Lexical acquisition in progressive aphasia and frontotemporal dementia

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Lexical acquisition in progressive aphasia and frontotemporal dementia

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We investigated the characteristics of language difficulty in frontotemporal dementia (FTD) by exposing these patients to a new verb in a naturalistic manner and then assessing acquisition of the grammatical, semantic, and thematic matrix information associated with the new word. We found that FTD patients have difficulty relative to healthy seniors in their acquisition of the new verb, but that progressive nonfluent aphasia (PNFA), semantic dementia (SD), and social/dysexecutive variant (SOC/EXEC) subgroups of FTD demonstrate relatively distinct impairment profiles. Specifically, PNFA patients showed relative difficulty assigning the new verb to its correct grammatical form class, reflecting compromised processing of the associated grammatical information. SD patients were impaired at associating the new word with its pictorial representation, suggesting impaired processing of the new verb’s semantic attributes. SOC/EXEC patients showed their greatest difficulty judging violations of the new word’s associated thematic roles, implying that limited executive resources underlie in part the difficulty in integrating grammatical and semantic information into a coherent thematic matrix. Similar impairment profiles were seen during a follow-up session one week after the initial evaluation. These deficits in lexical acquisition reflect the breakdown of a language-processing system that consists of highly interactive but partially dissociable grammatical, semantic, and resource-based components, leading to relatively distinct language-processing deficits in each subgroup of patients with FTD.

INTRODUCTION

Frontotemporal dementia (FTD) is a neurodegenerative disorder that presents in the sixth decade with language difficulty and/or a disorder of social comportment but minimal memory difficulty (Grossman, 2002; Snowden, Neary, & Mann, 1996). Although there is some debate about the specificity of clinical phenotypes at presentation (Kertesz, McMonagle, Blair, Davidson, & Munoz, 2005; Kertesz & Munoz, 2003; Mesulam, 2001), three clinical syndromes are generally accepted (Grossman, 2002; Grossman & Ash, 2004; Hodges & Patterson, 1996; Hodges et al., 1999; Neary et al., 1998; Snowden et al., 1996): progressive nonfluent aphasia (PNFA), semantic dementia (SD), and a disorder of social comportment and executive dysfunction (SOC/EXEC). Lexical acquisition is a sensitive and comprehensive way to assess language processing in these patients.
because semantic, grammatical, and thematic processes are all needed to acquire the corresponding components of a new word (Gillette, Gleitman, Gleitman, & Lederer, 1999; Grossman, Mickanin, Onishi, Robinson, & D’Esposito, 1997; Grossman, Stern, Gollomp, Vernon, & Hurtig, 1994). By presenting patients with a single new word, moreover, each component of the new word can serve as a control for other components while differences in individual patients’ experience with the lexicon are well controlled. To investigate language processing in FTD from this perspective, we taught these patients a new verb. We hypothesized that FTD patients would have difficulty learning the new word. Moreover, patients with each clinical syndrome were expected to exhibit a relatively distinct pattern of limited lexical acquisition reflecting the specific language impairment of each FTD subgroup.

Humans are life-long word learners. Dictionaries regularly admit new content words as they enter our vocabulary. Lexical acquisition depends on the processes necessary for the use of known words (Gillette et al., 1999; Grossman et al., 1997; Grossman et al., 1994). Consider the sentence “The man lours at the girl” paired with a picture showing a man frowning in disapproval at a girl. The unfamiliar phonological shape “lour” is immediately identified, particularly when encountered in a meaningful context. Processing the grammatical features of the sentence indicates that “lour” is in a sentence slot normally occupied by a verb. In the context of the paired picture, the semantic properties of the new word suggest that it is a verb of facial expression meaning “to show disapproval by frowning”. We also notice that the noun phrase “the man” serves in the thematic role of an agent that must be capable of expressing an emotion, and that an optional recipient of “lour” is an indirect object through the use of the preposition “at”. The thematic matrix of the verb thus can be constructed from its combined semantic and grammatical properties.

Healthy speakers appreciate all aspects of a new word as soon as it is presented. Although some adults appear to be “cautious” in their acceptance of a novel phonological shape as a new word due to either stylistic preferences or limited executive resources (Grossman et al., 1997; Grossman et al., 1994), selective disruption of the language system by a focal neurodegenerative disease such as FTD can result in profound difficulty in acquiring discrete components of a new word. To the extent that different acquisition patterns are seen in subgroups of patients with FTD, this may reflect several of the phenotypes that are related to the distinct anatomic distribution of disease (Gorno-Tempini et al., 2004; Grossman et al., 2004b; Rosen et al., 2002a; Williams, Nestor, & Hodges, 2005), rather than a single phenotype that may change depending on factors such as the point of ascertainment during the course of the disease (Kertesz et al., 2005; Kertesz & Munoz, 2003; Mesulam, 2001). PNFA patients are said to have limited speech output. Their speech is described as halting, nonfluent, and agrammatic (Ash et al., 2006b; Grossman et al., 1996; Snowden & Neary, 1994; Thompson, Ballard, Tait, Weintraub, & Mesulam, 1997). Some attribute the decreased speech output in PNFA in part to a problem expressing the phonological properties of a word (Croot, Patterson, & Hodges, 1998), while other research suggests a grammatical impairment constructing sentences (Ash, Moore, Antani, McCawley, & Grossman, 2005; Grossman et al., 1996; Thompson et al., 1997). Studies also have shown the breakdown of grammar at the level of sentence processing, manifested as impaired comprehension of grammatically complex sentences. This work has demonstrated difficulty with both “online” and “offline” grammatical judgement tasks, indicating that the poor grammatical comprehension in PNFA cannot be explained entirely by a production deficit or nonlinguistic difficulties such as limited executive resources (Grossman et al., 1996; Grossman, Rhee, & Antiquena, 2005; Price & Grossman, 2005). In this context, the semantic content of single words is said to be relatively preserved in PNFA (Grossman et al., 1996; Hodges & Patterson, 1996). Because of their disproportionate deficit parsing a sentence grammatically, PNFA patients may have specific difficulty acquiring the grammatical features of a new word.
SD patients’ speech is fluent but contains many word-finding pauses and may be empty of content (Grossman et al., 2004; Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Gouling, & Neary, 1989). This is attributed to a semantic memory impairment that also results in single-word comprehension difficulty. While most of the work in these patients has focused on nouns, recent studies have begun to demonstrate a comparable deficit with verbs (Bird, Lambon Ralph, Patterson, & Hodges, 2000; Yi, Moore, & Grossman, in press). Indeed, these patients are said to have a deficit appreciating not just words but the multimodal concepts underlying these words (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000; Hodges, Bozeat, Lambon Ralph, Patterson, & Spatt, 2000; Lambon Ralph, Graham, Patterson, & Hodges, 1999; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Rogers et al., 2004). Some studies have observed relatively preserved understanding of grammar and syntax (Garrard, Carroll, Vinson, & Vigliocco, 2004; Hodges et al., 1992; Snowden et al., 1989), though other work argues against this. For example, impaired semantic memory in SD may impact areas of language comprehension thought to depend in part on grammatical rules such as inflectional morphology (Patterson, Lambon Ralph, Hodges, & McClelland, 2001). As a result, SD patients may have difficulty acquiring the meaning of a new word, and this deficit in turn may compromise other aspects of lexical acquisition such as specific aspects of grammatical comprehension.

SOC/EXEC patients are said to have limited executive resources such as poor working memory, reduced selective attention, and limited planning and organization (Boone et al., 1999; Grossman, 2002; Razani, Boone, Miller, Lee, & Sherman, 2001). Recent studies suggest that impaired executive functioning in these patients may impact some aspects of language comprehension such as selective difficulty understanding verbs under a dual-task condition (Rhee, Moore, & Grossman, 2001). Another study assessing sentence processing in SOC/EXEC patients attributed impaired grammatical comprehension in part to a working-memory deficit (Cooke et al., 2003). One recent online study showed that SOC/EXEC patients have difficulty processing selection restrictions associated with a verb’s thematic matrix (Cooke, Moore, Dennis, & Grossman, 2006). The authors reasoned that executive resources are needed to organize and integrate the semantic and grammatical features that determine thematic relations. This deficit in mental organization and planning also results in poorly organized discourse (Ash et al., 2006b). The perception of the emotional states of other people is also impaired in SOC/EXEC patients (Gregory et al., 2002; Keane, Calder, Hodges, & Young, 2002; Mychack, Kramer, Boone, & Miller, 2001; Rahman, Sahakian, Hodges, Rogers, & Robbins, 1999; Rankin, Kramer, Mychack, & Miller, 2003; Rosen et al., 2002b), and this may reflect in part difficulty comprehending social or emotional states labelled by a word (Wood & Grafman, 2003). When considered together, these deficits suggest that SOC/EXEC patients may have difficulty in fully appreciating the meaning of this class of abstract words, or may have executive resources that limit acquisition of certain features of a new verb.

We examined these language profiles by exposing FTD patients to a new word. We chose to teach a verb because of the rich store of information that this class of words encodes, including semantic, grammatical, and thematic role information. By exposing individuals to a single, multifaceted stimulus, we could test whether one pattern of lexical acquisition impairment emerges in all FTD patients consistent with a single phenotype, or whether subgroups of patients are selectively insensitive to specific aspects of the new word consistent with multiple, dissociable phenotypes. We expected that PNFA patients would be disproportionately impaired in their acquisition of grammatical aspects of the new verb, SD patients would be most impaired in their understanding of the new verb’s semantic properties, and SOC/EXEC patients would have difficulty integrating grammatical and semantic features to appreciate thematic constraints associated with the new word.
EXPERIMENT

Method

Participants

Patients with a diagnosis of FTD based on a comprehensive medical and neurological examination were identified in the Cognitive Neurology Clinic of the Department of Neurology at the Hospital of the University of Pennsylvania. We recruited 25 patients diagnosed clinically with FTD based on published consensus criteria (Lund and Manchester Groups, 1994). Exclusion criteria included evidence of a second neurological condition such as vascular disease, hydrocephalus, or head trauma, a primary psychiatric disorder, sedating medications such as benzodiazepines, or an untreated medical condition affecting cognition such as hypothyroidism. Using a consensus mechanism based on two independent chart reviews, we classified patients into three clinically distinct subgroups according to the criteria described by Neary et al. (1998), as modified more recently during a reliability assessment (Davis, Price, Moore, Campea, & Grossman, 2001; Grossman & Ash, 2004; Price, Davis, Moore, Campea, & Grossman, 2001). Subgroups included patients with PNFA (n = 6), SD (n = 11), and SOC/EXEC (n = 8). Healthy controls (n = 17) were recruited using flyers posted throughout the community as well as spouses of patients not included in this study. Demographic data are summarized in Table 1. One-way analysis of variance (ANOVA) did not reveal significant differences between patient groups and healthy seniors in age at testing, F(3, 36) = 1.29, p = .29, or education level, F(3, 37) = 0.14, p = .94. Performance on other neuropsychological measures, summarized in Table 1, is consistent with these clinical diagnoses, showing semantic impairment in SD, naming difficulty in SD and PNFA, and minimal evidence for aphasia in SOC/EXEC. Informed consent was obtained for all research participants under a protocol approved by the University of Pennsylvania Institutional Review Board.

Materials

We taught patients the verb “lour”, a very-low-frequency English word expected to be unfamiliar to most participants. We chose to use a real

Table 1. Mean age, education, MMSE, and neuropsychological scores for participant groups

<table>
<thead>
<tr>
<th></th>
<th>Elderly control (n = 17)</th>
<th>PNFA (n = 6)</th>
<th>SD (n = 11)</th>
<th>SOC/EXEC (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td><strong>Mean</strong></td>
<td><strong>Mean</strong></td>
<td><strong>Mean</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Age at testing datea</td>
<td>69.41</td>
<td>73.67</td>
<td>67.09</td>
<td>63.75</td>
</tr>
<tr>
<td>Educationa</td>
<td>15.35</td>
<td>15.00</td>
<td>15.27</td>
<td>16.00</td>
</tr>
<tr>
<td>MMSEb</td>
<td>29.47</td>
<td>21.50</td>
<td>21.55</td>
<td>28.00</td>
</tr>
<tr>
<td>Episodic memoryc</td>
<td>–</td>
<td>–</td>
<td>–2.27</td>
<td>–0.67</td>
</tr>
<tr>
<td>Semantic memory</td>
<td>–</td>
<td>–</td>
<td>–2.27</td>
<td>–0.67</td>
</tr>
<tr>
<td>PPT wordsd</td>
<td>–</td>
<td>–1.52</td>
<td>–4.38</td>
<td>–1.52</td>
</tr>
<tr>
<td>PPT picturesd</td>
<td>–</td>
<td>–0.74</td>
<td>–5.21</td>
<td>–0.74</td>
</tr>
<tr>
<td>Namingd</td>
<td>–</td>
<td>–1.80</td>
<td>–3.91</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: PNFA = Progressive nonfluent aphasia; SD = semantic dementia; SOC/EXEC = disorder of social and executive functioning. Neuropsychological scores are z-scores relative to 25 age- and education-matched controls (significant at the p < .05 level when z-score exceeds –1.96).

aIn years; education was not available for one SOC/EXEC patient. bMMSE (Mini Mental State Examination) differs significantly from healthy seniors based on Wilcoxon log rank scores at p < .05. cRecognition memory accuracy for a 10-word list, intermixed with 10 foils, at a 2-minute delay following three learning trials. dPPT: Pyramid and Palm Trees Test—matching a target with one of two choices that is a semantic associate. dBoston Naming Test abbreviated version (15 items).
English verb rather than a pseudoword in order to avoid anomalous treatment of the word due to unknown phonotactic properties of English or violation of the coherence of allowable semantic concepts. The meaning assigned to “lour” for this experiment was “to look angry or sullen as if in disapproval”. As a verb of facial expression, “lour” takes a subject, the animate agent of the verb that can express an emotion, and an optional indirect object through the use of the preposition “at”, which is the recipient of the verb. Regular inflectional rules apply for bound grammatical morphemes (e.g., the third person singular is “lours”, the present participle is “louring”, and the past tense form is “loured”).

We constructed our experiment to expose participants to a representation of “lour” in a naturalistic manner, and we then examined the knowledge of “lour” that participants acquired in three subsequent experiments probing different aspects of the word. Participants thus were exposed to “lour” in the context of a brief story and without any prior indication that they would be learning a new word. Prior to the exposure period, participants performed a 10-item lexical decision task that included five familiar verbs, four pseudowords, and “lour”. Participants who endorsed “lour” as a known word were excluded from the data reported below. This eliminated 3 potential participants (1 healthy senior, 1 SD patient, and 1 SOC/EXEC patient). All participants included in this study thus reliably distinguished known verbs from pseudowords and treated “lour” like other pseudowords prior to the exposure period.

Pictorial illustrations of “lour” were edited from a children’s picture-book (Thompson & Knight, 1999). Images were scanned into digital format and were modified using Adobe Photoshop v6.0 to the specific needs of each stimulus. We assessed each participant’s visual–perceptual processing of complex pictured stimuli with a five-item, four-choice, picture–picture matching task. Stimuli for this control task were taken from the same source story as that for the stimuli for the experiment, and the target stimulus differed from all but one of the four available choices by one subtle feature. All healthy seniors but one (16 of 17, or 94.1%) erred on a single item or less. The 17th healthy senior was not assessed due to an omission, but this participant’s data were included due to high performance on the remaining tasks and perfect accuracy on the same task at the follow-up one week later (see below). Similar accuracy was seen in 4 of 6 (67%) PNFA patients, 11 of 11 (100%) SD patients, and 7 of 8 (88%) SOC/EXEC patients. One potential SD patient had been excluded from the study due to an error rate of greater than one item on the picture–picture matching task and an impairment matching pictures depicting known verbs of facial expression to the corresponding word on a word–picture matching task (see below). We do not have a good account for the visual–perceptual errors in the remaining 3 patients who missed more than one item since this study was not designed to investigate the basis for subtle visual–perceptual difficulty. Since they were unimpaired in their judgements on the word–picture matching task, we decided to include them in the subsequent analysis.

Procedure
In brief overview, participants were first presented the verb in the context of a narrated picture story, followed immediately by a sentence–picture matching task that reinforced specific aspects of the new verb. After a brief delay, we assessed participants’ mental representation of grammatical, semantic, and thematic matrix aspects of the new verb. Following a one-week delay, we assessed long-term retention of the new verb.

Exposure period. The new word was presented without warning in a naturalistic context, embedded in a brief eight-scene picture story, along with the following instructions:

I am going to show you a picture-story about a little girl. I will read the story aloud and you can follow along. Pay particular attention to the people in the story and the interactions between them. After we finish
the story I’m going to ask you a few questions about what happened.

Images were paired with a simple narrative printed beneath each picture. The text was read aloud by the experimenter with a natural cadence while the participant followed along. The narrative described an energetic girl who gets into trouble because she fails to obey her father. The final scene of the narrative served as the first exposure to the test verb, pairing “lour” with an illustration depicting an older man in a chair leaning forward and frowning in disapproval at the girl. The participant read and heard the sentence “Louise sees her father lour at her.”

A multiple-choice sentence–picture matching task was presented to each participant immediately following the narrative. In each trial, participants were asked to match one of four pictures to a target sentence. Each sentence was grammatically correct and was presented in the active voice using an uninflected form of the verb identical to that used in the initial story (e.g., “The man sees Louise lour at him”). Once the participant selected the target picture, positive reinforcement was given, and the next example was presented. If a picture other than the target was selected, the participant was told that “most people would select another picture” and was instructed to select again. This procedure was continued until the appropriate target picture was identified.

A total of nine trials were used. The first two trials served as training for the task and as a memory check to verify that participants could remember specific events from the story using familiar verbs. Performance on these two questions indicated that all patient groups had good recall of the probed events. Healthy seniors needed only a single attempt (mean number of choices = 1.00, SD = ±0.00) to identify characters from the story. Patients were also quite good at this task, requiring a mean of 1.36 (±0.47) attempts to identify characters from the story.

The seven remaining randomly ordered trials did not depend on specific recall of information from the story, although content from the story was used as stimulus material. Four trials used “lour”, and three trials used familiar English verbs. Each trial using “lour” highlighted a specific feature of the verb by manipulating the nature of the incorrect choices. Thus, one trial presented “lour” along with pictures depicting other facial expressions, another trial emphasized that “lour” takes an indirect object rather than a direct object, and a third trial demonstrated that “lour” is associated with a particular preposition.

Postexposure period. Prior to the postexposure assessments, a two-minute interference period was filled with a picture-naming task. Three postexposure assessments then were presented in a fixed order. We chose this order to limit the amount of information that participants could infer about “lour” from the context of each task. Two forms were created; one set was administered during the initial assessment, and the second was administered at the one-week follow-up session. Participants were randomly assigned to one set of materials for the first session. Mann–Whitney U tests comparing performance by healthy seniors detected no differences between forms. This was true for each individual task: grammar judgements (Z = −.78, p = .43); semantic word-picture matching (Z = −.45, p = .66); and thematic matrix judgements (Z = −.40, p = .69).

Grammatical sentence acceptability task. Participants were asked to judge the acceptability of 48 sentences that varied in grammatical appropriateness. This included 14 sentences containing the word “lour”, 22 sentences using known English verbs of facial expression, and 12 sentences that included a pronounceable pseudoword. This allowed us to balance roughly the number of items for which a “yes” response and a “no” response would be most appropriate. A total of 8 of the sentences with “lour” placed the new verb in a sentence slot normally occupied by a verb, twice without grammatical inflection and six times with a bound grammatical morpheme (equally divided among “-ed”, “-ing”, “-s”). The remaining 6 sentences placed “lour” in a nonverb slot in the sentence. These included using the word as a noun (e.g., “The lour saw the man glancing at him”), as a
preposition (e.g., “The woman walked lour the man”), or as an adjective (e.g., “The teachers stare at the lour students”).

Of the 24 sentences using a familiar verb of facial expression, 8 contained the target word used in the active voice without a bound grammatical morpheme, and 8 used a known verb in its inflected form (e.g., “-ed”, “-ing”, or “-s”). The remaining 6 sentences placed familiar verbs of facial expression into a sentence slot normally occupied by another grammatical word class (equally divided among noun, preposition, or adjective), as described above.

Half of the 12 sentences containing a pseudoword placed these items in a sentence slot normally occupied by a verb (“Shelley foups at both of the dancers”). The remainder were placed in the sentence slot of a noun, an adjective, or a preposition. The sentences using a pseudoword as a verb included 3 in which the pseudoword appeared uninflected and 3 in which the inflection of the pseudoword resembled the common bound grammatical morphemes (i.e., “-ed”, “-ing”, or “-s”) used above.

Sentences were matched for both word count and syllable count and were presented in a fixed random order. Participants read each sentence aloud but were monitored and corrected for any mistakes. Repetition of sentences was allowed as many times as a participant requested, and there was no time limit for responding. Participants were instructed to judge each sentence as acceptable or unacceptable (if the sentence “made sense” or was “good or bad”). To ensure patient comprehension, a brief training session was administered prior to the task with known verbs used both correctly and incorrectly and with pseudowords. Patients thus were exposed to each type of error to minimize confusion about the range of possible errors. The training was repeated if necessary until the examiner felt that the participant understood the instructions and the types of error.

Semantic picture–word matching task. Acquisition of the meaning of “lour” was assessed with a three-choice, word–picture matching task. To construct stimuli, we first taught young control participants the meaning of “lour” and then asked them to name the facial expression of approximately 50 pictures. Based on their responses, two sets of 15 pictures were selected that were consistently given a single name by test participants. Each set included 5 pictures in which “louring” was the preferred name and 10 in which a familiar verb of facial expression was preferred. Each of the pictures was paired with the target verb and two alternate foils. All choices were presented in the progressive form ending with “-ing” (including pseudowords). Alternate foils were a known verb of facial expression, a pseudoword, or “louring”. Participants were asked to select the word that best matched the picture.

Practice examples were given to introduce the task and to judge the participants’ task comprehension. This was repeated if necessary. To ensure that impaired accuracy was not the result of a visual–perceptual deficit, patient performance on the semantic picture–word matching task was compared to performance on the five-item, picture–picture, visual–perceptual matching task described above. Kendall tau correlation analysis failed to reveal a significant relationship between performance on these tasks ($r = .04; p = .80$). This was true for items in which the target was “lour” ($r = .10; p = .58$) and those in which the target was a known verb of facial expression ($r = -.05; p = .80$), suggesting that visual–perceptual difficulty was not determining performance on this task.

Thematic matrix sentence acceptability task. Participants’ acquisition of the appropriate thematic matrix for the new verb was assessed using a second sentence judgement task. A total of 52 sentences were administered, including 12 containing “lour”, 26 containing a known verb of facial expression, and 14 containing a pseudoword. A total of 6 used “lour” appropriately as a verb (3 uninflected, 3 with a grammatical inflection). A total of 6 violated the thematic coherence of the sentence by placing “lour” with an inanimate agent of the verb (e.g., “The pencils lour at the angry man”), with a sentence complement (e.g., “The boys lour that their mother is angry”), or with a direct object (e.g., “The young men lour the pushy woman”).
A total of 26 sentences using familiar verbs of facial expression were administered as well, including 20 in which the verb was used in its ideal form (12 grammatically inflected, 8 uninflected) and 6 sentences in which the verb was inappropriately paired with a direct object (2 sentences), a sentence complement (2 sentences), or an inanimate agent (2 sentences). A total of 14 sentences included a pseudoword used in a sentential slot for a verb (7 sentences) or a noun (7 sentences). Due to time constraints, four SD patients at the initial testing and two SOC/EXEC patients at the follow-up testing were not assessed on the thematic matrix sentence judgements.

**Final instructions at the end of the postexposure assessment.** Participants were informed that “lour” is a real word and that a formal definition of the word would be provided after the follow-up session had been completed one week later.

**Follow-up.** In order to assess participants’ retention of information regarding “lour” over a longer delay, we administered the alternate forms of the tasks probing grammatical, semantic, and thematic matrix information about the new verb approximately one week (mean = 7.27 days, SD = ± 1.29) following the initial exposure and assessment. One SD patient and one SOC/EXEC patient were not assessed due to scheduling difficulty.

**Statistical analyses**

We performed two types of analysis: We examined individual patient performance profiles in several different ways, and we performed more traditional analyses of averaged group performance. This allowed us to specify whether a single individual skewed group performance.

To assess individual patient performance profiles, we first identified an “ideal” pattern of lexical acquisition for each task. Criteria for an ideal performance pattern required (a) treating the new verb like a known verb of facial expression and (b) treating the new verb differently from a pseudoword. We verified the occurrence of this profile in individual control participants, examined the frequency with which this ideal pattern occurred in each patient subgroup for each task, and we assessed the ways in which each of the patient groups deviated qualitatively from this pattern by examining accuracy on items using “lour”, known verbs of facial expression, or pseudowords. Deviations from chance on the binomial or polynomial test was set at \( p < .05 \) (for pseudoword judgements on the grammatical task we used \( p = .073 \)).

In another analysis of individual patient performance, we assigned qualitative impairment profiles to impaired participants. Specifically, participants who were random only in their acceptance of items using “lour,” but accepted items using known words at better than chance and rejected pseudowords at better than chance, were given the profile of impaired only for “lour”. If an impairment was seen for items using “lour” and for known verbs, but performance was better than chance for rejecting pseudowords, a participant was considered impaired for “lour + known”. Participants impaired for “lour” and pseudowords at greater than chance were given the profile of impaired for “lour + pseudo”. On the semantic picture–word matching task, participants who were worse than chance when the target was “lour” and falsely endorsed a pseudoword as correct were considered “lour + pseudo”.

To perform more traditional group-wide analyses, we assessed performance averaged across subjects within each subgroup. This allowed us to examine specific error patterns for each class of stimuli within each task. Most statistical analyses used nonparametric tests because of the categorical nature of the analyses and the relatively small numbers of participants in some patient groups. The significance level for all tests was set at \( p < .05 \). All analyses were performed using SPSS statistical software package, v12.0 (SPSS, Chicago, IL, USA).

We found that some healthy seniors and some patients fail to endorse any use of “lour” on a particular task. This phenomenon has been seen in previous work assessing lexical acquisition in healthy adults and patients (Grossman et al., 1997; Grossman et al., 1994). Rather than
overinterpreting these data as acceptable behaviour or as impaired behaviour, we classified these participants as “cautious” and excluded them from the analysis. Since some patients exhibited a cautious profile on one task but not on other tasks within the battery, different numbers of testable participants contributed to performance on each task. “Cautious” patient data were included in the one-week follow-up comparisons due to the instructions at the end of the first session indicating that “lour” is a real word.

Results

Exposure period

All participants were able to learn about “lour”, but each FTD subgroup required more trials than did healthy seniors to accomplish this. Thus, 13 (76%) of 17 healthy seniors were accurate on their first choice of all four sentence–picture pairs using “lour”. Of the remaining 4 participants, only 1 erred on more than one trial, and no healthy senior erred on the fourth of these trials. Compared to healthy seniors, significantly fewer PNFA patients (1 of 6, or 17%; \( p = .02 \)) and SD patients (3 of 11, or 27%; \( p = .02 \)) were able to match all four sentences with “lour” to the target picture in a single attempt. Fewer SOC/EXEC patients (3 of 8, or 38%) than controls were accurate at sentence–picture matching, but this difference was not significant. By the fourth trial, most patients (PNFA: 5 of 6; SD: 8 of 11; and SOC/EXEC: 8 of 8) were able to match “lour” to a picture in a single attempt. Only 2 patients, 1 SD and 1 PNFA, required the maximum number of attempts to perform the final trial accurately.

Good learning in healthy seniors and modestly impaired learning in patients were corroborated in analyses of group profiles. Mann–Whitney U tests confirmed that PNFA patients (mean = 1.63 trials, \( SD = \pm 0.56, \ p < .01 \)), and SD patients (mean = 1.75 trials, \( SD = \pm 0.68, \ p < .01 \)) required significantly more guesses than did controls (mean = 1.07 trials, \( SD = \pm 0.15 \)) to match sentences with “lour” to the appropriate picture. The difference between controls and SOC/EXEC patients approached significance (mean = 1.22 trials, \( SD = \pm 0.21, \ p = .06 \)).

Postexposure assessment

We found unique patterns of performance with the new verb during the postexposure assessment of each group. Figure 1 summarizes the percentage of “ideal” patient profiles in each group on tasks monitoring grammatical, semantic, and thematic matrix aspects of the new verb. Healthy seniors were able to represent mentally grammatical, semantic, and thematic aspects of “lour,” despite the brief and naturalistic exposure. However, a chi-square analysis revealed significantly different performance profiles across patient groups (\( \chi^2 = 39.65, \ p < .001 \)). As shown in Figure 1, PNFA patients differed significantly from healthy seniors only in their grammatical judgements, although there was a trend toward impairment in thematic matrix judgements as well. Only SD patients differed from healthy seniors in their semantic judgements, although these patients also were impaired in their grammatical judgements. Only SOC/EXEC patients differed statistically from controls in their judgements of the thematic matrix associated with “lour”, although they were marginally impaired for semantic judgements.

Although all members of each patient group did not perform identically on each task, many individuals in each group demonstrated broadly similar trends. Patient 19187 with PNFA had a Mini Mental State Examination (MMSE) of 27 at the time of examination. She easily completed the exposure task by correctly identifying all nonlour trials on the first attempt. Testing revealed her greatest impairment on the grammatical judgement task, where she accepted “lour” used both as a preposition and an adjective, and rejected “lour” when inflected by a grammatical morpheme. Errors also included accepting known verbs in sentence slots reserved for a preposition or an adjective, but she had no difficulty rejecting sentences containing pseudowords. On the picture–word matching task she demonstrated excellent understanding of the emotional content of both “lour” and other verbs of facial expression.
On the thematic matrix judgement task, she was not significantly impaired in her judgements of "lour," known verbs, or pseudowords. This pattern was seen in 2 additional PNFA patients.

Patient 19249, an SD patient with an MMSE of 27, acquired "lour" quickly. Her judgements of grammatical violations of "lour" were not impaired, nor were her judgements of violations of the grammatical aspects of other known verbs of facial expressions. However, she had significant difficulty on the picture-word matching task. She was as likely to endorse a pseudoword as correct as she was to endorse "lour" on this task, although she missed only a single example using known words. On thematic matrix judgements, she again had little difficulty judging "lour," but inappropriately accepted a pseudoword as appropriate. This profile was seen in 4 SD patients.

Patient 19256 with SOC/EXEC had an MMSE of 30 at the time of testing. She acquired "lour" easily. She encountered little difficulty in acquiring grammatical or semantic information about the verb, although she tended to endorse pseudowords more frequently than did controls. Her greatest impairment involved assigning an appropriate thematic matrix to the verb. She accepted "lour" used with direct objects and sentence complements, while also accepting thematic violations of known verbs. This pattern was seen in 3 SOC/EXEC patients.

Performance patterns of each group on each task are detailed below.
**Grammatical sentence acceptability task.** Significantly fewer ideal profiles for grammatical features of the new verb were seen in PNFA patients (1 of 4, or 25%; $p = .01$) and SD patients (3 of 9, or 33%; $p = .003$) than healthy seniors (10 of 10, or 100%), as illustrated in Figure 1. Individual patient performance patterns, summarized in Figure 2, also revealed distinct impairment profiles in each group. Of the nonideal individuals, all impaired PNFA patients demonstrated deficit profiles for either “lour” or “lour + known”. This suggested that these patients had acquired enough about the phonological properties of “lour” to treat it differently from a pseudoword, but similar impairment judging known words suggested a grammatical processing deficit. Some SD patients and SOC/EXEC patients exhibited an impairment profile of “lour + pseudo”, however, suggesting difficulty at another level of processing during the acquisition of “lour” in these patients.

Detailed examination of group-wide performance confirmed qualitative differences between groups and provided some explanation for the different impairment profiles seen in each group (Table 2). Specifically, PNFA patients were impaired relative to controls in their judgments of the grammatical appropriateness of “lour” and known verbs, but accurately rejected pseudowords. They erred with “lour” by failing to accept inflected forms of the new verb used correctly. They were significantly more impaired than controls at judging violations of “lour” when it was substituted for a closed-class word (i.e., a preposition), but did not differ from controls when substituted for an open-class word (i.e., an adjective). Table 2 also shows a similar impairment with known verbs, emphasizing the grammatical processing impairment in PNFA.

SD patients also encountered difficulty with grammaticality judgments. Unlike PNFA patients, SD patients were significantly impaired for judgments of “lour” and pseudowords (Table 2). When erring in judgments of “lour” used incorrectly, SD patients accepted “lour” used as an open-class word (i.e., an adjective), but they correctly rejected “lour” used as a closed-class word (i.e., a preposition). These findings suggest that SD patients had learned enough to distinguish “lour” from closed-class vocabulary terms that structure sentences. However, SD patients may have lacked the semantic properties of “lour” to determine its content word category—that is, noun, verb, or adjective.

SOC/EXEC patients were not significantly impaired on their grammatical judgments of “lour” used correctly or incorrectly.

**Semantic picture—word matching task.** A total of 12 (86%) of 14 healthy control participants exhibited an ideal performance profile judging picture representations of “lour” and known verbs of facial expression. Compared to healthy seniors, Figure 1 shows that significantly fewer SD patients were ideal (1 of 7, 14%; $p = .003$). The number of ideal PNFA patients (3 of 4, 75%) and SOC/EXEC patients (4 of 10, or 40%) did not differ significantly from controls. Of the remaining
participants, Figure 3 shows that the majority of SD patients exhibited a “lour + pseudo” profile, but this profile was seen in a smaller number of PNFA and SOC/EXEC patients.

Table 2 shows that SD patients had significantly greater difficulty than healthy seniors at matching a picture to “lour”. SD patients were also significantly impaired at matching a picture to a known verb (Table 2), emphasizing the fundamental semantic deficit in these patients. SD patients also endorsed more pseudowords than did elderly controls, although this difference only approached significance. Difficulty with pseudowords on this task and the grammaticality judgement task suggests a deficit with the mental representation of lexical forms.

PNFA patients performed similarly to healthy seniors, accurately matching a picture to “lour” or to a known verb and not endorsing pseudowords as acceptable. This emphasizes the relatively selective impairment acquiring grammatical information about “lour” in PNFA patients.

Although SOC/EXEC patients did not differ from healthy seniors in their ability to match a picture to “lour” or to a known verb, they did have some difficulty learning the meaning of “lour”.

Thematic role judgements. All three FTD subgroups had difficulty acquiring thematic matrix information about “lour”. Figure 1 shows that, compared to 10 (83%) of 12 healthy seniors who achieved an ideal profile, significantly fewer SOC/EXEC patients (1 of 7, 14%; \( p = .006 \)) acquired the thematic matrix associated with “lour”. The difference in ideal participants for PNFA (1 of 4, 25%; \( p = .06 \)) compared to controls approached significance, but SD patients (2 of 4, 50%; \( p = .25 \)) did not demonstrate a significant impairment with thematic matrix judgements. Figure 4 shows that a large percentage of each

Table 2. Z-score analysis of FTD subgroups compared to that of healthy seniors

<table>
<thead>
<tr>
<th></th>
<th>PNFA</th>
<th>SD</th>
<th>SOC/EXEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grammaticality judgements&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lour: correct</td>
<td>−2.23*</td>
<td>−1.98*</td>
<td>−1.61</td>
</tr>
<tr>
<td>Lour: inflected</td>
<td>−2.31*</td>
<td>−1.89*</td>
<td>−1.62</td>
</tr>
<tr>
<td>Lour: uninflected</td>
<td>−1.68</td>
<td>−2.14*</td>
<td>−1.40</td>
</tr>
<tr>
<td>Lour: violation</td>
<td>−2.04*</td>
<td>−2.23*</td>
<td>−1.76</td>
</tr>
<tr>
<td>Lour: preposition</td>
<td>−2.34*</td>
<td>−1.21</td>
<td>−0.62</td>
</tr>
<tr>
<td>Lour: adjective</td>
<td>−1.58</td>
<td>−2.99*</td>
<td>−3.16*</td>
</tr>
<tr>
<td>Known verbs</td>
<td>−2.46*</td>
<td>−3.61*</td>
<td>−2.97*</td>
</tr>
<tr>
<td>Pseudowords</td>
<td>−0.27</td>
<td>−2.43*</td>
<td>−2.13*</td>
</tr>
<tr>
<td>Semantic picture matching&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lour items</td>
<td>−0.61</td>
<td>−3.21*</td>
<td>−1.45</td>
</tr>
<tr>
<td>Known verbs</td>
<td>−0.69</td>
<td>−2.57*</td>
<td>−0.20</td>
</tr>
<tr>
<td>Pseudowords</td>
<td>−0.37</td>
<td>−1.57</td>
<td>−0.13</td>
</tr>
<tr>
<td>Thematic matrix judgements&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lour: correct</td>
<td>−1.96*</td>
<td>−2.55*</td>
<td>−1.78</td>
</tr>
<tr>
<td>Lour: violation</td>
<td>−0.69</td>
<td>−1.02</td>
<td>−2.20*</td>
</tr>
<tr>
<td>Known verbs</td>
<td>−2.22*</td>
<td>−2.58*</td>
<td>−3.35*</td>
</tr>
<tr>
<td>Pseudowords</td>
<td>−1.03</td>
<td>−1.75</td>
<td>−1.76</td>
</tr>
</tbody>
</table>

Note: *Indicates patient group differences compared to healthy seniors based on Wilcoxon log rank scores, \( p < .05 \). FTD = frontotemporal dementia. PNFA = progressive nonfluent aphasia; SD = semantic dementia; SOC/EXEC = disorder of social and executive functioning.

*Grammaticality judgements include sentences using “lour”, known verbs and pseudowords. Also shown are sentences in which “lour” was used correctly in inflected and uninflected forms, and sentences using “lour” as a preposition or an adjective. *Semantic picture matching shows Z-scores in which “lour” or a known verb of facial expression were the target. Patients falsely endorsing a pseudoword as correct were compared in the “pseudoword” category. *For thematic matrix judgements, items in which “lour” was used correctly or items in which the thematic matrix was violated are compared to sentences using known verbs or pseudowords.
subgroup demonstrated an impairment profile for “lour + pseudo”, with the rest exhibiting a profile of “lour”.

SOC/EXEC patients were significantly more impaired than controls at judging sentences where “lour” is embedded in an inappropriate thematic matrix (Table 2). This paralleled their difficulty at judging sentences where the thematic matrix associated with a known verb of facial expression is violated. Unlike SD and PNFA patients who demonstrated significant difficulty with grammatical and/or semantic features of “lour”, SOC/EXEC patients were particularly impaired at integrating these sources of knowledge about “lour” into a coherent thematic matrix. This was emphasized by their parallel difficulty in judging thematic matrix violations of a known verb, in the context of relatively normal semantic and grammatical judgements of known verbs.

PNFA and SD patients were accurate at rejecting sentences violating the thematic matrix of “lour”, although they were impaired at judging sentences using “lour” correctly and using known verbs in a thematically anomalous manner.

Long-term follow-up
Table 3 shows mean patient performance across both testing sessions. Group performance was quite stable at one week following initial exposure. This was true for healthy seniors and all patient subgroups on all tasks.

Discussion
Despite no explicit training, we acquire new words rapidly and efficiently. On the basis of minimal exposure, comprehensive appreciation of a new verb’s multiple grammatical, semantic, and thematic components is accomplished impressively at all ages. In the present study, a majority of healthy seniors were able to acquire a new verb quickly and accurately, replicating our previous
work with the naturalistic acquisition of a motion verb and an adjective (Grossman et al., 1997; Grossman et al., 1994). This means that healthy seniors treated the new verb like a known word and also distinguished it from a pseudoword. The present study also showed that this knowledge, acquired naturalistically and without explicit learning, was retained by healthy seniors over the course of a week.

By comparison, each FTD patient subgroup experienced difficulty in acquiring and representing the new word “lour”. Moreover, FTD patient subgroups differed qualitatively in the type of information about “lour” that they were able to represent. Specifically, only PNFA patients showed fairly selective difficulty assigning the new verb to its correct grammatical form class; SD patients were impaired at associating the new word with its pictorial representation; and SOC/EXEC patients had a relatively prominent deficit judging violations of the new word’s associated thematic roles. These findings are consistent with the hypothesis that distinct patterns of lexical acquisition difficulty reflect different language processing impairments in each subgroup of patients with FTD. We infer from this a language-processing architecture that is highly interactive but contains partially dissociable grammatical and semantic components, where executive resources contribute to processing the thematic matrix of a verb, and where relatively unique impairments in this language-processing system reflect distinct phenotypes in subgroups of patients with FTD.

We discuss below the lexical acquisition profile of each FTD subgroup and some entailments for processing known words that emerge from these observations.

**Progressive nonfluent aphasics**

PNFA patients were most impaired in acquiring grammatical aspects of “lour”. Assessments of participants’ judgements of sentences violating grammatical aspects of a new verb thus revealed significantly fewer ideal PNFA patients than healthy seniors. This deficit was stable during a one-week follow-up. Notably, they did not differ from healthy seniors in their acquisition of the new verb’s meaning, emphasizing the selective nature of the lexical acquisition deficit in PNFA. Mounting evidence suggests that PNFA patients have significant difficulty in understanding grammatical aspects of known words (Rhee et al., 2001) and sentences (Cooke et al., 2006; Grossman et al., 1996; Grossman et al., 2005; Hodges & Patterson, 1996; Price & Grossman, 2005). In order to appreciate the major grammatical form class of a new word, grammatical and executive resources are needed to parse the sentence containing the word, and both of these components appear to be impaired in PNFA. We reason that the impaired parsing apparatus for processing grammatical aspects of a sentence limited the capacity of patients with PNFA to acquire the grammatical features of a novel lexical entry.
Evidence consistent with this claim comes from the observation that PNFA patients’ difficulty with grammatical aspects of the new verb paralleled their poor grammatical judgements of known verbs on the same task.

The specific types of error made by PNFA patients define in greater detail their impaired grammatical processing. PNFA patients had their greatest difficulty in judging the major grammatical subcategory violation of the new verb when it was substituted for a closed-class or function word. Closed-class words are thought to be important in organizing sentence structure at a grammatical level (Jackendoff, 1990). This unique difficulty in distinguishing between an open-class word like a verb and a functor belonging in a closed sentence slot reflects the profound grammatical processing limitations experienced by PNFA patients. This finding mirrors recent studies describing the tendency of PNFA patients to omit closed-class words in studies of speech output (Ash et al., 2005; Grossman et al., 1996; Snowden & Neary, 1994; Thompson et al., 1997). PNFA patients also had significant difficulty in accepting inflected forms of the new verb, although they did not differ from controls at judging uninflected forms (Ash, Koenig, Moore, & Grossman, 2006a). Our observations suggest that this is unlikely to be due to a phonologic deficit since these PNFA patients were able to process phonologic information sufficiently to acquire the phonologic shape of “lour” and distinguish this from pseudowords. Regardless of the specific basis for morphologic transformations (McClelland & Patterson, 2002; Pinker & Ullman, 2002), the relative difficulty recognizing the inflected form of a verb compared to its uninflected form in this study appears to be consistent with a deficit of grammatical processing in PNFA.

PNFA patients were less impaired at acquiring semantic information about “lour”. On a picture-matching task, PNFA patients did not differ from healthy seniors either in the number of participants exhibiting an ideal profile or in mean group performance scores. Even though PNFA patients have difficulty parsing a sentence into its major grammatical constituents and therefore are limited in their acquisition of a new word’s grammatical features, this does not prevent the PNFA patients from learning that the new word’s meaning involves a particular facial expression. Neuroimaging studies of PNFA associate their grammatical deficit with left inferior frontal cortex (Cooke et al., 2003; Gorno-Tempini et al., 2004; Grossman et al., 2004a; Grossman, Work, Gee, McMillan, & Moore, 2006; Nestor et al., 2003), while semantic difficulty in progressive aphasia has been related to disease in the left temporal lobe (Mummery, Patterson, Price, & Hodges, 2000; Mummery et al., 1999; Williams et al., 2005). This is consistent with a partial dissociation between these two components of language. PNFA patients’ ability to distinguish “lour” from pseudowords also suggests an intact capacity to associate a semantic representation with a phonological representation of the new verb. While PNFA patients produce frequent speech errors (Ash et al., 2005), successful acquisition of the semantic component of a new word implies that a deficit at the level of input phonology is unlikely to explain fully the pattern of impairment that we observed in PNFA. Indeed, these patients treated “lour” like a pseudoword on a pretest, emphasizing their productive acquisition of the phonologic shape following exposure to the story containing “lour”. The phonologic deficit in PNFA may be related to a limited phonologic output buffer that supports speech output (Chein & Fiez, 2001; Chein, Fissell, Jacobs, & Fiez, 2002), although additional work is needed to evaluate this hypothesis. The present findings instead appear to be more consistent with the hypothesis that the cognitive architecture of a language-processing system is highly interactive but involves partially dissociable grammatical and semantic components.

Semantic dementia patients
SD patients were impaired in acquiring the meaning of “lour”, as evidenced by their significant deficit with this new word on a picture–word matching task. Thus, these patients had difficulty associating the novel phonological shape “lour” with its meaning in the story. While it is beyond
the scope of this study to specify the precise source of difficulty acquiring a semantic representation for the new verb, these patients also had difficulty judging the meaning of known words on the same task, and they could not distinguish these words from pseudowords lacking semantic content. This is not due to a visual–perceptual deficit appreciating the pictures, as they performed successfully on a perceptual pretest with similar materials. We believe that these observations emphasize the semantic memory deficit in SD.

While considerable attention has been paid to the loss of object-associated knowledge represented by nouns (Bozeat et al., 2000; Bozeat, Lambon Ralph, Patterson, & Hodges, 2002; Rogers et al., 2004), few studies have examined the representation of verbs in SD. Because it is thought that the semantic structure underlying verb concepts differs from that underlying noun concepts (Miller & Fellbaum, 1991), the impairment for nouns in SD does not necessarily entail a semantic impairment with verbs. Two previous studies have examined verbs in SD. One report demonstrated reduced verb use in brief narratives and related this to measures of semantic comprehension (Bird et al., 2000). A second study showed that SD patients are significantly impaired at matching a verb to a description or a video in a multiple choice task and that this deficit is more prominent for verbs than for nouns (Yi et al., 2006). The present study also suggests that the class of concepts associated with verbs may be compromised in SD. Additional work is needed to study the differences between verb meaning and noun meaning in SD.

An impoverished semantic representation of the new verb also may have contributed to difficulty in representing specific aspects of the new verb’s grammatical features in SD. On the grammaticality judgement task, SD patients were impaired in judging the grammatical form class of “lour”. Unlike PNFA patients, SD patients also endorsed significantly more pseudowords than did healthy seniors. This might suggest that SD patients learned nothing about “lour” and that limited phonologic processing or poor verbal episodic memory resulted in difficulty in judging both semantic and grammatical aspects of the new word. Indeed, a number of progressive aphasics appear to have Alzheimer’s disease at autopsy (Davies et al., 2005; Forman et al., 2006; Galton, Patterson, Xuereb, & Hodges, 2000). While assessment of verbal episodic memory is difficult in SD due to their language deficits, we think that this is less likely to explain SD patients’ deficit fully, given their ability to recall specific elements of the story in the picture–sentence matching task following presentation of the story and their parallel deficit in judging known words, which does not depend on episodic memory.

Detailed inspection of performance on the grammatical judgement task also suggested an important exception to SD patients’ broadly impaired performance. Specifically, SD patients erred by accepting “lour” significantly more frequently than did healthy seniors when it was used in another open-class vocabulary slot such as an adjective, but they were as accurate as controls at judging an incorrect grammatical use of “lour” in a sentence slot ordinarily occupied by a closed-class term. This observation suggests that poor differentiation of grammatical subcategories within the open-class vocabulary in SD depends in part on semantic memory, although SD patients can distinguish between major grammatical categories like open class and closed class. This also implies adequate input phonology to support some lexical processing. This pattern of performance was stable over a one-week follow-up, moreover suggesting that long-term consolidation of new information can be accomplished in SD (Murre, Graham, & Hodges, 2001). Others have noted that impaired semantic memory can have effects on grammatical comprehension (Grossman et al., 2005). The potential role that semantic knowledge may play in distinguishing among open-class lexical categories like verb and noun emphasizes the selectively interactive nature of semantic and grammatical components of a language-processing system. The distinction between the grammatical roles and semantic roles of a word in a sentence is honoured by electroencephalogram (EEG) event-related potential studies (Friederici & Kilborn, 1991; Friederici, 1995) and functional magnetic
resonance imaging (fMRI) studies (Cooke et al., 2005; Friederici, Meyer, & von Cramon, 2000a; Friederici, Opitz, & von Cramon, 2000b; Friederici, Ruschemeyer, Hahne, & Fiebach, 2003) that attribute a special grammatical processing role to left inferior frontal cortex, coindexed to a left anterior negativity that parses a sentence grammatically early in the course of processing. This may represent the distinction between open and closed-class vocabularies that appears to be preserved in SD. This contrasts with left temporal fMRI activations, also seen during sentence processing (Cooke et al., 2005), which may contribute the major grammatical subcategory information represented in words. It is this latter distinction between noun and verb that may be compromised in SD. The learning profile in SD thus appears to be the result of impaired semantic processing of the new word, paralleling their impairment with known words, and extends previous observations of poor noun knowledge to impoverished verb knowledge. Although this semantic deficit did not appear to impair their recognition of a fundamental grammatical distinction between content words and closed-class words, their semantic impairment may have limited their ability to represent certain grammatical aspects of the new word, such as grammatical subcategory distinctions within the open-class vocabulary system.

Patients with a disorder of social and executive functioning

Because SOC/EXEC patients are not obviously aphasic, language difficulties might not at first be expected in this FTD subgroup. Indeed, these patients do not differ significantly from control participants on the grammatical sentence judgement task and the semantic picture-word matching task. However, SOC/EXEC patients demonstrated a novel pattern of impairment in judging violations of the thematic matrix of a new verb. They were similarly compromised at judging sentences containing a known verb that violates a thematic matrix. This deficit was also seen at one-week follow-up. This is consistent with a previous observation of insensitivity to violations of the thematic matrix in an online study of sentence processing in SOC/EXEC patients (Cooke et al., 2006). We hypothesize that the deficit acquiring the new verb’s thematic matrix is related in part to their limited executive resources. Specifically, processing the thematic information associated with a verb may involve integrating its semantic features and grammatical features, and this integrative process may depend on executive resources that are compromised in these patients (Kramer, Jurik, & Sha, 2003; Libon et al., 2006; Rascovsky et al., 2002; Razani et al., 2001; Rhee et al., 2001).

Knowledge of a verb’s thematic matrix appears to be closely linked to a verb’s semantic information. Only certain objects can be an agent of “lour”, for example – generally those that are animate and credited with some sense of affective capacity. However, a verb’s thematic matrix is also tied to its grammatical information. The recipient of an action thus may be instantiated as a direct object of a verb or an indirect object. Combined with its meaning as a verb of facial expression, grammatical attributes of “lour” preclude its taking a direct object, for example, but permit taking an indirect object that is the recipient of the action. Despite relatively better performance with grammatical and semantic attributes of “lour”, we believe that SOC/EXEC patients had difficulty in using executive resources during the exposure period that may be needed to integrate grammatical and semantic information about the new verb so that a thematic matrix can be developed. This hypothesis suggests that thematic matrix information associated with a verb may be an emergent property of combined semantic and grammatical knowledge and also represents another way in which grammatical and semantic components of a language-processing system may interact.

Much evidence now indicates a role for working memory, planning, and selective attention in language processing (Caplan & Waters, 1999; Gibson, 1998; Grossman et al., 2002a; Zurif, Swinney, Prather, Wingfield, & Brownell, 1995). A limitation in executive resources such as these is known to interfere with language processing in patients with central nervous system disease who are not aphasic (Cooke et al., 2003; Grossman,
Lee, Morris, Stern, & Hurtig, 2002b; Grossman et al., 2003; Keil & Kaszniai, 2002), and these language deficits are often correlated with limited executive resources. In a study of word–picture matching for verbs and nouns, for example, non-aphasic FTD patients with a SOC/EXEC profile were shown to have difficulty that worsened in the context of performing a secondary task simultaneously (Rhee et al., 2001). More recently, a significant disorder of discourse was identified in SOC/EXEC patients that correlated with limited executive resources and with cortical atrophy in a right frontal distribution (Ash et al., 2006b).

The importance of executive resources in learning about a verb's thematic matrix is brought out by the contrast with progressive aphasics. SD patients differed from healthy seniors in their ability to learn about word meaning and grammatical attributes of a word, but the limited representation of these domains nevertheless resulted in only modest difficulty in learning a new verb's thematic matrix. Likewise, PNFA patients differed from healthy seniors in their grammatical processing, but were not as impaired at learning the new verb's thematic matrix. We believe that PNFA and SD patients were able to learn something about the new verb's thematic matrix, despite their language-processing limitations, because their executive resources could bootstrap preserved aspects of language to support processing a sentence's thematic matrix. By comparison, SOC/EXEC patients were less impaired at learning about the semantic and grammatical properties of "lour", yet they had difficulty integrating these components into a coherent representation of the new word's thematic matrix. We hypothesize that the relatively unique deficit acquiring the thematic matrix component of a new verb is related in part to limited executive resources in SOC/EXEC patients.

It is noteworthy that SOC/EXEC patients were only modestly impaired on the semantic word–picture matching task despite the affective nature of the meaning of "lour". Much work has demonstrated a disorder of personality and social comportment in these patients (Eslinger et al., 2005; Gregory et al., 2002; Keane et al., 2002; Mychack et al., 2001; Rahman et al., 1999; Rankin et al., 2003; Rosen et al., 2002b). Impaired recognition of facial emotions also has been reported in these patients (Keane et al., 2002; Rosen et al., 2002b). Rather than attributing their difficulties to the degradation of social knowledge per se (Wood & Grafman, 2003), our findings are more consistent with the hypothesis that the social compartment difficulties of SOC/EXEC patients are due in part to a deficit in the executive resources that support applying their social knowledge to a situation such as word learning.

Limitations
The use of a novel verb as the target stimulus allowed simultaneous examination of semantic, grammatical, and thematic aspects of language in these patients, but generalizing our findings to other semantic classes, such as motion verbs or verbs of cognition, or to other major grammatical classes such as nouns, must be performed cautiously. Further studies examining acquisition of other word classes may prove informative in supporting our conclusions.

In order to assure the reproducibility of our results, we analysed the data according to two methods: individual patient profile comparisons and assessments of group scores. These methods revealed reasonably converging patterns of impairment in each patient group. However, our results must be interpreted cautiously because of the relatively small number of patients.

We did not explicitly pair the target verb with a formal definition, nor did we mention to patients our intention to teach a new word. Despite our attempts to create a naturalistic setting, the formalized nature of an experimental task may have been perceived as artificial and created reluctance to accept the new word as real. While this may have affected the patients' responses to a degree, each subgroup's distinct strengths and weaknesses on different tasks suggests that this is unlikely to have played a significant role in determining patient performance.

Proof that the difficulty seen in these patients is due to FTD awaits autopsy confirmation, and we make no claim that the deficits in these patients...
are diagnostically valid indicators of underlying histopathology. Indeed, other neurodegenerative conditions such as Alzheimer’s disease and corticobasal degeneration are known to cause progressive aphasia and a disorder of social comportment (Davies et al., 2005; Forman et al., 2006; Galton et al., 2000; Johnson, Head, Kim, Starr, & Cotman, 1999; Murray et al., 2006).

CONCLUSIONS

With these caveats in mind, we find partially distinct impairment profiles in subgroups of patients with FTD during the acquisition of a previously unfamiliar lexical concept. These data are consistent with a language-processing architecture that includes dissociable but highly interactive grammatical and semantic components. Because similar processes required to handle known words are also utilized in acquiring new words (Gillette et al., 1999; Grossman et al., 1997; Grossman et al., 1994), we believe that the lexical acquisition deficits in each patient subgroup reflect their broader language-processing impairments. A new verb thus encodes at least grammatical and semantic information. The resource-mediated integration of these two components of language may be necessary to appreciate the thematic matrix associated with a verb. These components of a verb appear to break down selectively in patients with FTD: PNFA patients show a relatively prominent deficit acquiring grammatical information about a new verb; SD patients are most impaired acquiring the new verb’s semantic information; SOC/EXEC patients, although not aphasic, appear to demonstrate resource-dependent difficulty in integrating semantic and grammatical information into a coherent thematic matrix. Relatively distinct lexical acquisition profiles such as these also emphasize the dissociable phenotypes of FTD subgroups.

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