP)(−PP)
5. *The man is putting the dollar. (−PP)

6. *The man is putting on the table. (−NP)
7. *The boy is sticking on the envelope. (−NP)

b. With an additional adjunct

Obligatory two-place verb (Ob2)

8. *The boy is carrying in the park. (−NP)(+locative)
9. *The boy is pulling to the house. (−NP)(+locative)

Obligatory three-place verb (Ob3)

10. *The boy is sticking in the morning. (−NP)(−PP)(+temporal)
11. *The man is putting in the afternoon. (−NP)(−PP)(+temporal)
12. *The man is putting the book at night. (−PP)(+temporal)

D. Ungrammatical sentences with an extra argument

Obligatory one-place verb (Ob1)

1. *The dog is barking the girl.
2. *The man is laughing the woman.
3. *The woman is listening the music.
4. *The girl is sitting the chair.
5. *The boy is swimming the girl.

Obligatory two-place verb

6. *The man is carrying the boy a box.
7. *The boy is catching her the ball.
8. *The girl is drying the man the dishes.
9. *The boy is pulling the girl the cart.
10. *The girl is pushing the boy the cart.

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