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Applied Psycholinguistics **36** (2015), 533–558
doi:10.1017/S0142716413000337

Does argument structure complexity affect reading? A case study of an Italian agrammatic patient with deep dyslexia

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Received: June 9, 2012 Accepted for publication: January 18, 2013

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ABSTRACT
The argument structure complexity hypothesis (Thompson, 2003) was introduced to account for the verb production pattern of agrammatic patients, who show greater difficulty in producing transitive versus unergative verbs (argument number effect) and in producing unaccusative versus unergative verbs (syntactic movement effect). The present study investigates these two effects in the reading performance of a patient (GR) suffering from deep dyslexia. GR read nouns significantly better than verbs; moreover, her performance was better on unergative than on transitive verbs, whereas the comparison between unergative and unaccusative verbs did not differ significantly. Data support the extension of the argument structure complexity hypothesis to word naming and suggest that the two aspects of argument structure complexity occur at different levels within models of lexical processing.

Verb argument structure (VAS) is a lexical feature that indicates the number and type of participants in the event described by a verb. Models of lexical production (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999) report this information as being stored in the lemma, that is, a "package of syntactic information" associated with a given lexical form. Lemmas contain information about the number of arguments required by a verb and the thematic roles the verb assigns to its arguments. In Levelt's model of lexical production, the activation of the information stored at the lemma level is followed by the retrieval of the phonological word form at the

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lexeme level, and then by the articulation of the target verb. Arguments are defined as obligatory elements required by verbs and receive a thematic role specifying the function of each participant in the action described by the verb. Verbs are classified as transitive when they require a direct object. Agentive transitive verbs assign the thematic roles of agent, that is, the performer of the action, and theme, that is, the undergoer, to their arguments.[1] In active sentences containing agentive transitive verbs (e.g., *to chase*) the agent corresponds to the grammatical subject of the sentence, whereas the direct object is the theme. For intransitive verbs, that is, verbs that do not take a direct object, unergative verbs (e.g., *to sneeze*) usually take only one argument, which receives the role of agent; on the contrary, unaccusative verbs (e.g., *to disappear*) assign the role of theme to their grammatical subjects. The latter are also supposed to differ from unergative verbs in their underlying syntactic structure. In Noam Chomsky's government and binding framework (1981), sentences have both a surface structure, representing the sentence as it appears to the hearer/reader (e.g., passive, interrogative, or relative clauses), and a deep structure (i.e., the clause in the affirmative active form). Furthermore, each clause is composed of a noun phrase (NP), that is, the grammatical subject, and a verb phrase (VP), which splits into a head (i.e., the main verb) and a complement, which in the case of transitive verbs often corresponds to a NP serving as direct object. According to the unaccusative hypothesis (Burzio, 1986; Perlmutter, 1978), the grammatical subject of unaccusative verbs is generated in the VP-internal position, that is, the position usually occupied by the direct object in transitive sentences, but moves to the subject position leaving a trace behind (Figure 1). Therefore, sentences containing an unaccusative verb are subject to syntactic movement (argument movement, or A-movement[2]) analogous to the movement underlying passive sentences. As in English, Italian unaccusative verbs are supposed to entail syntactic movement of the NP subject (A-movement), which is assigned the thematic role of theme before moving out of the VP. However, unlike English, where the distinction between unergative and unaccusative verbs relies exclusively on the possibility of using unaccusative verbs in certain linguistic constructions that are not supported by unergative verbs,[3] Italian verbs select different auxiliaries. Unaccusative verbs (e.g., *scomparire* [to disappear]) are preceded, in composite past forms, by the auxiliary *essere* (to be), whereas unergative verbs (e.g., *dormire* [to sleep]) take the auxiliary verb *avere* (to have); as an example, the composite past form of the verb *scomparire* is *è scomparso* (e.g., *il ragazzo è scomparso* [the boy has disappeared, lit. the boy *is disappeared*]), whereas in the case of the verb *dormire*, the composite past form is *ha dormito* (e.g., *il ragazzo ha dormito* [the boy *has slept*]). The claim that passive and unaccusative syntactic movement are the same operation is also supported by the use of the same auxiliary in the composite form of both verb types. In both cases, the auxiliary verb *essere* signals syntactic movement of the action theme to the subject position, as in the following examples: *il ragazzo è scomparso* (unaccusative movement, see above) and *il gatto è inseguito dal cane* (passive movement [the cat is chased by the dog]).

Several studies conducted on agrammatic patients speaking different languages have demonstrated that these patients experience increasing difficulty in processing verbs as the number of their arguments increases. For instance, Thompson, Lange, Schneider, and Shapiro (1997) tested 10 agrammatic patients with both

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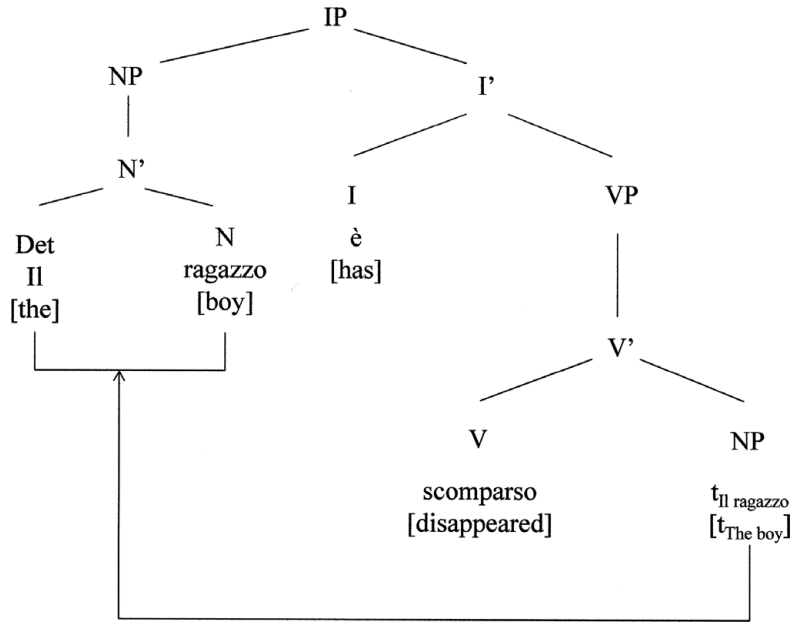


Figure 1. A syntactic representation of an unaccusative sentence (i.e., *il ragazzo è scomparso* [the boy has disappeared]). The arrow indicates the syntactic movement (argument movement) allowing thematic role assignment.

a sentence production and a confrontation naming task, showing that their verb production was significantly more impaired for three-place verbs, that is, verbs that take obligatorily three arguments (e.g., *to put:* Mike puts the book on the shelf), relative to two-place transitive verbs (e.g., *to wash:* Tom washes the dishes), which in turn proved to be more difficult to produce than one-place verbs such as *to snore* (e.g., John snores). Similar results were obtained by Kim and Thompson (2000, 2004) in a task in which agrammatic patients were asked to categorize verbs according to VAS. Difficulty in retrieving transitive verbs compared to unergative verbs was also reported by Luzzatti et al. (2002) for Italian agrammatic patients in a picture-naming task. In addition, these authors found the whole group of non-fluent aphasic patients ($N = 15$ participants, 6 with agrammatism) to be impaired on unaccusative verbs relative to both unergative and transitive verbs. A specific impairment affecting the naming of unaccusative verbs, which confirms that verb processing demands increase as the number of arguments they take increases, was also reported by Kegl (1995) and by Thompson (2003) in English agrammatic patients, and by Sanchez-Alonso, Martinez-Ferreiro, and Bastiaanse (2011) in Spanish agrammatic patients. In order to account for these data, Thompson proposed the argument structure complexity hypothesis (ASCH), which explains the pattern of impairment of the agrammatic patients' verb production as a function of VAS complexity, in terms of both the number of arguments taken by a verb

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and the presence of underlying syntactic movement. A more recent study (McAllister, Bachrach, Waters, Michaud, & Caplan, 2009) reported greater difficulty in both production and comprehension of sentences containing unaccusative verbs compared to sentences containing unergative verbs, not only in a group of aphasic patients, most of whom were suffering from fluent aphasia, but also in the group of age-matched control participants. Given that difficulty with the production and comprehension of the unaccusative sentences was not restricted to the aphasic patients, the authors interpreted their findings as a general effect of complexity rather than as the result of a linguistic deficit concerning syntactic movement, as assumed by the ASCH. Evidence for the influence of VAS complexity on verb processing has also been found in neuroimaging studies on normal participants, in which brain activation is more pronounced for two- and three-place transitive verbs than for unergative verbs. This activation, which was elicited by picture naming, short action video clips (den Ouden, Fix, Parrish, & Thompson, 2009), and a lexical decision task (Thompson et al., 2007), was located in the posterior left language areas and in the corresponding right hemisphere regions. However, not all experimental data are in line with the ASCH: for instance, Shetreet, Palti, Friedmann, and Hadar (2007) found an effect of the number of alternative subcategorization options[4] (but not of the number of arguments) on the activation of the language areas in normal participants. Findings of an effect of multiple verb subcategorization options on neural activity during sentence processing are consistent with behavioral studies on both normal and nonfluent aphasic participants (see Shapiro & Levine, 1990; Shapiro, Zurif, & Grimshaw, 1987).

Vis-à-vis the issue of unaccusativity, almost all data come from studies on language production in aphasia, with only a few reports from the neuroimaging literature, that is, the studies by Shetreet, Friedmann, and Hadar (2009) and by Shetreet and Friedmann (2012). These studies reported increased activation in the left inferior frontal gyrus and in the left middle temporal gyrus when healthy participants were processing unaccusative sentences as opposed to transitive or unergative sentences. The latter results support the aforementioned evidence from studies on aphasic participants: as mentioned earlier, Luzzatti et al. (2002) and Thompson (2003) reported more difficulties in retrieving unaccusative than unergative verbs, which was confirmed by Lee and Thompson (2004) in an elicited sentence production task with agrammatic patients who, however, did not show any comprehension deficit in sentences containing unaccusative verbs (but, for opposing results, see McAllister et al., 2009).

GRAMMATICAL CLASS EFFECTS IN DEEP DYSLEXIA (DD)

DD (Coltheart, Patterson & Marshall, 1980; Marshall & Newcombe, 1973) is an acquired reading disorder often co-occurring with agrammatic aphasia. Its main characteristic is the production of semantic errors when reading; for instance, *night* is read as *sleep*, or *river* as *ocean* (Patterson & Marcel, 1977; Plaut & Shallice, 1993). As well as semantic errors, patients suffering from DD also produce visual (e.g., *white* for *while*) and morphological (e.g., *class* for *classify*) errors. Their performance is also characterized by word frequency and imageability effects, that is, concrete nouns are read better than abstract nouns. DD reading performance

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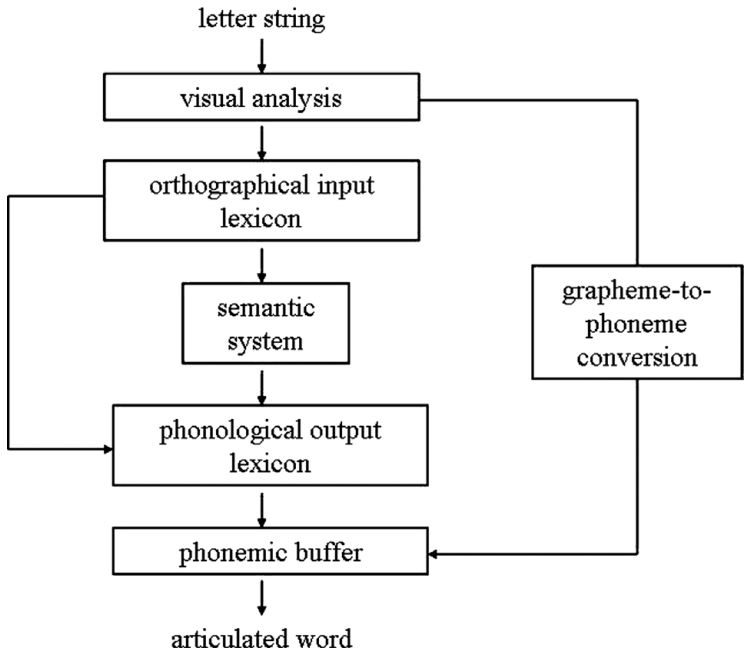


Figure 2. The dual-route model of reading (Coltheart, 2000). The model entails two distinct procedures for reading letter strings aloud: (right) the sublexical route and (b) the lexical–semantic route. The third route (i.e., the direct lexical route) differs from the lexical–semantic route in that it allows the lexical reading process to bypass the semantic system through a direct connection between the orthographical input and the phonological output lexicons.

is also influenced by the grammatical class of the word stimuli, with nouns being read better than adjectives, which in turn are read better than verbs and function words (prepositions, auxiliaries, etc.; see Luzzatti, Mondini & Semenza, 2001). Finally, DD patients are unable to read nonwords because of severe damage to the sublexical route of reading. Since the early 1970s, reading has been conceived as a dual-route process, that is, letter strings are read through two different routes (see Figure 2): the *sublexical route*, in which reading is accomplished by means of a grapheme-to-phoneme conversion (GPC) routine with no access to lexical information, and a *lexical–semantic route*, in which the phonological output word form of a written stimulus is accessed after retrieving a stored written lexical representation and the underlying conceptual knowledge. While the first route allows reading of regular words and of nonwords, that is, letter strings that do not have a lexical entry in the mental lexicon, the lexical route allows reading of regular words and of words with irregular grapheme-to-phoneme correspondence (e.g., *yacht*, *pint*, or *colonel*).

Observation of patients with preserved reading ability for irregular words but poor comprehension of their meaning (e.g., Schwartz, Saffran, & Marin, 1980)

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resulted in the introduction of a *direct lexical route* connecting the orthographic input lexicon to the phonological output lexicon (and bypassing the underlying conceptual knowledge), in addition to the aforementioned *lexical–semantic route*. Within this theoretical framework, DD is assumed to result from damage to the sublexical route and concomitant disruption of the direct lexical route (Nolan & Caramazza, 1982), which forces retrieval of phonological representations to follow access to conceptual knowledge. In addition, the fragility of either the semantic system itself or the connection between conceptual knowledge and the phonological output lexicon would account for the occurrence of semantic errors (Shallice & Warrington, 1980). This account, which is known as the "multiple-deficits account" of DD, considers the pattern of errors to be a result of residual left-hemisphere (LH) reading abilities. On the contrary, other authors (Coltheart, 1980, 2000; Saffran, Bogyo, Schwartz, & Marin, 1980) suggested that DD might reflect the emergence of right-hemisphere (RH) linguistic abilities, which are supposed to be limited to high-frequency concrete nouns. Examining this concept in greater depth, the right-hemisphere hypothesis (RHH) holds that an extensive LH lesion would cause damage to the LH orthographic lexicon, thus forcing reading performance to rely on RH orthographic processing, that is, rough lexical and conceptual stores, which are limited to high-frequency concrete nouns and no GPC. In addition, the RH is assumed to have almost no phonological output competence; therefore, any access to phonology would have to occur within the LH. A further account of DD stems from the failure-of-inhibition theory (FIT) proposed by Buchanan, McEwen, Westbury, and Libben (2003; see also Colangelo & Buchanan, 2005), according to which semantic substitutions in DD results from defective inhibition of semantically related competitors within the phonological output lexicon.

Investigations of DD have frequently provided the opportunity to test lexical processing models; Luzzatti et al. (2001), for instance, analyzed the performance of an Italian agrammatic patient with phonological/DD when reading morphologically complex words, in order to test Baayen et al.'s (Baayen, Burani, & Schreuder, 1997; Baayen, Dijkstra, & Schreuder, 1997) dual-route model of complex word processing.[5] This theory assumes an interaction between word frequency and (de)compositional processes and predicts that frequent forms are stored as a whole and thus retrieved faster than less frequent forms, which instead are subject to online (de)composition. The results reported by Luzzatti et al. (2001) supported this prediction by showing a significantly better reading performance on singular forms for singular-dominant nouns, that is, for nouns whose singular form is more frequent than the plural (e.g., *nose* vs. *noses*), whereas no difference emerged between the singular and the plural form of plural-dominant nouns. Another example is Buchanan et al.'s (2003) investigation of a DD patient's (JO) ability to implicitly and explicitly access semantic information and to use this information in a naming task. Their results, which showed that JO's ability to read nonwords as novel compounds (e.g., *earfly* vs. *earlark*) was influenced by semantics, supported the theory of implicit access to semantic information and were interpreted as evidence for a model of lexical processing known as PEIR.[6] In addition, studies of patients with DD have supplied information about cognitive models of processing of other types of stimuli, such as numbers (see, for instance, Cohen, Dehaene, & Verstichel, 1994).

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AIM OF THE STUDY

The aim of the present study is to investigate the influence of VAS complexity while reading verbs as singletons, by testing a patient suffering from agrammatism and DD. The studies on agrammatic patients mentioned above (see Luzzatti et al., 2002; Thompson, 2003; Thompson et al., 1997) revealed difficulty in producing both unaccusative and transitive verbs compared to unergative verbs. These data are accounted for by the ASCH (Thompson, 2003), which explains the dissociation across verb categories in terms of greater complexity (due either to the number of arguments or to syntactic movement of the constituents) of transitive and unaccusative verbs versus unergative verbs. Because agrammatism and DD share several features and usually co-occur, the hypothesis behind the present study was that a similar set of effects would also be found in the reading performance of deep dyslexic patients. In the "multiple-deficit account," DD is the consequence of an extensive left perisylvian lesion causing complete disruption of both the sublexical and the direct lexical reading route, obliging patients to rely on the lexical–semantic route, and so accessing word lemmas where information about VAS is stored (Levelt et al., 1999). Assuming that VAS properties are spared, the fact that DD patients are forced to read via the lexical–semantic route predicts that their reading performance should reflect an ASCH complexity effect in single-verb reading tasks as well.

Specifically, the goals of the present study are (a) to describe a specific impairment in reading verbs in comparison to nouns, in line with several previous studies showing an influence of grammatical class on the reading performance of DD patients, and (b) to test the hypothesis of a dissociated impairment across verb categories, based on their underlying VAS, in line with the predictions of the ASCH, particularly testing the argument number effect, by comparing unergative to transitive verbs, and testing the influence of A-movement, by comparing unergative to unaccusative verbs. As far as the first issue is concerned, we predict that verbs will be more impaired than nouns, as part of the grammatical class effect that usually occurs in DD. As to the second objective, we predict that the argument number effect will be elicited in a simple reading task, in line with neuroimaging studies that showed the modulation of language areas by argument number even in a lexical decision task (Thompson, Bonakdarpour, & Fix, 2010; Thompson et al., 2007). These data indicate an argument number effect that takes place as soon as lexical entries are accessed, so we expect DD patients to be more accurate in reading unergative than transitive verbs. Our expectations regarding the unaccusativity issue are less well defined; as for the argument number effect, almost all evidence in support of greater complexity of unaccusative versus unergative verbs comes from studies on verb production in aphasic participants (Kegl, 1995; Luzzatti et al., 2002; Thompson, 2003). Furthermore, contrary to the argument number issue, the only two neuroimaging studies reporting an unaccusativity effect used a semantic plausibility sentence judgment (Shetreet & Friedmann, 2012; Shetreet et al., 2009). The same holds for the study on normal participants conducted by Friedmann, Taranto, Shapiro, and Swinney (2008), who analyzed the processing of sentences containing unaccusative verbs. Therefore, we conducted a test to assess whether the syntactic complexity

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Table 1. *Participant's (GR) rate of accuracy in the picture-naming task*

	N	Correct	%	*z*	*p*
Unergative	17	6	35	Baseline	
Unaccusative	13	2	15	1.49	*ns*
Transitive	20	2	10	3.47	.06
Total verbs	50	10	20	Baseline	
Total nouns	50	35	70	25.2	<.001

Note: The statistical parameters (*z*) and significance result from a multivariate logistic regression analysis including word type, word frequency, imageability, and length.

underlying the processing of unaccusative verbs would also occur in a reading task.

MATERIALS AND METHODS

Participant

GR is a 34-year-old office worker with 13 years of education, who suffered from a left frontoparietal hematoma 3 years prior to the present study. Her language and cognitive abilities were assessed before and after intensive language training at the Villa Beretta Rehabilitation Unit. Her performance on the Italian version of the Aachen Aphasia Test (AAT; Luzzatti, Willmes, & de Bleser, 1996) revealed a moderate Broca aphasia with agrammatism; her speech was limited to short agrammatic utterances with rare production of verbs and almost complete omission of function words. Lexical retrieval in spontaneous speech was characterized by severe anomia and semantic paraphasias, whereas few phonological errors were observed. Confrontation naming on the AAT was mildly to moderately impaired; written comprehension was mildly impaired for single words[7] and moderately impaired for sentences (see Marelli, Aggujaro, Molteni, & Luzzatti, 2012, for a summary of the results obtained on the AAT). Her ability to retrieve nouns and verbs was further investigated with a picture-naming task (Crepaldi et al., 2006), in which GR was asked to name an equal number of objects ($N = 50$) and actions ($N = 50$). The results obtained on this task are illustrated in Table 1 and reveal significantly better performance on nouns than on verbs, as well as a difference in accuracy among different verb types. Semantic errors were found in naming both objects (33%) and actions (52%), and action naming elicited morphological errors (15%) that were frequently characterized by the substitution of verbs with derived nominals (e.g., *preghiera* [prayer] instead of *pregare* [to pray]; see Marelli et al., 2012).

Her reading performance was assessed with two additional tasks: a standard task (Toraldo, Cattani, Zonca, Saletta, & Luzzatti, 2006), evaluating her ability to read words and nonwords, and a test specifically designed to investigate the

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emergence of semantic errors in reading. The first task included a list of concrete nouns, abstract nouns, and function words. Words were mixed with phonotactically plausible pseudowords, in order to assess the integrity of the GPC reading routine, which is required for nonword processing. GR's performance on this task revealed that she was unable to read nonwords and function words, made a few semantic errors in reading words, and had a higher level of accuracy in reading concrete nouns as opposed to abstract nouns. The second task further explored the pattern of semantic errors in reading: the reading list was composed of pairs of semantically related words, each pair being composed of a high-frequency and a low-frequency word (e.g., *gatto–micio* [cat–kitten]). As expected, GR tended to produce semantic substitutions when reading low-frequency nouns, which were often substituted with a high-frequency synonym or a semantically related word (e.g., *micio* was read as *gatto*; see Marelli, Aggujaro, Molteni, & Luzzatti, 2009). Based on the results on both tasks, which demonstrated significant effects of lexicality, grammatical class, and imageability, GR was assessed as suffering from DD.

Materials

Seventy-eight verbs and 31 nouns were included in the experimental reading task. Verbs included in the task had to belong to only one of the following categories: *unaccusative* verbs, *unergative* verbs, or two-place *transitive* verbs. Optionally transitive verbs, that is, verbs that can be used both as unergative and as transitive (e.g., *mangiare* [to eat]),[8] and alternating unaccusative verbs, that is, verbs that can subcategorize both an unaccusative and a transitive sentence structure (e.g., *affondare* [to sink]),[9] were not included in the reading list. As far as the distinction between unaccusative and unergative verbs is concerned, the first criterion used to classify verbs as belonging to one of the two categories was agentivity: verbs in which the grammatical subject receives the role of theme were considered unaccusatives, whereas verbs in which the grammatical subject identifies the performer of the action (agent) were classified as unergative. An additional criterion used to identify unaccusative verbs was the auxiliary taken in the composite past form; for instance, *crollare* (to collapse) was classified as unaccusative, whereas *litigare* (to quarrel) was classified as unergative, because the first takes the auxiliary verb *essere* (to be) in the composite past tense (e.g., *l'edificio è crollato* [the building has collapsed, lit. *is collapsed*]), whereas the second takes *avere* (to have) as the auxiliary verb in the composite past form (e.g., *Maria e Gianni hanno litigato* [Maria and Gianni have quarreled]). Regarding the question of transitivity, all the verbs included in this class were classified as transitive by the authors and confirmed by an independent expert in linguistics. All verbs were matched for lemma frequency, length, and imageability; for the latter variable, values were obtained by asking a sample of 15 control participants to evaluate each verb on a Likert scale, ranging from 1 (*very low imageability*) to 7 (*very high imageability*). The final set of stimuli contained 78 verbs, 26 per category. All verbs were presented in the infinitive form (e.g., *parlare* [to talk]), which is the citation form of verbs in Italian and generally is the easiest verb form for agrammatic patients[10] to produce. Thirty-one nouns, all in the singular form (with the grammatical gender equally

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distributed between masculine and feminine), were also included in the reading list.

Procedure

The stimuli were randomly presented on a computer screen after projection of a fixation cross for 1500 ms. GR was asked to read each word aloud and then to press the spacebar to pass to the following item. There was no time limit, but if she was unable to read a word, she was encouraged to press the spacebar and proceed to the following word. Her entire production, pauses included, was transcribed manually. The task was administered twice, in order to assess test–retest consistency in the reading performance. The two testing sessions were separated by a 30-day interval to avoid any practice effects. No treatment was provided in between the two sessions. Performance over the two sessions was highly correlated (Pearson $r = .681, p < .001$). Given the high correlation between accuracy patterns in the two sessions and the relatively low number of correct responses in each session, the final scoring was computed as follows: items that were read correctly (including self-corrections) in at least one of the two sessions were assigned a score of 1, whereas items that were read incorrectly in both sessions were assigned a score of 0. Only responses that fully matched the target were computed as correct; that is, phonological substitutions were scored as errors.

RESULTS

The first observation about GR's results is her overall low performance on reading verbs (13 correct responses out of 78, see Table 2), which is in contrast with her high level of accuracy when reading nouns (27 correct responses out of 31). This performance is comparable to the results obtained in the picture-naming task, where she named 35 objects out of 50 and 10 actions out of 50 correctly (Table 1). Her high level of accuracy in reading nouns was constant across sessions, whereas her ability to read verbs improved in the second session (12 correct responses in the second session compared to 6 correct responses in the first session, out of a total of 78 verbs). With respect to our primary objective, that is, to investigate the possibility that the verb category (unergative, unaccusative, or transitive) could have influenced GR's ability to read verbs in isolation, the data indicate that she reads unergative verbs significantly better than unaccusative verbs, which in turn she found easier to read than two-place transitive verbs (see Table 2). A similar pattern of performance was also found in the picture-naming task (Table 1). An analysis of GR's errors in the reading task indicates that when encountering difficulty, she tended to give up and move on to the following item without giving any response (see Table 3), something she did most frequently when reading verbs. Among the types of error that usually characterize DD, visual errors (e.g., *accedere* [to access] → *accendere* [to light up]) were more frequent than morphological errors (e.g., *badare* [to look after] → *badante* [employed caregiver]), which in turn were more frequent than semantic errors (e.g., *rispondere* [to answer] → *pronto* [hello]). A few unrelated responses and two mixed errors, that is, errors that were classified as being both visual and morphological (e.g., *ipotizzare* [to

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Table 2. *Participant's (GR) rate of accuracy in the word-reading task*

	N	Correct	%	*z*	*p*
Unergative	26	8	31	Baseline	
Unaccusative	26	4	15	0.604	*ns*
Transitive	26	1	4	−2.286	.022
Total verbs	78	13	17	Baseline	
Total nouns	31	27	87	2.312	.021

Note: The statistical parameters (*z*) and significance result from a multivariate logistic regression analysis including word type, word frequency, imageability, and length.

hypothesize] → *ipnotico* [hypnotic], via *ipnotizzare* [to hypnotize]) or both visual and semantic (e.g., *esistere* [to exist] → *stranieri* [foreigners], via *estero* [abroad]), also emerged (see Appendix B).

As shown in Table 3, errors occurred with almost the same frequency across the two sessions. Errors in reading nouns were mostly visual ($N = 3$) or semantic ($N = 3$); in only one case did a morphological error occur. Visual errors were equally distributed across verb types, whereas morphological and semantic errors were mostly limited to unergative and transitive verbs. Morphological errors occurring more frequently when reading unergative ($N = 7$) than transitive verbs ($N = 3$). Only one morphological error occurred on unaccusative verbs. On the contrary, unrelated errors mostly emerged for unaccusative verbs. In a few cases ($N = 3$), visual errors caused target verbs to be misread as verbs with a different argument structure: a transitive verb was produced for an unergative verb (*accendere* [to light up] for *accedere* [to access], *stira* [(he/she) irons] for *stare* [to stay]), and an unaccusative verb was produced for an unergative verb (*partire* [to leave] for *partecipare* [to participate]). In another case, a semantic error caused an unergative verb to be produced for a transitive verb (*telefonare* [to phone] for *richiamare* [to call back]). The number of semantic errors found for verbs (6% of the total number of errors) in the reading task is clearly lower than the proportion of semantic errors found in the picture-naming task (52%), whereas morphological errors only show a mild discrepancy across tasks (11% vs. 15%).

Quantitative data analysis

The first aspect to be investigated was the grammatical class effect. A logistic regression, conducted using the mixed-effects model approach (Jaeger, 2008) and running in R (R Core Team, 2012) with the lme4 package (Bates, Maechler, & Bolker, 2012), was performed on GR's accuracy data, with the dependent variable being the probability that a given item was read correctly in at least one of the two sessions. *Verb regularity* (for verbs) and *grammatical gender* (for nouns)

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Table 3. *Qualitative analysis of participant's (GR) performance over the two sessions*

	First Session				Second Session			
		Verbs				Verbs		
	Nouns ($N = 31$)	Unergative ($N = 26$)	Unaccusative ($N = 26$)	Transitive ($N = 26$)	Nouns ($N = 31$)	Unergative ($N = 26$)	Unaccusative ($N = 26$)	Transitive ($N = 26$)
Correct	23	4	2	0	24	7	4	1
Visual errors	2	2	1	1	1	3	3	3
Morphological errors	1	5	0	0	0	2	1	3
Semantic errors	1	1	0	2	2	1	0	2
Mixed errors	0	0	0	1	0	0	1	0
Graph/phon substitutions	0	0	0	1	0	0	0	0
Unrelated	0	0	1	0	0	0	3	0
No response	4	14	22	21	4	13	14	17

Note: Mixed errors refers to those errors that were classified as belonging simultaneously to two of the following categories: visual errors, morphological errors, or semantic errors. Graph/phon substitutions are substitutions of a grapheme/phoneme, when it was not clear if it was classifiable as a phonological substitution or as a visual error.

were introduced as random factors in the analyses. *Grammatical class* and all the remaining variables (*word frequency*, *length*, and *imageability*) were included as predictors in the regression design. In order to reduce the skewness of their distribution, length, frequency, and imageability values were transformed into logarithms. The regression was performed by introducing one predictor at a time and by using an analysis of variance (ANOVA) to compare the previous model with that including the newly introduced variable. The effect of *grammatical class* was found to be highly significant both as a single predictor (estimate = 4.196, $SE = 1.112$, $z = 3.773$, $p < .001$) and following the addition of *imageability* (grammatical class, estimate = 3.443, $SE = 1.121$, $z = 3.071$, $p = .002$; imageability, estimate = 4.533, $SE = 1.304$, $z = 3.478$, $p < .001$) as well as of the other lexical variables. The model that best fitted the data contained *grammatical class*, *length*, *word frequency*, and *imageability* as predictors in the regression analysis. With the exception of word frequency, which was found to be slightly above the threshold for statistical significance (estimate = 0.634, $SE = 0.330$, $z = 1.920$, $p = .055$), all the other factors significantly predicted GR's accuracy on the reading task (grammatical class, estimate = 5.453, $SE = 2.358$, $z = 2.312$, $p = .021$; imageability, estimate = 5.902, $SE = 1.605$, $z = 3.677$, $p < .001$; length, estimate = -4.606, $SE = 2.201$, $z = -2.092$, $p = .036$). The data show that the grammatical class effect persists after the effect of imageability was taken into account.

We then performed an additional logistic regression analysis on GR's accuracy for verbs only, in order to investigate the effect of VAS complexity. In this case, *verb type* replaced *grammatical category* as a predictor in the regression analysis. The model that proved to best fit our data contained *verb type*, *imageability*, and *length* as predictors. Although *length* was not significant in the multivariate analysis (estimate = -5.947, $SE = 3.586$, $z = -1.659$, *ns*), *imageability* was found to predict the patient's response to the task (estimate = 10.322, $SE = 3.380$, $z = 3.054$, $p < .001$). As far as the effect of *verb type* is concerned, accuracy in reading verbs was highest for unergative verbs and progressively less accurate for unaccusative and for transitive verbs, but only the difference between unergative and transitive verbs proved to be statistically significant (estimate = -3.499, $SE = 1.530$, $z = -2.286$, $p = .022$), with the comparison between unaccusative and transitive verbs being marginally significant (estimate = -2.745, $SE = 1.427$, $z = -1.923$, $p = .054$). On the contrary, the comparison between unergative and unaccusative verbs (estimate = -0.754, $SE = 1.248$, $z = -0.604$, *ns*) did not approach significance (Table 2).

A subsequent analysis was performed to investigate any associations between error types and verb categories. The analysis was carried out by collapsing the number of errors across the two sessions and excluding items that did not elicit any response. In addition, the only grapheme/phoneme substitution error (see Table 3) was collapsed into the category of unrelated responses just for the purpose of the present analysis. The chi-square statistics demonstrated a tendency toward statistical significance ($\chi^2 = 12$, $p = .06$) when considering all verb categories (unergative, unaccusative, and transitive). A significant difference in the distribution of error types across verb categories was found when considering unergative and unaccusative verbs only ($\chi^2 = 8.51$, $p = .036$), whereas no significant association between error type and verb type was found for unergative and transitive verbs ($\chi^2 = 2.56$, *ns*).

https://doi.org/10.1017/S0142716413000337 Published online by Cambridge University Press

DISCUSSION

The present study investigated the effect of grammatical class on the reading performance of an agrammatic patient suffering from DD (GR) with respect to two main issues: (a) the dissociation between nouns and verbs and its relationship to imageability; and (b) the effect of verb type as defined by the ASCH (Thompson, 2003). The specific aim of the present study was to investigate the prediction that verbs with a more complex VAS, that is, more complex either because they take more than one argument (e.g., transitive verbs) or because their syntactic structure entails A-movement (i.e., unaccusative verbs), are more difficult to produce than verbs with a simpler VAS. GR performed a reading task including both nouns and verbs, the latter being unergative, unaccusative, or transitive. The majority of errors consisted of no responses. The qualitative analysis of the remaining errors revealed a rate of visual, morphological, and semantic errors that is similar to the pattern that emerged on the baseline reading task (Toraldo et al., 2006) but lower than that arising from a specific test designed to elicit semantic errors (Marelli et al., 2009). Picture naming of nouns and verbs (Crepaldi et al., 2006) was also severely impaired, and the rate of morphological and semantic errors was higher than in the reading task.

The distribution of error types in reading verbs was significantly different across verb categories for the comparison between unergative and unaccusative verbs, with morphological and semantic errors occurring more frequently when reading unergative verbs. No differences were found between transitive and unergative verbs with respect to the distribution of error types. The analysis of GR's performance on this task revealed that her ability to read verbs was greatly impaired, whereas her reading of nouns was only slightly impaired. The pattern of impairment found replicates the data reported by Marelli et al. (2012), who tested the same patient on several tasks and found an effect of grammatical class and concreteness in her production. These findings are in line with the literature reporting a grammaticality effect in DD, as outlined by Coltheart et al. (1980) and supported by subsequent research (see, for instance, Luzzatti et al., 2001). The main finding of the present study is a dissociated pattern of impairment among verb types, that is, a disproportionate impairment of transitive verbs, which replicates, using a reading task, the effect of VAS complexity found in the production of agrammatic patients on picture naming, picture description, and verb categorization in various languages (see Luzzatti et al., 2002, for Italian; Lee & Thompson, 2004; and Thompson, 2003, for English; Jonkers, 2000; and Jonkers & Bastiaanse, 1996, 1998, for Dutch; De Bleser & Kauschke, 2003, for German; Sanchez-Alonso et al., 2011, for Spanish). The results will be discussed (a) in light of the debate on the relation between imageability and grammatical effects, (b) with reference to theories of the mental representation of VAS at the lemma level, and (c) in light of theoretical accounts of DD.

Grammatical class effects and imageability

Grammatical class and imageability effects on reading accuracy are typical symptoms of DD. They have often been interpreted as strongly interconnected, particularly in relation to the impaired ability to read function words and verbs with

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respect to nouns. A similar position has been assumed by some authors to account for the disproportionate verb impairment in the production of agrammatic patients (Bird, Howard, & Franklin, 2000, 2003): according to this account, grammatical class effect would result from differences in imageability between nouns and verbs. This assumption is in contrast with the position of other authors (Berndt, Haedinges, Burton, & Mitchum, 2002; Caramazza & Hillis, 1991; Rapp & Caramazza, 2002), who assumed a separate representation of nouns and verbs within the mental lexicon, and is challenged by the experimental evidence of a persistent grammatical class effect even after partialing out the effect of imageability (see Aggujaro, Crepaldi, Pistarini, Tarico, & Luzzatti, 2006; Luzzatti et al., 2002). However, as discussed by Crepaldi, Berlingeri, Paulesu, and Luzzatti (2011) in a recent review, many studies addressing the issue of noun–verb processing have revealed the influence of several other nongrammatical factors (word frequency, actionality, and semantic distinctions within grammatical classes) on the dissociated noun–verb performance found in aphasic patients. Hence, instead of a distinct representation of nouns and verbs within the mental lexicon, those results suggest that grammatical and lexical–semantic factors may both contribute to dissociated performance on nouns and verbs in aphasia. The present experiment outlines a highly significant grammatical class effect in reading, which is in line with the data obtained from the picture-naming task, and indicates a much better production of nouns than of verbs. Although initially nouns and verbs were not matched for length, frequency, and imageability, these variables and their interactions were included as predictors in the logistic regression model. The results show a persistent grammatical class effect despite the introduction of imageability in the regression model, indicating that the dissociated performance between nouns and verbs was not caused by the different degree of imageability, which is in contrast with Bird et al.'s (2000, 2003) hypothesis.

The main finding of this study regards the dissociation between verb categories (unergative, transitive, and unaccusative verbs). In this case, the three lists of verbs were matched for imageability, as well as for the usual lexical variables. Imageability was also included as a predictor in the logistic regression analysis to partial out its influence from the VAS effect. As in the noun–verb dissociation, the effect of verb type persisted even after partialing out the effect of imageability.

Word reading and argument structure complexity

With regard to VAS complexity, the patient's performance on a reading task followed the gradient of complexity indicated by the ASCH: unergative verbs elicited the highest number of correct responses, and accuracy was progressively lower for unaccusative and transitive verbs, although only the difference between unergative and transitive verbs proved to be statistically significant, with the comparison between unaccusative and transitive verbs being marginally significant. As outlined in the introduction, the ASCH assumes two aspects of argument structure complexity: the number of arguments taken by verbs and the presence of underlying syntactic movement. On the basis of expectations grounded in VAS complexity, verbs taking more than one argument, for instance, transitive verbs, are more difficult to retrieve than are unergative verbs, which take only one. With respect to syntactic movement, unaccusative verbs are expected to be more difficult to

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process than are unergative verbs because their construction entails the movement of one of the constituents, similar to the movement occurring in passive sentences (Burzio, 1986; Perlmutter, 1978). The results obtained in the present study are in line with the first of these two predictions but not the second, because syntactic movement did not elicit a significant decrease in accuracy on unaccusative verbs in GR. The absence of an A-movement effect in our data could be due to the limited number of correct responses given by GR. However, an alternative account of this result is possible, that is, that these two effects (argument number and syntactic movement) occur at different levels of lexical processing. Specifically, we assume that argument number, being lexical in nature, becomes available as soon as the lemma is accessed. As far as the issue of unaccusativity is concerned, a further step in terms of language processing is necessary. Unaccusative and unergative verbs do not differ in the number of required arguments but in the way their arguments are subcategorized in a sentence; therefore, the higher complexity of unaccusative verbs compared to unergative verbs may arise only when minimal syntactic activation is required. This hypothesis, as well as accounting for the present data, offers an explanation for the fact that the effect of A-movement for verbs has been found both in a sentence context and in a picture-naming task, but not in a single-word reading task, as discussed further below.

As already mentioned, the influence exerted by the *number of arguments* taken by verbs has been reported in studies assessing verb production in aphasic patients both as singletons and in a sentence context (Jonkers & Bastiaanse, 1998; Luzzatti et al., 2002; Thompson, 2003), as well as in neuroimaging studies testing the processing of both isolated verbs and of verbs in a sentence context (Ben-Shachar, Hendler, Kahn, Ben-Bashat, & Grodzinsky, 2003; den Ouden et al., 2009; Shetreet et al., 2007; Thompson et al., 2007). Moreover, the complexity effect deriving from the number of arguments was elicited not only in tasks requiring production but also by verb categorization (Kim & Thompson, 2000) and lexical decision (Thompson et al., 2007, 2010), that is, in the absence of a syntactic context.

As far as the *effect of syntactic movement* is concerned, evidence that the processing of unaccusative verbs is more demanding than that required for unergative verbs stems mainly from studies on verb retrieval deficits in aphasic patients, both in picture-naming (Luzzatti et al., 2002; Thompson, 2003) and in sentence-production tasks (Lee & Thompson, 2004; Thompson, 2003). A more recent study (McAllister et al., 2009) also reported an effect of A-movement on the performance of both aphasic patients and control participants, showing higher levels of accuracy in producing and comprehending sentences that contain unergative verbs relative to unaccusative verbs. Neuroimaging studies conducted to date have shown an effect of unaccusativity only when processing sentences (see Shetreet et al., 2009, 2012). In conclusion, there is no evidence of an unaccusativity effect for verbs as singletons in tasks other than picture naming, which, when designed to elicit verb production, entail the depiction of the participant(s) in the action, thus increasing the likelihood that a (minimal) sentence structure will be prepared. This assumption is consistent with the results obtained by Cairns, Marshall, Cairns, and Dipper (2007), showing that when asked to name the participants of a given action, control subjects mostly start with the agent, following the same participant order as when producing sentences. Thus, it can be assumed that the effect of unaccusativity, that is, the effect of syntactic movement, may occur while retrieving verbs in a

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picture-naming task but not when participants are asked to perform a lexical decision task or to read verbs aloud, because syntax is unlikely to be activated in the last two conditions. Therefore, it can be assumed that the representation of the number of arguments taken by verbs is contained at the lemma level, whereas the effect of unaccusativity is likely to arise at a postlemma level (e.g., the stage of *grammatical encoding*).[11] In our study, picture-naming data were collected from a different pool of verbs than those used in the word-reading task, thus impeding a full comparison between results of the two tests. GR's performance on the picture-naming task revealed a tendency in line with the aforementioned hypothesis. Of the few verbs GR correctly retrieved, the majority were unergative (35%), whereas only 15% of unaccusative and 10% of transitive verbs were named correctly, suggesting better lexical retrieval when an action is described by an unergative verb rather than by either an unaccusative or a transitive verb.

Lemma access and theories of DD

The present study showed that, in spite of the severity of the lexical damage GR suffered and the resulting severity of her reading impairment, her access to lexical–syntactic features, that is, *lemmas*, where information about VAS is stored, is relatively well preserved. This is consistent with an interpretation of DD based on a cognitive model of the reading process: assuming damage to both the GPC and the direct lexical route ("multiple-deficits account"; Newcombe & Marshall, 1980; Nolan & Caramazza, 1982; Shallice & Warrington, 1980), reading can be achieved through the lexical–semantic route only, thus implying access to the semantic and lexical features of words. Therefore, the possibility of accessing lemma information (assumed to be located between semantics and lexeme information in the processing stream; Levelt, 1989, 2001) is in line with this model. As described in the introductory section, another interpretation of DD is the RHH (Coltheart, 1980, 2000; Saffran, Bogyo, Schwartz, & Marin, 1980), which considers the symptoms of DD as resulting from the emerging linguistic abilities of the RH, limited to frequent and concrete nouns. Within this theoretical framework, if lemma information is retrieved before the phonological word form, two alternative options need to be considered: (a) lemma information is stored in both hemispheres, and so DD patients may access it in the RH; (b) lemmas are represented only in the LH, so DD patients would still be able to access this information. The second option seems to be more likely: written words are processed in the RH up to the retrieval of semantic features, after which the processing has to shift to the LH to access lemma information. Given that the RH is assumed to have a concrete linguistic competence, the possibility of accessing abstract lemma information seems unlikely.

A third account of DD is the FIT (Buchanan et al., 2003), according to which both semantic paralexia and the impossibility of reading nonwords are explained as defective inhibition of the semantic competitors within the semantic system and of the coactivated words within the phonological output lexicon respectively. This theory has a significant advantage in that it explains the complexity of DD symptoms in terms of a single mechanism: the defective inhibition of active competitors. Unfortunately, it does not offer an explanation for the grammatical class and imageability effects that are often observed in DD. The FIT is based on

https://doi.org/10.1017/S0142716413000337 Published online by Cambridge University Press

the PEIR model of lexical production, which posits a distinction between implicit and explicit access to phonological, semantic, and morphological information. According to this model, DD is caused by impaired explicit access to phonological representations, in spite of preserved implicit access. Because GR was able to access VAS information, our results are consistent with a spared implicit access to word lexical information. However, Buchanan et al's theory does not offer an explanation for the grammatical class and imageability effects, and inhibition of lexical competitors is not sufficient to explain a greater impairment in reading transitive versus unergative verbs.

Conclusion

To conclude, the results of this study reveal a dissociated pattern of impairment between unergative and transitive verbs, which indicates, in line with the ASCH, that the effect of the number of arguments is also present in a reading task. However, the absence of a clear difference in levels of accuracy between unergative and unaccusative verbs, which would also be predicted by the ASCH, suggests that the processing of unaccusative verbs may arise at a separate postlexical grammatical encoding level. Given the slight difference in the raw scores obtained by GR on unergative and unaccusative verbs, this claim requires substantiation by further evidence from studies of other DD patients. GR's sensitivity to VAS properties supports the theory that her access to lexical–syntactic word properties (stored at the lemma level) has been spared. The possibility for DD patients to access lemma information is in line with both the multiple-deficit and the RHH accounts of DD, while the FIT only partially accounts for our data.

APPENDIX A

Items included in the word-reading task

N	Word Type	Item	English Trans.	WF	LENG	IMG
V1	Unergative	*accedere*	To access	61	8	3.1
V2	Unergative	*aderire*	To join	103	7	2.5
V3	Unergative	*approfittare*	To profit	133	12	2.4
V4	Unergative	*badare*	To look after	99	6	2.7
V5	Unergative	*beneficiare*	To benefit	25	11	2.1
V6	Unergative	*camminare*	To walk	234	9	5.6
V7	Unergative	*collaborare*	To collaborate	115	11	3.7
V8	Unergative	*convivere*	To live with	71	9	4.0
V9	Unergative	*debuttare*	To start off	58	9	3.1
V10	Unergative	*esitare*	To hesitate	93	7	2.7
V11	Unergative	*esordire*	To begin	61	8	2.8
V12	Unergative	*funzionare*	To work	301	10	3.2
V13	Unergative	*godere*	To enjoy	241	6	4.9
V14	Unergative	*insistere*	To insist	244	9	3.1
V15	Unergative	*litigare*	To quarrel	58	8	4.9
V16	Unergative	*navigare*	To navigate	48	8	5.4

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APPENDIX A (*cont.*)

N	Word Type	Item	English Trans.	WF	LENG	IMG
V17	Unergative	*obbedire*	To obey	38	8	3.6
V18	Unergative	*parlare*	To speak	2969	7	5.6
V19	Unergative	*partecipare*	To participate	462	11	3.5
V20	Unergative	*ragionare*	To reason	75	9	3.3
V21	Unergative	*reagire*	To react	170	7	2.9
V22	Unergative	*resistere*	To resist	184	9	3.1
V23	Unergative	*rispondere*	To reply	1289	10	4.7
V24	Unergative	*scherzare*	To joke	126	9	4.2
V25	Unergative	*usufruire*	To take advantage of	32	9	2.3
V26	Unergative	*viaggiare*	To travel	215	9	5.5
V27	Unaccusative	*appartenere*	To belong	312	11	2.3
V28	Unaccusative	*approdare*	To land	89	9	3.4
V29	Unaccusative	*assomigliare*	To look like	77	12	4.0
V30	Unaccusative	*circolare*	To circulate	114	9	3.9
V31	Unaccusative	*confluire*	To merge	31	9	3.2
V32	Unaccusative	*crollare*	To collapse	102	8	4.7
V33	Unaccusative	*dipendere*	To depend	263	9	2.3
V34	Unaccusative	*esistere*	To exist	917	8	2.4
V35	Unaccusative	*prevalere*	To prevail	91	9	3.2
V36	Unaccusative	*provenire*	To come from	235	9	2.0
V37	Unaccusative	*rabbrividire*	To shiver	20	12	4.1
V38	Unaccusative	*ricadere*	To fall back	51	8	2.9
V39	Unaccusative	*rientrare*	To get back	306	9	3.0
V40	Unaccusative	*rinascere*	To come back to life	40	9	1.9
V41	Unaccusative	*risorgere*	To resurrect	23	9	3.1
V42	Unaccusative	*risultare*	To result	468	9	1.7
V43	Unaccusative	*scappare*	To run away	215	8	5.2
V44	Unaccusative	*scaturire*	To spring out	51	9	2.1
V45	Unaccusative	*scivolare*	To slip	99	9	5.3
V46	Unaccusative	*scomparire*	To disappear	300	10	3.8
V47	Unaccusative	*somigliare*	To look like	71	10	3.9
V48	Unaccusative	*sopravvivere*	To survive	131	12	2.5
V49	Unaccusative	*sorgere*	To rise	144	7	4.3
V50	Unaccusative	*spettare*	To be up to	140	8	1.5
V51	Unaccusative	*stare*	To stay	4391	5	3.0
V52	Unaccusative	*tramontare*	To set	31	10	4.8
V53	Transitive	*ammettere*	To admit	443	9	2.7
V54	Transitive	*approvare*	To approve	254	9	3.3
V55	Transitive	*arredare*	To furnish	36	8	4.8
V56	Transitive	*autorizzare*	To authorize	96	11	2.3
V57	Transitive	*avvisare*	To warn	46	8	4.0
V58	Transitive	*conoscere*	To know	1362	9	3.1
V59	Transitive	*convocare*	To summon	143	9	3.8
V60	Transitive	*dimezzare*	To halve	29	9	3.8
V61	Transitive	*esplorare*	To explore	54	9	4.3
V62	Transitive	*esporre*	To expose	234	7	4.3
V63	Transitive	*imprigionare*	To imprison	20	12	4.6
V64	Transitive	*incoraggiare*	To encourage	75	12	4.3

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APPENDIX A (*cont.*)

N	Word Type	Item	English Trans.	WF	LENG	IMG
V65	Transitive	*inseguire*	To chase	133	9	5.0
V66	Transitive	*invadere*	To invade	96	8	3.3
V67	Transitive	*ipotizzare*	To hypothesize	88	10	2.3
V68	Transitive	*nascondere*	To hide	491	10	4.7
V69	Transitive	*percepire*	To perceive	81	9	2.3
V70	Transitive	*perquisire*	To frisk	20	10	4.3
V71	Transitive	*preoccupare*	To worry	235	11	3.1
V72	Transitive	*privilegiare*	To privilege	51	12	2.2
V73	Transitive	*richiamare*	To phone back	152	10	3.5
V74	Transitive	*rifiutare*	To reject	333	9	4.5
V75	Transitive	*rispettare*	To respect	268	10	2.9
V76	Transitive	*stabilire*	To state	390	9	2.2
V77	Transitive	*trovare*	To find	3267	7	4.2
V78	Transitive	*vantare*	To boast	93	7	2.7
N1	Noun	*bambola*	doll	46	7	6.7
N2	Noun	*biscotto*	biscuit	25	8	6.9
N3	Noun	*calzoni*	trousers	15	7	6.1
N4	Noun	*carota*	carrot	41	6	6.9
N5	Noun	*colesterolo*	cholesterol	18	11	3.1
N6	Noun	*corsa*	run	456	5	5.5
N7	Noun	*dominio*	domain	62	7	2.2
N8	Noun	*enciclopedia*	encyclopedia	18	12	6.3
N9	Noun	*ferro*	iron	206	5	6.1
N10	Noun	*fortuna*	luck	400	7	2.3
N11	Noun	*giostra*	carousel	21	7	6.4
N12	Noun	*lievito*	yeast	4	7	6.1
N13	Noun	*militare*	soldier	162	8	5.9
N14	Noun	*nomina*	appointment	110	6	2.3
N15	Noun	*pastore*	shepherd	51	7	6.4
N16	Noun	*pavimento*	floor	100	9	6.3
N17	Noun	*pirata*	pirate	26	6	6.6
N18	Noun	*posta*	mail	134	5	6.3
N19	Noun	*ricompensa*	reward	13	10	3.9
N20	Noun	*rinoceronte*	rhinoceros	7	11	6.7
N21	Noun	*rovina*	ruin	67	6	3.9
N22	Noun	*sagrestano*	sexton	3	10	5.7
N23	Noun	*saracinesca*	shutter	19	11	6.3
N24	Noun	*sentimento*	feeling	266	10	3.1
N25	Noun	*tavolo*	table	390	6	7.0
N26	Noun	*telefono*	telephone	433	8	6.8
N27	Noun	*treno*	train	230	5	7.0
N28	Noun	*veterinario*	veterinarian	21	11	6.1
N29	Noun	*viso*	face	284	4	6.1
N30	Noun	*vittoria*	victory	419	9	5.1
N31	Noun	*zimbello*	laughingstock	2	8	3.4

Note: Word type, and lexical variables (WF, written word frequency; LENG, length; IMG, imageability) are listed for each item, together with the corresponding meaning in English.

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APPENDIX B

Reading errors committed by a patient (GR) on both sessions

N	Word Type	Target	Production	English Trans.	Error Type	Session
V1	Unergative	accedere	accendere	To light up	Visual	1st
V6	Unergative	camminare	cammino	Walk [noun/verb?]	Morphological	1st
V8	Unergative	convivere	vivendo	Living	Morphological	1st
V12	Unergative	funzionare	funivia	Cableway	Visual	1st
V16	Unergative	navigare	navale	Nautical	Morphological	1st
V20	Unergative	ragionare	ragioniere	Accountant	Morphological	1st
V23	Unergative	rispondere	pronto	Hello	Semantic	1st
V26	Unergative	viaggiare	viaggi	[You] travel/trips [noun]	Morphological	1st
V32	Unaccusative	crollare	trasloco	Move [noun]	Unrelated	1st
V51	Unaccusative	stare	stira	[He/she] irons	Visual	1st
V53	Transitive	ammettere	manette	Handcuffs	Visual	1st
V61	Transitive	esplorare	espiorare[a]	[Neologism] [verb]	Graph/phon subst	1st
V67	Transitive	ipotizzare	ipnotico	Hypnotic	Mixed (v+m)	1st
V68	Transitive	nascondere	moscacieca	Blindsman's bluff	Semantic	1st
V73	Transitive	richiamare	telefonare	To phone	Semantic	1st
N12	Noun	lievito	vaniglia	Vanilla	Semantic	1st
N14	Noun	nomina	domino	Domino	Visual	1st
N28	Noun	veterinario	veterinaria	Female veterinarian	Morphological	1st
N30	Noun	zimbello	zio bello	Handsome uncle	Visual	1st
V1	Unergative	accedere	accendere	To light up	Visual	2nd
V4	Unergative	badare	badante	Caregiver	Morphological	2nd
V12	Unergative	funzionare	funivia	Cableway	Visual	2nd
V19	Unergative	partecipare	partire	To leave	Visual	2nd

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APPENDIX B (*cont.*)

N	Word Type	Target	Production	English Trans.	Error Type	Session
V20	Unergative	ragionare	ragioneria	Accounting	Morphological	2nd
V23	Unergative	rispondere	cognome	Last name	Semantic	2nd
V34	Unaccusative	esistere	stranieri	Foreigners	Mixed (v+s)	2nd
V40	Unaccusative	rinascere	rinascente	Rinascente [Name of a department store, lit. resurgent]	Morphological	2nd
V42	Unaccusative	risultare	scrivanie	Desks	Unrelated	2nd
V43	Unaccusative	scappare	scarpe	Shoes	Visual	2nd
V48	Unaccusative	sopravvivere	forevivi[a]	[Neologism] [noun/verb?]	Unrelated	2nd
V49	Unaccusative	sorgere	scivolare	To slip	Unrelated	2nd
V50	Unaccusative	spettare	spettacolo	Show [noun]	Visual	2nd
V51	Unaccusative	stare	stira	[He/she] irons	Visual	2nd
V53	Transitive	ammettere	manette	Handcuffs	Visual	2nd
V61	Transitive	esplorare	guardare	To watch	Semantic	2nd
V63	Transitive	imprigionare	prigioniere	Female prisoners	Morphological	2nd
V68	Transitive	nascondere	nascondino	Hide-and-seek	Morphological	2nd
V73	Transitive	richiamare	mare	Sea	Visual	2nd
V74	Transitive	rifiutare	pattumiera	Trash	Semantic	2nd
V76	Transitive	stabilire	stabile	Stable	Morphological	2nd
V78	Transitive	vantare	divano	Couch	Visual	2nd
N15	Noun	pastore	pecora	Sheep	Semantic	2nd
N23	Noun	saracinesca	farmacia	Pharmacy	Semantic	2nd
N29	Noun	viso	vaso	Vase	Visual	2nd

Note: Only lexical substitutions are listed. v, visual; m, morphological; s, semantic; graph/phonol subs, graphemic/phonological substitution.
[a]Neologisms.

ACKNOWLEDGMENTS

Preliminary results of this study were presented at the Seventh International Conference on the Mental Lexicon, Windsor, 2010; at the American Academy of Clinical Neuropsychology Congress, Chicago, 2010; and at Structuring the Argument: A Multidisciplinary Workshop on the Mental Representation of Verbal Argument Structure, Paris, 2011. The authors are thankful to Cynthia K. Thompson and to the reviewers for the comments on a previous version of the manuscript, as well as to Jennifer Mack, Carlo Geraci, and Alessio Toraldo for some helpful suggestions. The last author acknowledges support from Ministero dell'Istruzione, dell'Università e della Ricerca (20074EKLSX_002) and Finlombardia (ASTIL 2010).

NOTES

1. Transitive verbs that describe psychological states ("psych-verbs") assign thematic roles in two different ways. In agent–experiencer verbs (e.g., *to fear*), the grammatical subject receives the role of experiencer, whereas object–experiencer verbs (e.g., *to frighten*) assign the thematic role of experiencer to the direct object.
2. A-movement is defined as the movement of a NP to a position assigning a grammatical function (e.g. subject or object) and where inflectional properties (e.g., agreement or tense) are checked (see Chomsky, 1995).
3. There are several ways of testing unaccusativity in English: for instance, the past participle of unaccusative verbs (but not unergative verbs) can also be used as an adjective modifying a noun (e.g., *the fallen vase* vs. **the slept man*). In addition, unaccusative verbs can be inserted in the "expletive there" construction, that is, where an unaccusative verb is preceded by *there* and followed by the grammatical subject, as in *there fell a vase in the kitchen*, the same construction is ungrammatical with unergative verbs (e.g., **there slept John in his bed*). See Levin (1993) for a more detailed description of the several tests for unaccusativity in English.
4. The number of subcategorization options indicates the number of different syntactic constituents that can follow a verb. For instance, verbs like *to chase* can only be complemented by a NP (e.g., *The cat chases the mouse*), whereas the verb *to believe* can take either a prepositional phrase or a clause (complementizer phrase) as its argument (e.g., *the judge believed in the witness* as well as *the woman believed that her husband was telling the truth* are both grammatical).
5. *Dual route* models were introduced as a compromise solution in the debate between supporters of the *full-listing* and those of the *full-parsing* models of complex words processing. While *full-listing* theories assume that morphologically complex words are represented as a whole in the lexicon, independently of morphologically related forms, *full-parsing* models are based on a fully decomposed representation of inflected and derived forms, where the root and the suffixes are stored separately and (de)composed online.
6. According to the PEIR, production is based on explicit access, which follows implicit access, which in turn depends on intact representations. This model of lexical processing is the theoretical framework in which the FIT was conceived.
7. The AAT comprehension subtest does not make a distinction between nouns and verbs.

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8. The verb *mangiare* (to eat) is optionally transitive in that it can be used either as an unergative (e.g., *Carlo mangia velocemente* [Carlo eats fast]) or as a transitive verb (e.g., *Carlo mangia un panino* [Carlo eats a sandwich]).
9. Alternating unaccusative verbs (e.g., *to break*) support both a transitive (e.g., *John broke the glass*) and an unaccusative form (e.g., *The glass broke*) that causes them to be processed differently from pure unaccusative verbs (e.g., *to bloom*). This difference is supported by studies conducted on both normal (see Friedmann et al., 2008) and aphasic participants (see Bastiaanse & van Zonneveld, 2005).
10. Italian has a rich morphology, with both verbs and nouns always being inflected. Unlike English, the deletion of the inflectional affix of a verb or a noun would result in a nonword. However, not all inflections are equally difficult for Italian agrammatic patients: they usually produce verbs either in the infinitive form (e.g., *mangiare* [to eat]) or in the third-person singular present tense (e.g., *mangia* [he/she eats]).
11. In Levelt's model of lexical selection (Levelt, 2001; Levelt et al.,1999), *grammatical encoding* is the stage in which the creation of the "syntactic environment," that is, the realization of phrases and clauses, begins.

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