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Linguistica e Neuroscienze Cognitive (XXIII ciclo)

**An investigation of argument structure processing in normal  
and aphasic participants:**

**A test of the Argument Structure Complexity Hypothesis**

**(Thompson, 2003)**



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*To my grandma, Giulia,  
who first introduced me to written language,  
by teaching me how to read.*

## TABLE OF CONTENTS

<i>Abstract</i> .....	6
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### *Part 1: Theory*

1. Verbs, arguments and models of lexical production.....	8
1.1. Verbs and arguments within the theoretical framework of generative grammar.....	8
1.2. Unaccusativity in Italian.....	10
1.3. Multiple argument structures and subcategorization options.....	11
1.4. Arguments and adjuncts.....	13
1.5. Argument structure in models of language production.....	13
1.6. An alternative account: The constructional approach to argument structure.....	17
2. Acquired disorders of language processing:	
The several sides of aphasia.....	19
2.1. Aphasia: Definition and principles of classification.....	19
2.2. Morpho-syntactic deficits in aphasia.....	20
2.3. The verb-specific impairment in nonfluent aphasia.....	22
2.4. Acquired dyslexia and grammatical class effects: the case of deep dyslexia.....	25
3. Verb argument structure deficits in aphasia.....	29
3.1. The Argument Structure Complexity Hypothesis (ASCH).....	29
3.2. Argument structure complexity I: the effect of the number of arguments.....	30
3.3. Argument structure complexity II: the effect of syntactic movement.....	31
3.4. Argument structure processing in healthy individuals.....	32
3.5. Processing arguments and adjuncts in nonfluent aphasia.....	33
3.6. Fluent aphasia and argument structure deficits.....	34
3.7. A study of argument realization during sentence production: picture description in fluent and nonfluent aphasic patients.....	34

## ***Part 2: Experimental data***

4. Aim of the study.....	40
5. Experiment 1: A study on the processing of transitive and intransitive verbs in healthy Italian participants.....	43
5.1. Introduction.....	43
5.2. Aim of the study.....	45
5.3. Participants.....	45
5.4. Materials and methods.....	46
5.5. Procedure.....	47
5.6. Results.....	48
5.7. Discussion.....	50
6. Experiment 2: Accessing semantic and argument structure information while completing a sentence: data from English normal participants.....	53
6.1. Introduction.....	53
6.2. Aim of the study.....	54
6.3. Participants.....	55
6.4. Materials and methods.....	55
6.4.1. Argument structure choice (Condition 1).....	56
6.4.2. Semantic choice (Condition 2).....	58
6.5. Procedure.....	58
6.6. Results.....	59
6.7. Discussion.....	62

7. Experiment 3: Argument structure and lemma access in fluent and nonfluent aphasia.....	65
7.1. Introduction.....	65
7.2. Aim of the study.....	68
7.3. Participants.....	
7.4. Materials and methods.....	
7.5. Results.....	70
7.6. Discussion.....	75
8. Experiment 4: A test of the ASCH in a word naming task.....	79
8.1. Introduction.....	79
8.1.1. Why studying deep dyslexia?.....	80
8.2. Aim of the study.....	82
8.3. Participant.....	83
8.4. Materials and methods.....	85
8.5. Results.....	86
8.5.1. Quantitative data analysis.....	88
8.6. Discussion.....	89
8.6.1. Grammatical class effects and imageability.....	90
8.6.2. Word naming and argument structure complexity.....	91
8.6.3. Lemma access and theories of deep dyslexia.....	94
9. General discussion.....	96
10. Acknowledgements.....	100
11. References.....	102

## **Abstract**

The study was conducted so as to test the mental organization of verb argument structure (VAS) and the generalization of the predictions based on the Argument Structure Complexity Hypothesis (ASCH; Thompson, 2003), which explains the pattern of impairment of the agrammatic patients' verb production as a function of the argument structure complexity, i.e. both in terms of the number of arguments taken by a verb (transitive vs. unergative verbs) and of the presence of syntactic movement (unaccusative vs. unergative verbs). The aim was i) to test the effect of the number of arguments in a task tapping lemma access bypassing overt production, in both neurologically unimpaired (Experiment 1 and 2) and aphasic participants (Experiment 3), and ii) to test the effect both of the number of arguments and of syntactic movement in a patient with deep dyslexia (Experiment 4). Moreover, an additional goal was to inform about the deficit underlying the verb-specific impairment that characterizes nonfluent aphasia, by testing the hypothesis of a defective lemma access as compared to a deficit at the level of grammatical encoding (Experiment 3). A third goal was to test the assumption of a separate level of representation for semantic and VAS information, as suggested by models of contemporary psycholinguistics (Experiment 2). In Experiment 1, 2 and 3 participants were asked to perform a sentence completion task by choosing among two verb options that differed either in the VAS (unergative vs. two-place transitive verb) or in the verb semantic content (Condition 2 of Experiment 2 only). Experiment 4 provided instead a deep dyslexic patient with a word naming task that was performed both on verbs belonging to different categories (unergative, unaccusative, transitive) and on nouns. Results from Experiment 1, 2 and 3 demonstrate that access to VAS information is faster (for healthy subjects) and easier (for aphasic patients) for unergative than for transitive verbs, thus suggesting the possibility that the ASCH more generally reflects an aspect of normal language processing. In addition, results from Experiment 4 offer support only to the first prediction of the ASCH, suggesting that the effect of the number of arguments and the effect of syntactic movement arise at different level of processing. Finally, data from Experiment 2 demonstrate that VAS and semantic information can be accessed independently, in line with models of contemporary psycholinguistics.

**Part 1**

**Theory**

# 1. Verbs, arguments and models of lexical production

## 1.1. Verbs and arguments within the theoretical framework of generative grammar

A verb argument structure (VAS) is a feature specifying the number and type of participants in the event described by a verb. Arguments are elements obligatorily required by a verb: an argument is defined as external when it is generated outside the verb phrase (VP)<sup>1</sup> within the sentence syntactic structure, e.g. the grammatical subject. On the contrary, internal arguments originate inside the VP, e.g. the verb direct object. For instance, in (1a), the grammatical subject of the sentence, i.e. the noun phrase (NP) *the man*, is an external argument; the same holds for the NP *the dog* in (1b), whereas in the same sentence the NP *the cat* is the verb internal argument, which also plays the role of direct object of the verb *to chase*.

(1) a. The man snored

[<sub>IP</sub>The man[<sub>VP</sub>snored]]

b. The dog chased the cat

[<sub>IP</sub>The dog[<sub>VP</sub>chased <sub>NP</sub>the cat]]

c. The girl put the book on the shelf

[<sub>IP</sub>The girl[<sub>VP</sub>put <sub>NP</sub>the book <sub>PP</sub>on the shelf]]

Verbs require at least one argument<sup>2</sup>, which plays the role of the grammatical subject in the sentence. As far as the number of required arguments, transitive verbs require at least two arguments, one of which is the direct object (1b). However, there are transitive verbs that require three arguments, e.g. *to put* (1c). In (1c), both the NP *the book* and the prepositional phrase (PP) *on the shelf* are indeed obligatory elements subcategorized by the verb. On the other side, intransitive verbs usually take only one argument, corresponding to the grammatical subject of the sentence.

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<sup>1</sup> Within the theoretical framework of Chomsky's Government and Binding Theory (Chomsky, 1981; Chomsky & Lasnik, 1991), a sentence may be represented as a tree with nodes and branches. Each node splits into a head, a complement and a specifier. As far as the verb phrase (VP) node, it may be either constituted of the verb (V) only (see(1a)), or the complement position may be filled by a noun phrase (NP, see (1b)).

<sup>2</sup> An exception to this rule is represented by Italian meteorological verbs as *piovere* and impersonal verbs as *sembrare*, which do not take a grammatical subject (e.g. *piove* [(it) rains], *sembra* [(it) seems]); furthermore, Italian language allows subject prodrop, i.e. the omission of subject pronouns.



However, the distinction is not always straightforward: indeed, many verbs - both in English and Italian - are optionally transitive, i.e. they may take an internal argument, which under some circumstances is not necessary. For instance, the verb *to read* can be either followed by a direct object (2b), by a direct and an indirect object (2c), or can occur in an intransitive construction (2a)

(2) a. Liz is reading

b. Cindy reads the novel

c. The teacher reads the novel to the children

As far as intransitive verbs are concerned, they can be further classified into two categories according to the type of arguments they require. In detail, unergative verbs like *to snore* (1a) take an external argument, i.e. the grammatical subject of the sentence; on the contrary, in unaccusative sentences as (3) the grammatical subject is an internal argument. Indeed, according to the so-called Unaccusative Hypothesis (Perlmutter, 1978; Burzio, 1986), grammatical subjects of unaccusative sentences originate within the VP, i.e. in the position of the direct object, and then move outside the VP to the position of grammatical subject.

(3) The book disappeared

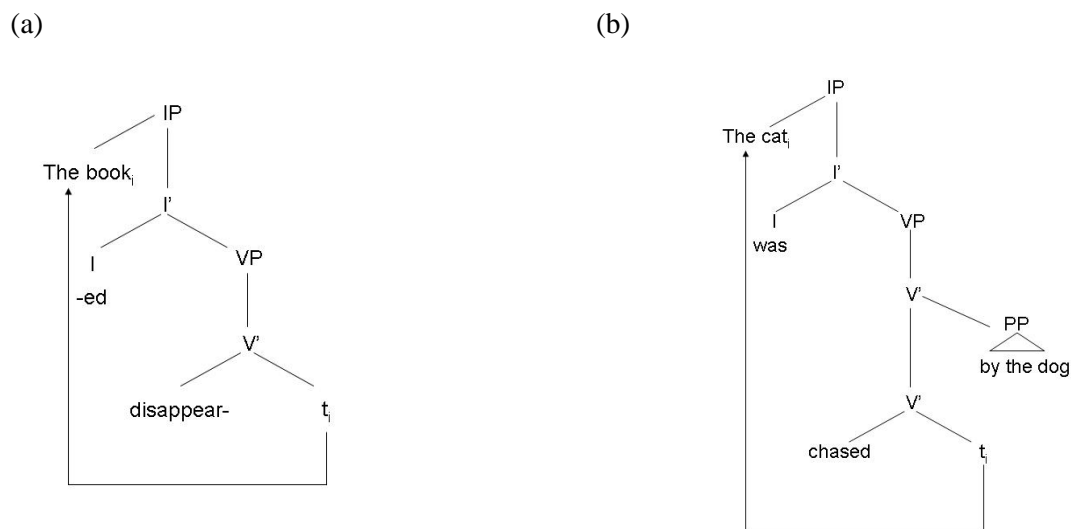
[<sub>IP</sub>The book<sub>i</sub> [<sub>VP</sub>disappeared *t<sub>i</sub>*]]

The difference in the type of arguments taken by unergative and unaccusative verbs reflects a difference in the deep structure (d-structure)<sup>3</sup> of corresponding sentences, in that unaccusative sentences entail a syntactic movement analogous to the movement underlying passive sentences (Figure 1). Indeed, in both unaccusative and passive sentences, the NP-direct object of the verb moves out of the VP leaving a trace (*t*) behind. A trace is a silent element that plays the function of allowing thematic role assignment, i.e. the process by which arguments are assigned a specific

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<sup>3</sup> According to the theoretical framework of generative grammar, each sentence has a deep structure (d-structure), i.e. the sentence in the declarative, affirmative and active form. The application of transformational rules to the d-structure results in the surface structure (s-structure), which corresponds to sentence as it appears to the speaker, e.g. in the passive form (Chomsky, 1995).

thematic role identifying the role that each participant plays in the action described by the verb. In active transitive sentences as *the dog chases the cat*, the NP-subject *the dog* receives the role of Agent since it performs the action; the NP-object *the cat* receives instead the role of Theme, which identifies the participant who undergoes the action. Both in passive and unaccusative sentences, the main verb assigns the role of Theme to the NP-subject, as a result of syntactic movement (see Figure1).



**Figure 1.** (1a). Representation of the unaccusative sentence *The book disappeared*. (1b). Representation of the passive sentence *The cat was chased by the dog*. As outlined in the picture, the syntactic movement entailed by the two sentences is very similar, in that it involves the NP-subject that originates in the post-verbal complement position and then moves out of the VP to the position occupied by the grammatical subject, i.e. the specifier of the Inflectional Phrase (IP). The black arrow highlights the syntactic movement and the co-indexation of the noun constituent (NP). Note that in (1b) the role of Agent is assigned to the prepositional phrase (PP) *by the dog*.

## 1.2. Unaccusativity in Italian

The same difference in d-structure between unergative and unaccusative verbs illustrated in Figure 1 for English applies to Italian. However, Italian and English differ with respect to the way unergative and unaccusative verbs may be distinguished. In detail, English unaccusative verbs may be distinguished from unergative verbs because they can be used in some linguistic constructions

that are not supported by unergative verbs<sup>4</sup>. The distinction is easier in Italian than in English because Italian verbs select different auxiliaries: unaccusative verbs (e.g. *cadere* [to fall]) are preceded – in composite past forms - by the auxiliary *essere* [to be], whereas unergative verbs (e.g. *dormire* [to sleep]) require the auxiliary verb *avere* [to have]. For instance, the composite past form of the verb *cadere* would be *è caduto* (e.g. *Il ragazzo è caduto* [The boy has fallen, lit. The boy is fallen]), whereas for the verb *dormire* the composite past form is *ha dormito* (e.g. *Gianni ha dormito* [Gianni has slept]). A distinction based on the type of auxiliary is common to other languages, like French and Dutch. Moreover, in Italian, the claim of a similarity between passive and unaccusative sentences in their underlying syntactic structure – as outlined by the Unaccusative Hypothesis - is also supported by the use of the same auxiliary in the composite form of both verb types. Indeed, both require the verb *essere*, as shown in (4)

(4) a. *Il ragazzo è caduto* (unaccusative)

[The boy has fallen, lit. The boy is fallen]

b. *Il gatto è inseguito dal cane* (passive)

[The cat is chased by the dog]

### 1.3. Multiple argument structures and subcategorization options

As already mentioned, sometimes the classification of verbs into a category according to their argument structure is not straightforward. Indeed, besides the case of optionally transitive verbs (see 1.1), which may be implemented either in a transitive or in an unergative sentence, there are verbs (see (5)) that may occur either in an unaccusative (5a) or in a transitive (5b) construction.

(5) a. The vase broke

b. The girl broke the vase

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<sup>4</sup> There are several ways of testing unaccusativity in English (see Levin, 1993): for instance the past participle form of unaccusative verbs - unlike unergative ones - 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, i.e. while an unaccusative verb can be 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*).

These verbs are much more common in English than in Italian, and are known as “alternating unaccusative verbs”. One of the rare examples in Italian is represented by *affondare* [to sink] (6), which can occur either in (6a) or in (6b).

(6) a. *La nave è affondata* (unaccusative)

[The ship sank, lit. The ship is sank]

b. *I pirati hanno affondato la nave* (transitive)

[The pirates sank the ship]

In addition, there are verbs that take three different argument structures, as *correre* [to run] in (7):

(7) a. *Mario ha corso tutto il giorno* (unergative)

[Mario ran all day, lit. Mario has run all day]

b. *Mario è corso fino a casa* (unaccusative)

[Mario ran home, lit. Mario is run home]

c. *Mario ha corso la maratona di New York* (transitive)

[Mario ran the marathon in New York, lit. Mario has run the marathon in New York]

Verbs like (7) have multiple argument structures, often entailing a different number of arguments. Furthermore, some verbs have only one argument structure but may be implemented in different syntactic structures. This is the case of verbs like *spruzzare* [to spray], which may be implemented in two different syntactic structures, as shown in (8)

(8). a. *Carlo spruzza il muro con la vernice*

[Carlo sprays the wall with the paint]

b. *Carlo spruzza la vernice sul muro*

[Carlo sprays the paint on the wall]

Those verbs have two different subcategorization options, one (8a) where the instrument (*la vernice* [the paint]) is realized as a PP-adjunct following the direct object (*il muro* [the wall]), and one (8b) where *la vernice* is realized as a NP-object followed by a PP-argument (*sul muro* [on the wall]) that receives the role of Goal<sup>5</sup>.

Another example of verbs with multiple subcategorization options is *to believe*, which can either occur in a sentence as *the woman believed her husband*, where the verb is followed by a NP-direct object, in a sentence as *the woman believed in God*, where a PP-indirect object follows the verb, or in a sentence as *the woman believed that her husband was telling the truth*, where the verb is followed by a Complementizer Phrase (CP) that serves as the verb direct object.

#### *1.4. Arguments and adjuncts*

As above mentioned, arguments are obligatorily required by verbs; adjuncts are instead never necessary. An example of adjunct is given in (9), by the PP *in the kitchen*.

(9) The woman was cooking pasta in the kitchen

In (9), the PP *in the kitchen* is an adjunct in that it adds a specification to the verb and to its arguments (see Byng & Black, 1989), but is unnecessary for the syntactic implementation of the verb in the sentence. Adjuncts differ from arguments in that they are not specified by VP (Jackendoff, 1977). As a consequence of this, they are not verb-specific and they do not receive any thematic role from the verb (Grimshaw, 1990).

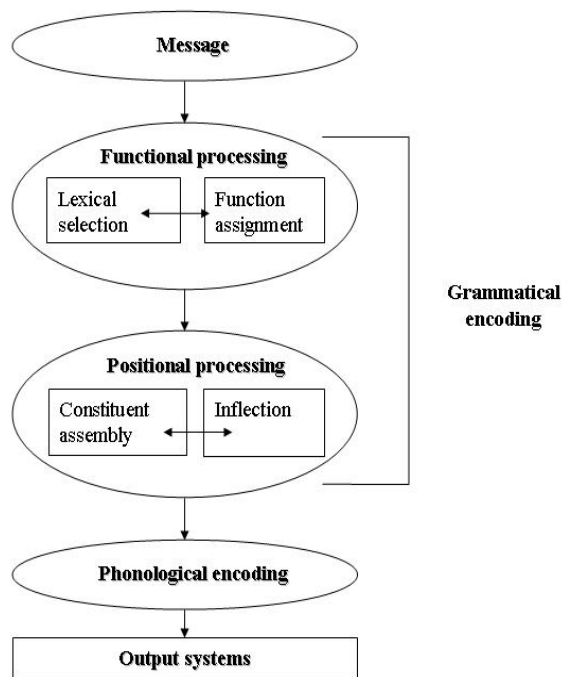
#### *1.5. Argument structure in models of language production*

Some of the most influential theories of sentence production entail a representation of VAS and the thematic roles assigned by a verb to its arguments. In the psycholinguistic literature, the model introduced by Bock & Levelt (1994), and based on Garrett's (1980) model of sentence production, assumes that syntactic planning is carried out in two stages: the functional level and the positional

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<sup>5</sup> The thematic role of Goal identifies the thing/person that is the final recipient of an action.

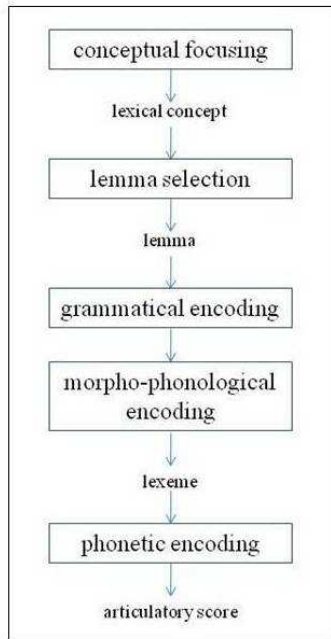
level. The functional level corresponds to the process of accessing word lemmas – defined by Levelt (1989) as “packages of syntactic information” – which specify, e.g. the grammatical gender of nouns, the number and type of arguments for verbs, and the thematic roles assigned by a verb to its arguments. The positional level entails the specification of the position of each lexical unit within a sentence, together with the introduction of closed-class words (e.g. auxiliaries, prepositions) and the specification of bound morphemes, e.g. inflectional and derivational affixes. The following step is phonological encoding, i.e. the stage at which the word phonological representation (lexeme) is accessed. According to this model (Figure 2), lemmas are accessed strictly before lexemes, following the assumption of modularity (Fodor, 1983).



**Figure 2.**

Bock & Levelt’s (1994) model of lexical production. As in Garrett (1980), the first level entails the abstract representation of the content (message). The following stage is the functional level, where lemmas are selected, and verb arguments as well as information about the verb thematic roles are made available. At this level, planning involves several constituents at the same time. The next stage is positional processing, in which – within each phrase – a specific position is assigned to each lexical unit. Only at this level, closed class words are inserted into the syntactic structure. The following level is phonological encoding, i.e. access to the word phonological representation (lexeme). The latter are then sent to output systems for articulation.

The assumption of modularity still remains in the latest version of Levelt's model (Levelt, Roelofs & Meyer, 1999; Levelt, 2001; see Figure 3), which is based on a computational model named WEAVER ++ (Roelofs, 1997). As outlined in Figure 3, the production process begins with conceptual preparation, i.e. the process by which the intentional message is transformed into a "lexical concept" and which is modulated by semantic and pragmatic factors as the speaker's perspective. Within this level, lexical concepts are conceived as nodes whose connections specify conceptual relations (e.g. "as to"). Once a specific lexical concept is selected, activation spreads to the following level, i.e. lexical selection. Each lexical concept spreads activation not only to the correspondent lemma, but also to its "neighbors", i.e. to lemmas that have connections with it. Lemma selection takes place according to a statistically-driven process whereby "during any minimal time unit, the probability of selecting the target lemma equals the ratio of its activation to the sum of activation of all lemmas" (Levelt, 2001). Lemmas are connected to nodes specifying syntactic features, e.g. in the case of a verb like *to take*, nodes will specify the grammatical category (verb), the required number of arguments (two), and other parameters like tense and aspect. Lemma access therefore implies that syntactic information is made available and is then used for grammatical encoding, i.e. the process by which phrases and propositions are created. Selected lemmas then spread activation to the following level: the morpho-phonological encoding, i.e. the stage where the phonological representation of a word (lexeme) is retrieved. At this level several types of information are accessed, i.e. morphological (related to the constituent morphemes), metrical (concerning the position of accents) and segmental (regarding the constituent phonemes). The penultimate stage is phonetic encoding, i.e. a preliminary and abstract encoding of the word as a motor sequence of articulatory gestures. The latter is eventually executed by the articulatory system.

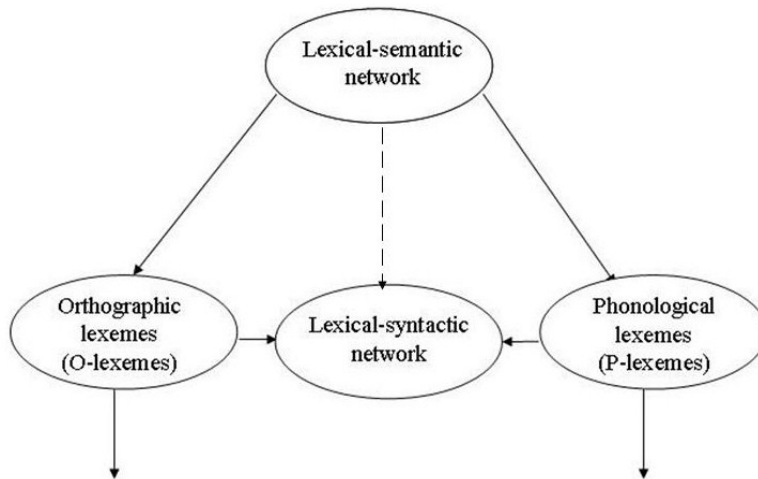


**Figure 3.**  
Levelt et al.'s model of spoken production  
(adapted from Levelt, Roelofs & Meyer,  
1999).

Both models (Bock & Levelt, 1994, Levelt et al., 1999) assume a strictly serial lemma-lexeme access, i.e. the syntactic properties of the upcoming word are accessed before the phonological word form is retrieved. An alternative view is the one offered by Caramazza (1997), who developed a model of lexical production – known as the *independent network model* – aimed at overcoming lemma-lexeme seriality (see Figure 4). According to Caramazza, the information that in Levelt is assumed to be stored at the lemma level is divided into two independent networks: semantic features are assumed to be part of a lexical-semantic network, whereas the lexical-syntactic network contains information on grammatical class, gender, auxiliary type and argument structure. The model also entails two modality-specific lexeme networks for phonological (P-lexemes) and orthographical (O-lexemes) representations. The basic assumption of this model is that the lexical-semantic network (i) projects to both P and O-lexemes, which in turn project to the lexical-syntactic network and (ii) is directly connected to the lexical-syntactic network. The activation of a lexical-semantic representation spreads simultaneously and independently to both the lexical-syntactic and the word-form (lexeme) systems. However, while the lexeme-networks can reach the activation threshold and thus be directly activated by the lexical-semantic network, the lexical-syntactic system can only be primed by it, and needs to be reinforced by the



phonological/orthographic representation in order to be activated. Therefore, the full activation of information concerning the word grammatical class and VAS follows the retrieval of either the orthographic or the phonological lexeme.



**Figure 4.**  
Caramazza's model of lexical production  
adapted from Caramazza (1997)

#### *1.6. An alternative account: The constructional approach to argument structure*

According to the models of language production earlier presented, which refer to a psycholinguistic approach, argument structure is a lexical feature, i.e. a property of the verb, and it is stored at a separate level of processing from semantic information. In detail, following Levelt's work (Levelt, 1989; Bock & Levelt, 1994; Levelt et al., 1999, 2001), argument structure information is stored at the lemma level, which is conceived as being subsequent and separate from the level of semantic information. Caramazza (1997) posits instead argument structure information as being stored in the lexical-syntactic network, which is considered as separate from the lexical-semantic network. Therefore, even if those two models differ with respect to their architecture, they share the fact that semantic and argument structure information are independently and separately stored.

However, not all the literature is in line with this assumption. A theoretical linguistics-based approach, i.e. the constructional approach to argument structure (Goldberg, 1995, 2003), holds a different position. Within this theoretical framework, verbs and VAS are stored as constructions, i.e. as "stored pairings of form and function" (Goldberg, 2003), each carrying a specific meaning.

Following Pinker (1989), the constructional approach assumes that sentence structure is predictable from the verb semantic representation, and therefore different sentence structures reflect differences in the verb meaning or in the discourse function (see (10), examples taken from Goldberg, 2003). According to this approach, argument structure is conceived as a piece of information carried by the construction (e.g. transitive, unaccusative, passive) and not by the verb, as stated by psycholinguistic approaches. Moreover, semantic and argument structure information are supposed to be strictly tied to each other and represented at the same level of processing, so that the semantics of the construction determines the way the verb realizes its arguments.

- (10) a. He sliced the bread (transitive)  
b. Pat sliced the carrots into the salad (causative motion)  
c. Pat sliced Chris a piece of pie (ditransitive)  
d. Pat sliced the box open (resultative)  
e. Emeril sliced and diced his way to stardom (way construction)

## 2. Acquired language disorders: The several sides of aphasia

### 2.1. Aphasia: Definition and principles of classification

Aphasia is an acquired language disorder that involves both the production and the comprehension of linguistic messages and occurs in individuals with a history of normal language acquisition, usually following an acquired brain lesion of the left hemisphere. The language disorder often addresses multiple linguistic units and modalities. Several types of aphasia have been described in the literature, according to the extent of the damage to the different linguistic units. The main criterion for classification is fluency – a complex concept that takes into account phrase length, prosody, articulation and verbal agility – which allows differentiation between fluent and nonfluent aphasia types. Nonfluent aphasia is usually characterized by reduced and effortful speech, with production of short sentences, and often entails alteration of the melodic line (prosody) and articulatory difficulties. On the other side, fluent aphasic patients usually show abundant, well articulated speech, where syntax is usually complex but featuring frequent lexical, semantic and phonological deficits. Following the neoassociationist approach developed by Geschwind (1965) and his colleagues (see Benson & Ardila, 1996) and based on the original model by Wernicke-Lichtheim (Wernicke, 1874; Lichtheim, 1885), aphasic syndromes can be classified as follows.

Nonfluent aphasic syndromes include: global aphasia, Broca's aphasia and transcortical motor aphasia. *Global aphasia* usually follows a broad lesion of the left hemisphere causing severe impairment of all language aspects: speech output is scarce and often limited to production of stereotypic utterances (such as "tan"), reading and writing are usually abolished, and language comprehension is also severely impaired. *Broca's aphasia* is characterized by reduced effortful speech output, with impaired articulation (*apraxia of speech*, Rosenbeck, Kent & La Pointe, 1989) and production of short sentences; anomia, i.e. difficulty in lexical retrieval, is always present and Broca's aphasic patients often suffer from agrammatism (see 2.2.). Reading aloud and repetition are massively impaired, comprehension is mostly defective when it must rely on syntactic processing, i.e. in case of syntactically complex sentences (passive, interrogative, relative sentences). The brain lesion in Broca's aphasia is often localized in the frontal lobe, and it includes Broca's area as well as adjacent areas. *Transcortical motor aphasia* is an infrequent form of

nonfluent aphasia whose main symptom is verbal initiation difficulty in spite of a good naming ability as well as good comprehension and repetition skills.

Fluent aphasic syndromes include instead: Wernicke's aphasia, conduction aphasia, transcortical sensory aphasia and anomic aphasia. Patients suffering from *Wernicke's aphasia* demonstrate abundant speech output, with normal phrase length and absence of articulatory deficits. However, production is usually characterized by lexical and phonological paraphasias as well as by *passé-partout* words (e.g. *thing*), which render the communication less effective. Language comprehension is often impaired, as well as written language (reading, writing) and word repetition. The main symptom of *conduction aphasia* is a word repetition deficit, associated with phonemic paraphasias and *conduites d'approche* – successive repairs in approaching the target word - in speech output. Reading aloud and writing are impaired, but oral and written comprehension are mainly spared. *Transcortical sensory aphasia* is a form of aphasia where language comprehension and production are severely impaired due to severe lexical-semantic damage. Writing and – to a lesser extent – reading are also impaired; on the contrary, word and sentence repetition are relatively preserved. Patients suffering from *anomic aphasia* mainly show lexical retrieval deficits in picture naming tasks as well as in spontaneous speech; comprehension and repetition are relatively preserved, and reading and writing are only mildly impaired or unimpaired.

## 2.2. Morpho-syntactic deficit in aphasia

Some aphasic patients exhibit specific difficulties in syntactic processing, which are usually identifiable as agrammatism or paragrammatism.

*Agrammatism* is often associated with Broca's aphasia, and it is characterized by a so-called “telegraphic” output, i.e. sentences are usually very short (3-4 words in length), with omission of closed-class vocabulary and omission (in English) or substitution (in Italian) of bound morphemes (inflectional or derivational affixes)<sup>6</sup>. Agrammatism also entails difficulties in sentence comprehension, when the latter must rely on syntax or cannot be accomplished through the use of

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<sup>6</sup> A crucial difference between English and Italian is that the latter is a language with rich morphology, where almost all words are inflected. While in English the omission of bound morphemes results in the production of the word root (e.g. *playing* → *play*), which is still a meaningful word, in Italian an analogous omission would result in a non-word (e.g. *giocando* → *\*gioc*). Therefore, bound morphemes as verb inflections are usually subject to substitutions (e.g. *giocando* → *gioca*).

extra-linguistic (pragmatic) information (Caramazza & Zurif, 1976; Schwartz, Saffran and Marin, 1980a). For instance, agrammatic patients show difficulty in processing syntactically complex sentences such as passive, interrogative and relative sentences. However, patients are usually able to perform a grammaticality judgment on the same non-canonical sentences they cannot comprehend (see Linebarger, Schwartz & Saffran, 1983).

*Paragrammatism* is a morpho-syntactic disorder sometimes co-occurring with fluent forms of aphasia. The main symptom of paragrammatism is the substitution of inflectional and derivational morphemes and of closed-class words; furthermore, speech production is characterized by blendings, i.e. errors resulting from the merger of two different syntactic constructions. Examples are given in (11) for English (see Butterworth & Howard, 1987) and in (12) for Italian (see Luzzatti, 2005):

(11) a. \*They're not prepared to be *of helpful*

Resulting from the blend of

b. They're not prepared to be *of help*

c. They're not prepared to be *helpful*

(12) a. \*Il gatto va *a cerca di topi*

Resulting from the blend of

b. Il gatto va *in cerca di topi*

c. Il gatto va *a caccia di topi*

### 2.3. *The verb-specific impairment in nonfluent aphasia*

There are several sources of evidence in the aphasia literature of a specific difficulty in producing verbs (compared to nouns) in nonfluent aphasic patients, and particularly in agrammatism.

Verbs differ from nouns in several ways: first of all, while nouns indicate entities, verbs describe processes (Laudanna & Voghera, 2002). Secondly, verbs are usually acquired later in time than nouns during language acquisition (Gentner, 1981). Nouns have many more lexical-semantic

neighbors (categories) than verbs. An additional difference between nouns and verbs lies in the type of information on which the definition of a noun or a verb is based: in detail, verb knowledge is based on functional information, whereas knowledge of nouns mostly relies on visual information (McCarthy & Warrington, 1985). A related issue is represented by the lower capability of verbs vs. nouns of eliciting concepts associated with a mental image, i.e. verbs have lower imageability (or concreteness) than nouns (Bird, Howard & Franklin, 2000, 2001, 2002). Last but not least, verbs have a specific argument structure, whereas nouns do not<sup>7</sup>.

Several neuropsychological studies outlined a difficulty for agrammatic patients to name verbs when compared to nouns, and the opposite pattern for anomia patients (see Miceli, Silveri, Villa & Caramazza, 1984; McCarthy & Warrington, 1985; Zingeser & Berndt, 1988). However, later studies pointed out that verb-specific impairment is not restricted to agrammatic patients, but often generalizes to fluent aphasia (see Kohn, Lorch & Pearson, 1989; Berndt, Mitchum, Haendiges & Sandson, 1997a, 1997b). These results were interpreted as being in favor of a noun-verb double dissociation within the mental lexicon, which led to a number of studies aimed at identifying the neural correlates of verb and noun processing in the brain. In detail, Damasio & Tranel (1993) proposed that the noun-specific impairment came about following left-hemisphere temporal lesions, whereas the verb-specific deficit was a consequence of lesions involving the left inferior frontal gyrus. This hypothesis has recently been challenged by anatomo-correlative studies (see Aggujaro, Crepaldi, Pistarini, Taricco & Luzzatti, 2006; Tranel, Manzel, Asp & Kemmerer, 2008) as well as by neuroimaging studies (see Crepaldi, Berlinger, Paulesu & Luzzatti, 2011, for a recent review) showing a far more complex pattern of brain damage related to verb-specific impairment. Moreover, not all the literature is in line with the existence of a verb-noun double dissociation. For instance, according to Jonkers and Bastiaanse (1998), all aphasic patients show a better retrieval of nouns than of verbs, the opposite pattern deriving from linguistic and psycholinguistic variables that influence word retrieval.

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<sup>7</sup> There are however some abstract nouns deriving from the verb root (e.g. *distruzione* [destruction], deriving from *distruggere* [to destroy]) and verbs defining familiar relations like *zio* [uncle] that require a complement (e.g. *la distruzione della città* [the destruction of the city]).

Verb-specific impairment in nonfluent aphasia has been subject to several contrasting interpretations in the literature. The ongoing debate on its nature entails two main positions: the interpretation in terms of grammatical-class effect and the semantic account. In detail, the first assumes that the noun-verb dissociation reflects a different representation of verbs and nouns within the mental lexicon, and particularly either at the lemma level (Berndt et al., 1997a, 1997b; Crepaldi et al., 2006) or at the lexeme level (Rapp and Caramazza, 2002). A semantic account of the verb production deficit was first proposed by McCarthy and Warrington (1985), who interpreted the phenomenon in terms of disruption of the underlying knowledge: indeed, while nouns usually refer to objects and rely on visual information, verbs refer to actions and rely on functional information. According to this hypothesis, it is functional knowledge that is damaged in agrammatic patients. A related semantically-based account is the one proposed by Bird and co-workers (2000, 2001, 2002), who assumed that verbs are significantly more difficult to produce than nouns because they have lower levels of imageability, i.e. they are less capable of eliciting concept associated with mental images. Since imageability usually has an influence on aphasic patients' performance in a variety of tasks, this account is relevant to the debate in that it entails an explanation of the noun-verb dissociation in terms of a unitary semantic deficit. However, the semantic account has been challenged by the findings of Rapp and Caramazza (2002), who described the case of a patient showing a noun-verb dissociation whose impairment varied according to the linguistic modality, i.e. a verb-specific impairment in written production and a noun-specific impairment in spoken production. In fact, these results cannot be accounted for by a semantic deficit, which would cause the same pattern of impairment in all modalities. Furthermore, Luzzatti and co-workers (2002) conducted a study on a group of fluent and nonfluent aphasic patients, in order to test the extent of the verb-specific impairment in aphasia and its relation to imageability. The authors found a verb-specific impairment in the group of nonfluent aphasic patients and conducted a bivariate logistic regression on each of these patients in order to evaluate the noun-verb dissociated pattern of accuracy while taking into account the effect of imageability. The results of this analysis pointed out that, while the verb-specific impairment disappeared in many patients after imageability was partialled out, some patients still showed a specific deficit for

verbs. Therefore, these data discourage an interpretation of the noun-verb dissociation in terms of a damage to the sensorial/conceptual system, rather suggesting a grammatical class deficit.

Even theories that consider the verb production deficit in agrammatic aphasia as grammatically driven differ with respect to the locus of the verb deficit. For instance, Caramazza and co-workers (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Rapp & Caramazza, 2002) hypothesize that the verb-noun dissociation reflects selective impairments of either noun or verb processing at a late lexical stage, i.e. either the orthographical or the phonological output lexicon. The possibility that the verb-specific deficit is located at an earlier stage of language processing was introduced by Berndt and colleagues (1997a, 1997b; Berndt, Haedinger, Burton & Mitchum, 2002). A similar position was held by Crepaldi and co-workers (2006), who tested 16 aphasic patients in a picture naming task and a sentence completion task eliciting the production of both nouns and verbs. The results outlined a clear co-occurrence of imageability and grammatical class effects, which was attributed either to the role of the right hemisphere (RH), as suggested by Coltheart (2000; Coltheart, Patterson & Marshall, 1987) or to a lexical-syntactic deficit (lemma level) involving the VAS. In their paper, Bastiaanse & van Zonneveld (2005) assume that the verb deficit is located at the lemma level, and outline three contrasting hypotheses, i.e. damage to verb lemmas, defective lemma access or a deficit in grammatical encoding. The authors discuss that damage to verb lemmas is not likely to be responsible of the verb production deficit: indeed, given that there is only one set of lemmas, damage to lemma representations would be reflected in comprehension tasks as well. The latter has however been disconfirmed by research demonstrating spared comprehension of verbs as singletons in agrammatic patients (see Jonkers, 1998). The two main contrasting positions are therefore the following: defective lemma access, as assumed by Kim & Thompson (2000), and a deficit in the process of grammatical encoding, i.e. the post-lemma level in which sentence constituents are assigned their position within the sentence. The latter was proposed by Bastiaanse and van Zonneveld (2005) in order to account for the difference in the performance of agrammatic patients in producing the same verbs in simple vs. complex syntactic structure. In detail, the authors tested patients suffering from Broca's aphasia in two experiments using the same set of verbs in two conditions that differed in grammatical complexity. The results outlined lower

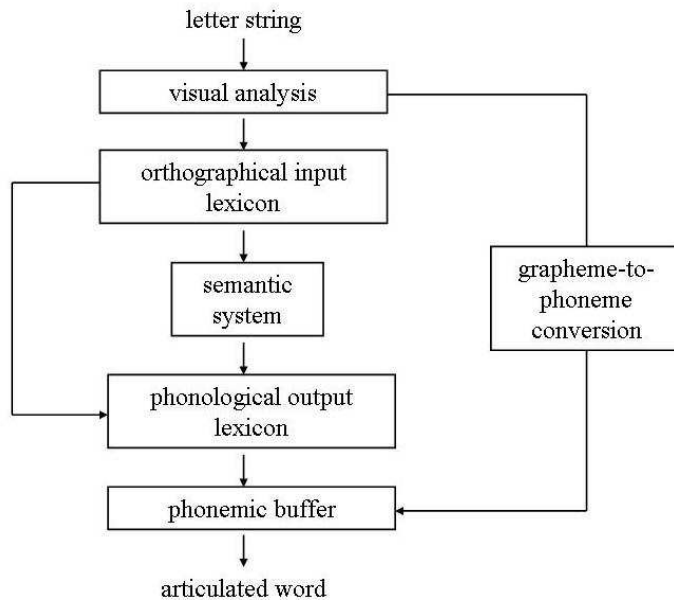


accuracy in performing the task in the complex condition, suggesting that the verb deficit is related to the sentence syntactic structure. Therefore, the authors claimed that the locus of the deficit is subsequent to lemma retrieval, i.e. at the level of grammatical encoding. Besides the several accounts presented so far, there is a group of theories proposing that a purely syntactic deficit is responsible of the symptoms of agrammatism (e.g. see Grodzinsky, 2000, for the Trace-Deletion Hypothesis; Friedmann, 2000, for the Tree-Pruning Hypothesis). However, these accounts will not be discussed since they are outside the scope of the experimental research presented in Part 2.

#### *2.4. Acquired dyslexia and grammatical class effects: The case of deep dyslexia.*

Besides the difficulties in spoken production and comprehension, aphasic patients often show a deficit in reading words aloud, as a result of the acquired brain lesion. The reading disorder is defined as acquired dyslexia, and can assume different features according to which reading procedure is damaged. The present classification of the several forms of acquired dyslexia is based on a cognitive model (dual-route model, see Coltheart, Curtis, Atkins & Haller, 1993; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) that describes the unimpaired reading process as relying on two separate procedures (or routes, see Figure 5): the sub-lexical route and the lexical-semantic route. The first provides a reading process accomplished by means of a grapheme-to-phoneme conversion (GPC) routine, in which letter strings are segmented into the constituent graphemes, which in turn are translated into the corresponding phonemes and then assembled into a phonological string that enters the phonological buffer to be temporarily stored until articulated. On the contrary, reading aloud through the lexical-semantic route entails the following steps: 1) visual analysis of a given letter string, 2) retrieval of the orthographic representation through access to the orthographic input lexicon (OIL), 3) retrieval of the semantic features associated with the word, 4) access to the phonological output lexicon (POL), where the phonological representation of the word is retrieved, 5) storage of the phonological representation within the phonemic buffer and 6) articulation. While the sub-lexical route allows for reading of regular words and of non-words, i.e. letter strings that do not have a lexical entry in the mental lexicon, the lexical-semantic route allows

for reading of regular words and of words with irregular grapheme-to-phoneme correspondence (e.g. *yacht*, *pint* or *colonel*).



**Figure 5.** *Dual-route model of reading.* The model entails two distinct procedures for reading letter strings aloud: the sub-lexical route is represented on the right of the picture, whereas the lexical-semantic route is depicted at the center. The third route, i.e. the direct lexical route, is different from the previous route in that it allows the reading process to bypass the semantic system through the connection between the orthographical input lexicon and the phonological output lexicon.

When the lexical-semantic route is impaired, reading aloud is possible for non-words (e.g. *mecker*) and regular words (e.g. *carrot*), in that both can be read via the application of the GPC rules; on the contrary, reading irregular words like *colonel* is impossible, since it relies on the retrieval of the word's phonological representation, which is stored in the POL. The latter is the type of impairment underlying a specific form of acquired dyslexia, namely *surface dyslexia*. When the sub-lexical route is damaged, reading aloud is possible only for words, i.e. letter strings that have a representation within the mental lexicon, whereas reading of non-words is impaired: this is the pattern that identifies *phonological dyslexia*, a reading disorder often co-occurring with nonfluent aphasia. The observation of patients with preserved reading ability for irregular words but poor comprehension of their meaning (e.g. Schwartz, Saffran & Marin 1980b) called for the introduction of a direct lexical route connecting the OIL to the POL (and bypassing the underlying conceptual knowledge) in addition to the aforementioned lexical-semantic route.

*Deep dyslexia* (DD) (Marshall & Newcombe, 1973; Coltheart, Patterson & Marshall, 1980), is an acquired reading disorder often co-occurring with agrammatic aphasia. Its main characteristic is the

occurrence of semantic errors in the patients' reading performance: for instance, *night* is read as *sleep*, or *river* as *ocean* (Patterson & Marcel, 1977; Plaut & Shallice, 1993). Besides semantic errors, patients suffering from deep dyslexia also produce visual (e.g. *white* for *while*) and morphological errors (*class* vs. *classify*). Their performance is also characterized by word frequency effects and by imageability effects, i.e. concrete nouns are read better than abstract nouns. The DD reading performance is also influenced by 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.). Finally, DD patients are unable to read non-words, because of the severe damage of the sub-lexical route of reading.

Within this theoretical framework, DD is assumed to result from damage to the sub-lexical route and concomitant disruption of the direct lexical route (see Nolan & Caramazza, 1982), which force the retrieval of phonological representations to follow the access of conceptual knowledge. An additional fragility of either the semantic system itself or of the connection between semantics and the phonological output lexicon would account for the occurrence of semantic errors (Shallice & Warrington, 1980).

Similarly to the noun-verb dissociation shown by nonfluent aphasic patients in production, the part-of-the speech effect and the imageability effect that characterize DD have often been interpreted as consequences of the same core semantic deficit (Bird et al., 2000, 2001, 2002; see 2.3.).

Deep dyslexia is quite rare and because of its particular features has been subject to several attempts to explain the co-occurrence of its symptoms. Following the aforementioned dual-route model of reading, DD is conceived as resulting from multiple sources of damage within the model; within this framework, the pattern of errors observed in DD is assumed to result from residual abilities of the left hemisphere (LH). The latter approach is usually referred to as the "multiple-deficit account" of DD. Another popular account is the so-called "Right-Hemisphere Hypothesis (RHH)", proposed by Coltheart and colleagues (1980) and by Saffran, Boygo, Schwartz & Marin (1980). These authors suggested that DD would reflect the emerging right hemisphere (RH) linguistic abilities, which are supposed to be limited to high-frequency concrete nouns. In detail, according to the RHH, an extensive LH lesion would cause damage to the LH orthographic input

lexicon, thus forcing reading performance to rely on RH orthographic processing, i.e. rough lexical and conceptual stores, which are limited to high-frequency concrete nouns and no GPC. The RH, however, is assumed to have no phonological competence: therefore, access to phonology would have to occur within the LH. A further account of DD arises from the “Failure-of-Inhibition Theory” (FIT) proposed by Buchanan, McEwen, Westbury and Libben (2003; see also Colangelo & Buchanan, 2005), according to which the presence of semantic substitutions in DD would derive from defective inhibition of semantically related competitors within the phonological output lexicon.

### 3. Verb argument structure deficits in aphasia

Several studies, as earlier discussed, demonstrated a verb-specific impairment in aphasic patients, and particularly in patients suffering from Broca's aphasia with agrammatism. The selective difficulty in verb production has been attributed to many factors, including the low imageability of verbs in comparison to nouns, as explained in 2.3. Other factors influencing verb production in aphasia are the possibility of verbs to be associated with different actions (see Kemmerer & Tranel, 2000), as well as the semantic reversibility of some actions (e.g. *pull* and *push* describe the same action, but with a reversal of thematic roles) and the verb instrumentality, which according to Jonkers and Bastiaanse (1996) renders verbs more difficult to retrieve for aphasic patients. A particularly relevant factor influencing aphasic patients' ability to produce verbs is verb argument structure (VAS), as shown by several studies that will be discussed in detail. Most studies focused on nonfluent aphasic patients and particularly agrammatic patients, reporting an increasing difficulty in verb production as more complex becomes the VAS.

#### *3.1. The Argument Structure Complexity Hypothesis (ASCH)*

The "Argument Structure Complexity Hypothesis", or ASCH, was proposed by Thompson (2003) in order to account for findings concerning the influence of argument structure complexity on verb production in agrammatic aphasia. According to this hypothesis, verbs with a complex argument structure – both in terms of the number of arguments taken by a verb and of the presence of syntactic movement in the underlying structure – are more difficult to produce for agrammatic patients. As far as the first issue, i.e. the number of arguments taken by a verb, the different degree of verb complexity is reflected by the difference between unergative and transitive verbs (see 1.1.), whereas the second issue, i.e. the presence of movement in the underlying syntactic structure, refers to the difference between unergative and unaccusative verbs (see 1.1. and 1.2.). Studies assessing the two aforementioned issues in both aphasic and neurologically unimpaired participants will be described in the following two paragraphs.

### 3.2. *Argument structure complexity I: the effect of the number of arguments*

The assumption made by the ASCH concerning the number of arguments taken by a verb is supported by several studies on aphasic patients in different languages. Thompson, Lange, Schneider & Shapiro (1997) tested 10 agrammatic patients on a picture description task and on an elicited sentence production task in order to test the effect of the number of arguments taken by the verb. Data showed that agrammatic patients more easily produced unergative verbs than transitive verbs. Two-place transitive verbs were easier to produce than verbs such as *to give* or *to put*, which require a three-place-argument structure. Finally, even the latter were more easily produced than verbs such as *to say* or *to know*, which are usually followed by a whole sentence, e.g. *the girl knows the cat is under the bed*. Similar results were obtained by Kim & Thompson (2000, 2004), both in a picture naming task and a verb categorization task, and further support was offered by Thompson (2003). Data in line with these findings also come from studies on agrammatic patients' production in other languages, including Dutch (Jonkers, 2000), Hungarian (Kiss, 2000), Italian (Luzzatti et al., 2002), German (De Bleser & Kauschke, 2003) and Russian (Dragoy & Bastiaanse, 2010). However, not all studies report a gradient of difficulty going in the same direction as predicted by the ASCH. For instance, Jonkers and Bastiaanse (1998) tested two patients suffering from fluent aphasia, reporting in one of them a reverse pattern of impairment, with transitive verbs being retrieved more easily than intransitive verbs in a picture naming task. Furthermore, data regarding a complexity effect elicited by the number of arguments taken by a verb come from studies on nonfluent agrammatic patients' production: with the exception of one study (see Schwartz et al., 1980a) in which sentence comprehension was less accurate for transitive vs. intransitive verbs, other studies (see for instance Kim & Thompson, 2000, 2004) failed to report an influence of argument structure complexity on comprehension. Thus, the ASCH can account for the pattern of verb production in agrammatic patients, but not in comprehension. However, there are a few studies reporting a modulation of patients' responses by the number of verb arguments in tasks that do not involve overt production: one is the aforementioned studies by Kim & Thompson (2000, 2004), which outlined agrammatic patients' better performance in categorizing intransitive verbs vs. transitive verbs; two additional studies (Shapiro & Levine, 1990; Shapiro, Gordon, Hack

& Killackey, 1993) analyzed instead reaction times in fluent and nonfluent aphasic patients while performing a cross-modal lexical decision task, reporting longer reaction times to verbs taking three arguments (e.g. *to sell*, *to lend*) than to two-place transitive verbs. Converging evidence also comes from a neuroimaging study on five agrammatic patients (Thompson, Bonakdarpour & Fix, 2010), which showed an effect of the number of arguments (one-place vs. two- and three-place verbs) on brain activation in the right angular gyrus. These results reveal an activation of the homologue region that was shown to be activated by verbs with complex argument structure in healthy participants. Indeed, the same study reported increasing brain activation within the posterior areas of the left hemisphere (angular gyrus, supramarginal gyrus) when healthy participants performed the same task as aphasic patients, i.e. a lexical decision task.

### *3.3. Argument structure complexity II: the effect of syntactic movement*

The assumption of the ASCH concerning the higher complexity of unaccusative in comparison to unergative verbs has found support in the literature on aphasia in several languages. The first study to show that unaccusative verbs were particularly impaired in agrammatic aphasia was conducted by Kegl (1995). Luzzatti and co-workers (2002) tested a large group of fluent and nonfluent aphasic patients and found that – only in the group of nonfluent aphasic patients - unaccusative verbs were more impaired than unergative verbs in a picture naming task. Similar results were obtained for the English language by Thompson (2003) and Thompson and Lee (2009) in agrammatic patients, and Sánchez-Alonso, Martínez-Ferreiro & Bastiaanse (2011) reported analogous results for Spanish. A greater difficulty in both production and comprehension of unaccusative vs. unergative sentences was found by McAllister, Bachrach, Waters, Michaud & Caplan (2009) for the group of aphasic patients (including both nonfluent and fluent aphasic patients) and for age-matched participants. Given that the difficulty with production and comprehension of unaccusative sentences was not restricted to aphasic patients, the authors claim that their findings are better interpreted as a general effect of complexity and not as a linguistic deficit concerning syntactic movement, as assumed by the ASCH.

### 3.4. *Argument structure processing in healthy individuals*

To sum up, most behavioral studies that addressed the issue of argument structure complexity in aphasia – with a few exceptions - report results that are in line with the ASCH. Evidence also comes from studies conducted on neurologically unimpaired participants.

There are a few studies (Shapiro, Zurif & Grimshaw, 1987; Shapiro & Levine, 1990) reporting a modulation of reaction times to verbs with different argument structure: in both these studies, however, higher reaction times were elicited by verbs that had multiple subcategorization options (e.g. *to sell*, *to lend*) in comparison to verbs that had only one option (*to exhibit*). Another study (Friedmann, Taranto, Swinney & Shapiro, 2008) that used the same paradigm as the previous two studies, i.e. cross-modal lexical decision task, showed that control participants processed unaccusative verbs in a different way from unergative verbs, specifically participants demonstrated a re-activation of the trace for unaccusative but not for unergative verbs, in line with the Unaccusative Hypothesis (see 1.1.). Most evidence of an effect of argument structure complexity on verb processing in normal participants comes instead from neuroimaging studies. Thompson et al. (2007), in a study examining one-, two-, and three-argument verbs, found graded activation in the angular gyrus for young participants. This brain area in the left hemisphere was active for processing two- versus one-argument verbs, and bilaterally for processing three versus one-argument verbs. Similar effects were reported by Ben-Shachar, Hendler, Kahn, Ben-Bashat & Grodzinsky (2003), who also found activation in the posterior peri-sylvian language network (PPN) – and particularly of superior temporal gyrus (STG) and sulcus - for verbs with a more complex argument structure. Shetreet, Palti, Friedmann & Hadar (2007) found activation of the PPN and an additional left inferior frontal (BA 47) activation for verbs with more dense subcategorization frames, but did not report any difference for verbs taking different number of arguments. While the last two studies tested verb processing in a sentence context, Thompson and co-workers used a lexical decision paradigm, thus testing the effect of the number of arguments with verbs in isolation. Den Ouden, Fix, Parrish & Thompson (2009) investigated the effect of VAS complexity by asking young participants to perform an action/object naming task, where stimuli were either pictures or videos. Results outlined greater activation of the PPN bilaterally – with a prevalence in the left



hemisphere - for transitive vs. unergative; an additional activation of the left inferior frontal gyrus including Broca's area was found as well.

As to the issue of unaccusativity, a recent neuroimaging study carried out by Shetreet, Friedmann & Hadar (2009) found an increase in the activation of the left inferior frontal gyrus and of the left posterior middle temporal gyrus for unaccusative sentences vs. unergative sentences by using a plausibility judgment task.

To summarize, the joint consideration of both psycholinguistic and neuroimaging research indicates that argument structure complexity influences normal language processing by causing an increasing processing load within left frontal inferior and left posterior temporal language areas. This has been shown to be reflected in a modulation of reaction times according to verb complexity, but only for some aspects of argument structure complexity, i.e. the possibility of subcategorizing multiple argument structures and the movement of constituents within the syntactic structure of unaccusative sentences (Shapiro et al., 1987; Shapiro & Levine, 1990; Friedmann et al., 2008).

### *3.5. Processing arguments and adjuncts in nonfluent aphasia*

The main difference between arguments and adjuncts relies on the fact that, while arguments are obligatorily required by a verb, adjuncts add some information to action expressed by a verb without being necessary to make the sentence grammatically correct. Given this difference, some authors investigated the possibility of these two word categories to be differently impaired in acquired language disorders. A few studies examined the production of arguments and adjuncts in aphasic patients, suggesting that arguments are better preserved than adjuncts. For instance, Canseco-Gonzalez, Shapiro, Zurif & Baker (1990) trained a severe Broca's aphasic patient in an artificial language and reported that the patient had more difficulty learning symbols representing verbs in sentences where the third element was an adjunct rather than an argument. Further evidence comes from a study by Shapiro, McNamara, Zurif, Lanzoni & Cermak (1992), who reported that a group of amnesic patients were more impaired in repeating sentences with adjuncts than those with arguments only. However, not all results are in line with the findings so far presented: Byng and Black (1989) found that six aphasic patients produced adjunct phrases

successfully. A recent study by Lee and Thompson (2011) addressed the issue of the linguistic difference between arguments and adjuncts by testing 9 agrammatic patients and 13 age-matched individuals in a sentence production task, where participants were instructed to generate a sentence using the verb and the nouns presented on a screen. While the difference in accuracy between producing arguments and adjuncts was not statistically significant, the inspection of eye-movement data revealed a greater processing cost for adjuncts vs. arguments for both groups.

### *3.6. Fluent aphasia and argument structure deficits*

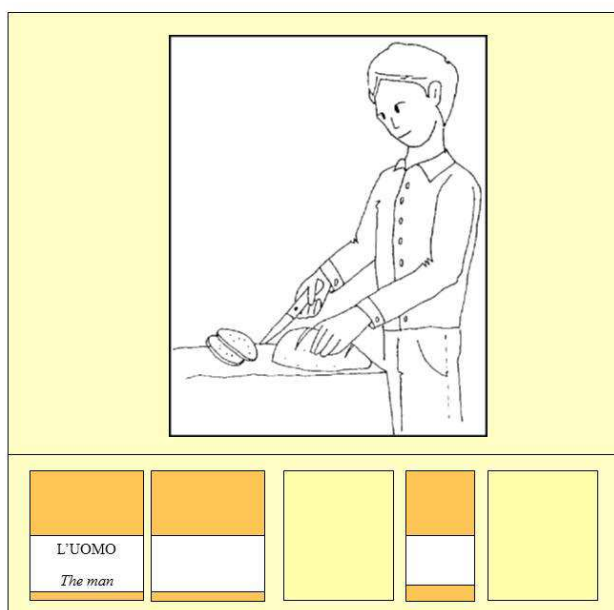
Despite the evidence reporting an effect of argument structure complexity for nonfluent aphasic patients only, some studies suggested that the same phenomena characterizing the verb deficits in nonfluent aphasia could apply to fluent patients as well. For instance, Luzzatti and co-workers (2001) demonstrated that fluent aphasic patients suffered from difficulty in comprehending passive sentences and - more in general - syntactically complex sentences, similar to agrammatic patients. Moreover, McAllister and colleagues (2009) found a specific impairment in comprehending and producing unaccusative sentences in a group of aphasic patients (N=9), the majority of which suffered from mild fluent aphasia. Since the main difference between unaccusative and unergative sentences relies in syntactic complexity, i.e. in the presence of syntactic movement in sentences with unaccusative verbs, data indicate that grammatical disorders typically associated with agrammatism may apply to fluent patients as well, as previously suggested by other studies (Lukatela, Shankweiler & Crain, 1995; Berndt et al., 1997a, 1997b).

### *3.7. A study of argument realization during sentence production: picture description in fluent and nonfluent aphasic patients*

In a previous study (Barbieri, Basso, Frustaci & Luzzatti, 2010), we investigated aphasic patients' ability of producing verb arguments within transitive sentences. Based on the clinical evidence reporting errors in verb argument production in aphasic patients, fluent and nonfluent aphasic patients were tested as to their production of verb arguments in a picture description task, in order

to inform about the locus of the verb production deficit in aphasia as well as to test the prediction of lemma-lexeme seriality entailed in Levelt's model (Bock & Levelt, 1994; Level et al., 1999).

Seven aphasic patients - five suffering from nonfluent aphasia with agrammatism and two from fluent aphasia - and ten neurologically unimpaired individuals participated in the study. In Experiment 1, participants underwent a picture description task administered in two conditions: in the first they were asked to provide a free description of the image, while in the second they had to complete the sentence structure provided by the examiner (see Figure 6).

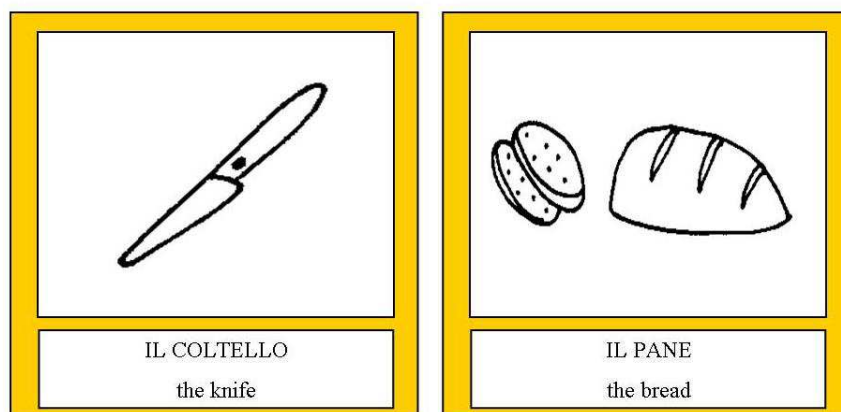


**Figure 6.**

Sketched representation of item n°52, *L'uomo affetta il pane con il coltello* (The man slices the bread with the knife). In Condition 1, subjects were shown only the upper part of the figure, and were asked to describe the picture by saying who is depicted in the figure, what the person is doing and which tool he/she is using. In Condition 2, participants were also presented with the sentence structure (lower part of the figure), were asked to complete it using two flash cards provided by the examiner and to spell out the sentence.

The task was composed of 53 images depicting transitive actions that needed an instrument to be performed (e.g. *affettare* [to slice]). Target sentences were made of five elements: the grammatical subject (or Agent), the verb, the direct object (or Theme), the preposition introducing the PP-adjunct and the name of the tool. Pictures were all shown twice to the patients, once in each condition. In detail, in Condition 1 participants were presented with the picture and asked to describe it by using a sentence that contained all the participants in the action and the instrument used to perform it. In Condition 2, the picture was presented in conjunction with the sentence structure, where the grammatical subject was already shown, and participants were asked to add a

verb and then complete the sentence by placing two flash cards – one depicting the Theme and the other depicting the tool of the action – in the correct place (see Figure 7).



**Figure 7.**

Example of the flash card supplied to the participants to fill the gaps of Figure 6. The picture on the right represents the direct object and has to be located after the verb. The picture on the left depicts the tool by which the action is carried out and should be placed in the final position.

Results showed that five patients – 4 suffering from agrammatism and one from Wernicke’s aphasia – produced many errors where the selected verb was appropriate for the picture but used with an incorrect argument structure. For instance, patients produced errors like *\*la donna taglia la forbice con la carta* [lit. \*the woman cuts (the) scissors with the paper] for the target sentence *la donna taglia la carta con la forbice* [the woman cuts the paper with (the) scissors], or *\*il muratore costruisce il mattone per il muro* [lit. \*the mason builds the brick for the wall] for the target sentence *il muratore costruisce il muro con i mattoni* [the mason builds the wall with (the) bricks]. Data from Experiment 1 thus indicate that fluent and nonfluent patients, when describing pictures, may retrieve the correct verb but use it with an incorrect argument structure. In particular, patients tended to adopt the argument structure typical of the verb *usare* [to use], which requires a tool as a direct object, e.g. *la donna usa il cucchiaio per la minestra* [the lady uses the spoon for the soup]<sup>8</sup>. In some cases, patients produced errors like *\*la donna chiude la chiave* [lit. \*the lady closes the

<sup>8</sup> Some errors produced by our patients suggest that they could have used the correct verb with a default argument structure, i.e. the argument structure of the verb *usare* [to use]. For instance, the sentence *\*La signora cuce l’ago per il bottone* [lit. The lady sews the needle for the button] would be correct if the patient substituted the verb *cuce* [sews] with the verb *usa* [uses].

key], which could also be interpreted as deriving from the omission of the preposition *con* [with] in the target sentence *la donna chiude con la chiave* [the woman closes with the key]. Therefore, in order to test the latter hypothesis, the five patients who showed deficits in verb production in the sentence completion task were also tested for the use of prepositions within prepositional compounds and in a sentence context (Experiment 2). Patients performed two tasks: the first (Luzzatti & De Bleser, 1996) elicited the production of prepositions within noun phrases like *pasta al forno* [baked pasta, lit. pasta on the oven]; the second (Lonzi & Luzzatti, 1995) tested patients' ability of retrieving prepositions in a sentence context, as in *Giovanni andrà dal dottore per una visita* [Giovanni will go to the doctor for a medical examination]. The results of Experiment 2 indicated that at least 4 out of 5 patients were often able to retrieve the correct prepositions; in particular, only a few omissions were made in the task where participants were asked to insert prepositions in a sentence, even when the preposition was subcategorized by the verb, i.e. when it was introducing a verb argument.

Data from Experiment 2 discouraged an interpretation of results from the sentence completion task in terms of preposition omissions and offered support to our primary hypothesis, i.e. a real argument structure deficit. In particular, our data indicate that fluent patients may present argument structure deficits as well. Moreover, the fact that patients spontaneously retrieved the correct verb used with an incorrect argument structure suggests that the verb production deficit in these patients is located at the lemma level. Therefore, a difficulty in accessing lemma information may be hypothesized. In our study, we concluded by suggesting that the phonological word form (lexeme) may be retrieved without accessing argument structure information (lemma), which is in contrast to the strict lemma-lexeme seriality assumed by Levelt (Bock & Levelt, 1994; Levelt et al., 1999). Instead, the results were interpreted in light of Caramazza's model (1997), by assuming that information about VAS is not fully activated due to a disconnection between the lexical-syntactic network and the P-lexeme (see Figure 4).

In conclusion, the previous study suggests the possibility of encountering argument structure deficits in fluent aphasia as well. Moreover, the nature of the errors produced by most patients indicates a deficit at the lemma level, and in particular arising from a defective access to lemma

information. However, in our study we adopted a picture description task, i.e. a production task, without specifically testing lemma access. Therefore, a more detailed investigation of aphasic patients' access to argument structure information is required in order to further inform about the locus of the VAS production deficit in aphasia.

## **Part 2**

### **Experimental data**

#### 4. Aim of the study

As widely described in the introduction, the literature on aphasia has outlined that the argument structure is a verb feature influencing both the normal participants' and aphasic patients' language processing in a variety of tasks. In detail, research conducted mostly on English (see Shapiro & Levine, 1990; Shapiro et al., 1993; Kegl, 1995; Thompson et al., 1997; Kim & Thompson, 2000, 2004; Thompson, 2003) but also on other languages (Jonkers, 2000; Kiss, 2000; Luzzatti et al., 2002; De Bleser & Kauschke, 2003; Dragoy & Bastiaanse, 2010) outlined that verbs requiring two or more arguments (e.g. transitive verbs) are more difficult to produce than verbs requiring only one argument, i.e. unergative verbs, for aphasic patients, and particularly for nonfluent agrammatic patients. Moreover, among verbs that require only one obligatory element, unergative verbs were found to be better preserved in both sentence production and comprehension of aphasic patients (see Luzzatti et al., 2002; Thompson, 2003; Thompson & Lee, 2009 for production; McAllister et al., 2009 for both production and comprehension). An explanation of those data is offered by the Argument Structure Complexity Hypothesis (ASCH, Thompson, 2003), according to which the agrammatic patients' performance in production is inversely related to the argument structure complexity, such that their performance becomes worse as the number of verb arguments increases, and becomes worse on verbs that entail syntactic movement in their underlying structure compared to verbs that do not.

Despite most of the studies described in Part 1 investigated the production of verb arguments in agrammatism, some authors suggested that a similar pattern could be found in fluent aphasic patients as well (see Luzzatti et al., 2001; McAllister et al., 2009; Barbieri et al., 2010). Moreover, most studies assessed patients' production in picture naming tasks, as well as in spontaneous speech or sentence production. Only a few studies investigated argument structure processing in tasks that do not require overt production (see Schwartz et al., 1980a; Shapiro & Levine, 1990; Shapiro et al., 1993; Kim & Thompson, 2000, 2004, McAllister et al., 2009), with results being often controversial. As far as argument structure processing in healthy individuals is concerned, data mostly come from neuroimaging studies (Thompson et al., 2007; den Ouden et al., 2009; Shetreet et al., 2009) and they are not always in line with the predictions made by the ASCH (see



Shetreet et al., 2007). In addition, there is currently scarce evidence (but see Shapiro et al., 1987; Shapiro & Levine, 1990) regarding an effect of argument structure complexity on the performance (accuracy, reaction times) of neurologically unimpaired participants.

Given all these premises, the first goal of the present research is to test the mental organization of VAS and the generalization of the predictions of the ASCH, with respect to both the comparison between transitive and unergative verbs and between unergative and unaccusative verbs. In detail, the aims are the following: i) to test the effect of the number of verb arguments in a task that does not require overt production but instead requires explicit access to information about the VAS in Italian-speaking healthy participants (Experiment 1) as well as in fluent and nonfluent aphasic patients (Experiment 3); ii) to test both the effect of the number of arguments and of the presence of syntactic movement in a word naming task by testing a patient suffering from deep dyslexia (Experiment 4). A second goal is to inform about the deficit underlying the verb-specific deficit that characterizes nonfluent aphasia (Experiment 3), by testing the hypothesis of a defective lemma access (Kim & Thompson, 2000) as compared to a post-lemma deficit at the level of grammatical encoding (see Bastiaanse & van Zonneveld, 2005). An additional goal was to investigate the independence between access to semantic and to VAS information, as suggested by models of contemporary psycholinguistics, by testing healthy participants in a sentence completion task while manipulating the type of information required to perform the task (Experiment 2).

Four experiments will be described in this section. In *Experiment 1*, a group of 20 Italian young normal participants were tested in a sentence completion task where they were asked to complete a sentence by selecting the correct verb among two alternatives that were similar as to their semantic content, but differed as to their VAS, i.e. one was an unergative and one was a transitive verb. Reaction times were used as a measure of participants' performance to the task. *Experiment 2* was conducted on neurologically unimpaired participants, all native speakers of American English, who underwent an analogous sentence completion task as the one used in Experiment 1, but administered in two conditions, i.e. one in which verb selection was based on the VAS, and one where verbs had to be chosen according to their semantic content. In *Experiment 3*, the same task used in Experiment 1 was administered to ten fluent and nonfluent aphasic patients, in order to test

the possibility for them to access VAS. In this case, accuracy was the only measure of the patients' performance, which was compared to the performance of ten age-matched control participants. Finally, *Experiment 4* illustrates the case of an agrammatic patient suffering from deep dyslexia, who was tested as to her ability of naming actions and reading verbs with different argument structure.

## 5. Experiment 1: A study on the processing of transitive and intransitive verbs in healthy Italian participants

### 5.1. Introduction

Several studies have demonstrated a verb-specific impairment in aphasic patients, and particularly in patients suffering from Broca's aphasia and agrammatism (see Miceli et al., 1984; McCarthy & Warrington, 1985; Zingeser & Berndt, 1988; Jonkers & Bastiaanse, 1998; Luzzatti et al., 2002; Kim & Thompson, 2000, 2004). A relevant factor influencing the aphasic patients' ability to produce verbs is verb argument structure (VAS), as defined in Part 1. According to VAS, verbs are classified as transitive when they require at least two arguments, one of which is the verb direct object, and as intransitive when they require only one argument, i.e. the verb grammatical subject. Among intransitive verbs, unergative verbs assign the role of Agent to the grammatical subject, whereas unaccusative verbs assign the role of Theme to it. Unaccusative verbs are also assumed – following the Unaccusative Hypothesis (Perlmutter, 1978; Burzio, 1986) to be syntactically more complex than unergative in that their underlying syntactic structure contains A-movement, as illustrated in Figure 1a (see 1.1. and 1.2. for a detailed description of the different types of verbs).

Most of the studies addressing the issue of the influence of VAS complexity on verb processing in aphasia have focused on nonfluent aphasic patients and particularly on agrammatic patients, reporting an increasing difficulty in verb production as VAS becomes more complex. In particular, several studies showed a lower accuracy for agrammatic patients in producing transitive than unergative verbs, primarily in English (see Thompson et al., 1997; Kim & Thompson, 2000; Thompson, 2003; Kim & Thompson, 2004), but also in other languages, among which Italian (see Luzzatti et al., 2002). A specific difficulty in processing unaccusative verbs, as compared to unergative verbs, has been found in agrammatism (Kegl, 1995; Thompson, 2003, Thompson & Lee, 2009), more generally in nonfluent aphasia (Luzzatti et al., 2002) and in some cases in fluent aphasia as well (see McAllister et al., 2009). The possibility that argument structure deficits may occur in fluent aphasia is also suggested by the study described in 3.7. (Barbieri et al., 2010).

The “Argument Structure Complexity Hypothesis” (ASCH) was proposed by Thompson (2003) in order to account for findings concerning the influence of argument structure complexity on verb

production in agrammatic aphasia. According to this hypothesis, verbs with a complex argument structure – both in terms of the number of arguments taken by a verb and of the presence of syntactic movement in the underlying structure – are more difficult to process for agrammatic patients. Despite a few evidences in contrast with the predictions based on the ASCH (see Jonkers & Bastiaanse, 1998), this hypothesis has received large support, at least as far as results on agrammatic patients' production. Only a few studies reported an influence of VAS complexity in tasks that do not require overt production. Among those, Kim & Thompson (2000, 2004) outlined that agrammatic patients performed better on intransitive than on transitive verbs in a verb categorization task. Moreover, two studies (Shapiro & Levine, 1990; Shapiro et al., 1993) reported longer reaction times – for nonfluent patients only - to verbs taking three arguments (e.g. *to sell, to lend*) than to two-place transitive verbs in a cross-modal lexical decision task. Two further studies (Schwartz et al., 1980a; McAllister et al., 2009), outlined an influence of VAS complexity on aphasic patients' performance in comprehension. The predictions based on the ASCH have also been tested in neuroimaging studies conducted on neurologically unimpaired participants (see 3.4.), with results mostly showing a greater amount of brain activation for transitive verbs than for unergative verbs, mainly within the posterior language areas in the left hemisphere (see Ben-Shachar et al., 2003; Thompson et al., 2007; den Ouden et al., 2009), but also in the left inferior frontal gyrus including Broca's area (den Ouden et al., 2009). However, Shetreet and co-workers (2007) found activation of the left posterior language areas and an additional left inferior frontal (BA47) activation for verbs bearing multiple subcategorization frames (see 1.3.), but did not report any difference between two-place and one-place verbs. With respect to the issue of unaccusativity, a recent neuroimaging study carried out by Shetreet and colleagues (2009) found increased activation in the left inferior frontal gyrus and in the left posterior middle temporal gyrus for unaccusative sentences vs. unergative sentences by using a plausibility judgment task.

To summarize, the joint consideration of both behavioral and neuroimaging data indicates that VAS complexity not only influences the performance of aphasic patients in verb production, but also modulates brain activity within areas supporting language processing of neurologically unimpaired subjects. However, reaction times data have often failed to support the neuroimaging

data (see for instance Shetreet et al., 2007, Thompson et al., 2010), and only a few psycholinguistic studies have reported a VAS-related modulation of reaction times in neurologically unimpaired participants (see Shapiro et al., 1987; Shapiro & Levine, 1990).

Given all these premises, the aim of the present study was to investigate the effect of VAS complexity – as outlined by the ASCH - on normal language processing, by using a task that did not require overt production and tapped access to VAS information.

### *5.2. Aim of the study*

The present study aims to investigate the extent to which the first prediction of the ASCH, i.e. the greater complexity of transitive verbs in comparison to unergative verbs, generalizes to 1) a task that does not require overt production and to 2) normal language processing in healthy individuals. The assumption of a more demanding processing for transitive vs. unergative verbs was tested by means of a sentence completion task in which native speakers of Italian were asked to choose the correct verb out of two options that were equally semantically acceptable within the given sentence context. The task was structured so as to require explicit lemma access without asking participants for overt sentence production; moreover, verb options were created so that participants could perform the task correctly only if they based their choice on argument structure properties. The main prediction was that, if the ASCH could account for the performance of control participants, a modulation of reaction times to the task should be observed, i.e. participants should be faster in selecting unergative verbs than transitive verbs.

### *5.3. Participants*

Twenty undergraduate students at the University of Milano-Bicocca participated in the study. Participants were selected so as to have normal or corrected-to-normal vision, to have no previous history of language disorders and to be native speakers of Italian only.

#### 5.4. Materials and methods

A list of thirty-five Italian verb synonymous (or semantically strictly related) pairs was prepared. Each pair consisted of an unergative verb (e.g. *obbedire* [to conform]) and a transitive verb (e.g. *esaudire* [to fulfill]). Only strictly unergative verbs and strictly two-place transitive verbs, i.e. verbs requiring two arguments, were included in the study. The selection of unergative verbs relied on two sources of information: the type of auxiliary taken at the composite verb form, and the thematic role assigned to the grammatical subject. Unergative and unaccusative verbs are indeed more easily distinguishable in Italian than in English, given the different auxiliary they select in the composite form. For instance, an unergative verb like *dormire* [to sleep] is inflected as *ha dormito*, [(he) has slept], whereas the unaccusative verb *scomparire* would be inflected as *è scomparso*, [(he) has disappeared, lit. is disappeared]. As in English, unergative verbs assign the role of Agent to their grammatical subjects, whereas unaccusative verbs assign to the subject the role of Theme. As far as transitive verbs are concerned, optionally transitive verbs as *mangiare* [to eat] were excluded, since they can be either used in a transitive or in an unergative construction.

Verbs were paired so as to be either synonyms or both semantically compatible with a given sentence frame. Verb pairs were matched for lemma frequency, imageability and length in letters. Imageability values were obtained by asking 12 native speakers of Italian to judge all items as to their capability of eliciting mental images when reading them. Evaluations were given by assigning a score ranging from 1 (very low imageability) to 7 (very high imageability). Since transitive and unergative verbs were always presented in pairs, matching was performed by paired t-tests for each of the considered lexical variables (frequency:  $t=0.295$ ,  $p=n.s.$ ; imageability:  $t=0.195$ ,  $p=n.s.$ ; length:  $t=1.060$ ,  $p=n.s.$ ).

Thirty-five sentence frames were prepared, all bearing the same syntactic structure, with a NP grammatical subject, a blank for the verb, and two post-verbal elements, the last of which was always an adjunct. Sentence pairs were made of two sentence frames, with one fitting the unergative option and one fitting the transitive option, as illustrated in (13) for the verb pair *obbedire/esaudire* [conform/fulfill]. The first post-verbal element could either be a noun phrase

(NP) or a prepositional phrase (PP) according to which of the two verb options fitted the sentence frame.

(13) a. *La segretaria \_\_\_\_\_ agli ordini del capo*

[The secretary \_\_\_\_\_ to the directions of the boss]

b. *La segretaria \_\_\_\_\_ gli ordini del capo*

[The secretary \_\_\_\_\_ the directions of the boss]

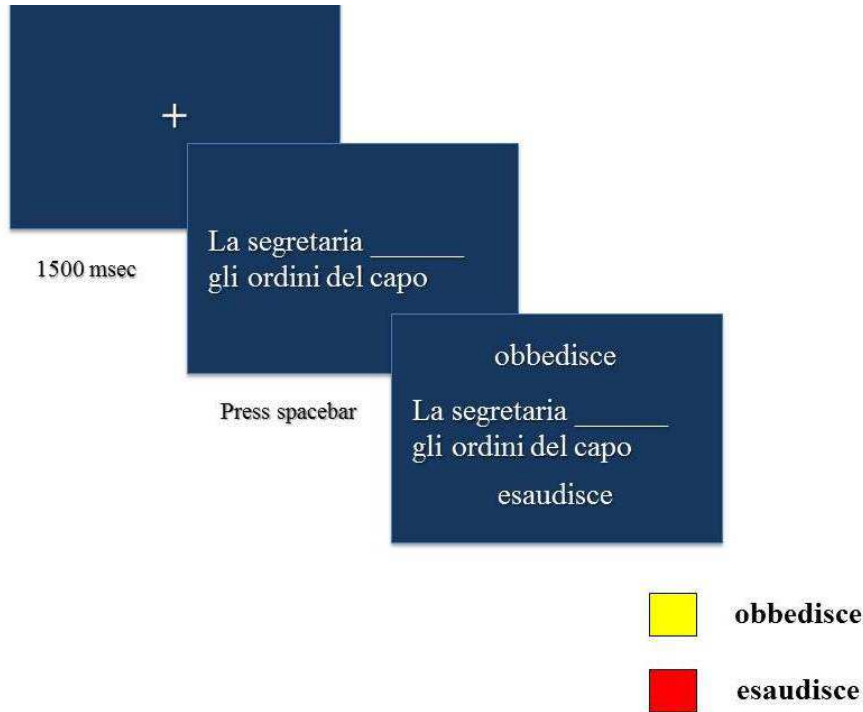
In (13a) the sentence frame fits the unergative option, i.e. the verb *obbedisce* [conforms], whereas in (13b) the sentence frame fits the transitive option *esaudisce* [fulfills].

Each element of the sentence pairs was assigned to a list, so that each list contained only one version – either the unergative or the transitive - of the sentence frame associated to a given verb pair, and participants were randomly assigned to one of the two lists in order to avoid any learning effect. An equal number of sentences of each type was included in the two lists.

### 5.5. Procedure

The task was performed on a laptop in a silent room, and the experiment ran in E-Prime (Psychology Software Tools, Inc.). Stimuli were presented in white on a dark blue screen. Participants read the instructions on the computer screen and were then shown with six practice items in order to familiarize with the task. The instructions were then repeated before beginning with the experimental trials. The procedure was the following for each trial: a fixation cross (+) appeared at the center of a computer screen for 1500 milliseconds (ms) and followed by a sentence with a blank in the verb position. Participants silently read the sentence and pressed the spacebar as soon as they had finished. Two verb options then appeared on the screen, one above and one under the sentence; subjects were instructed to choose the correct option - as fast as they could - by pressing the corresponding response button, i.e. the yellow button – corresponding to the “y” key on the keyboard – if they thought the correct verb was the one above the sentence and the red button – corresponding to the “b” key on the keyboard – for the verb appearing below the sentence

(see Figure 8). Both response accuracy and reaction times were recorded; reaction times were measured starting from the onset of the two verb options until the choice was made.



**Figure 8.**

Procedure used in Experiment 1 for the sentence completion task. After a fixation cross (+) lasting 1500 ms, participants were instructed to read the sentence frame, i.e. the sentence with a blank in the verb position, and then press the spacebar as soon as they completed the reading. The sentence represented here illustrates of one experimental items included in the study, i.e. *La segretaria \_\_\_\_\_ gli ordini del capo* [The secretary \_\_\_\_\_ the directions of the boss]. Then, the two verb options (e.g. *obbedisce* [conforms] and *esaudisce* [fulfills]) associated with the sentence frame appeared on the screen, one above and one under the target sentence. Participants were instructed to press the yellow key (placed onto the “y” key on the keyboard) in order to choose the option that was displayed above the target sentence, and to press the red key (placed onto the “b” key on the keyboard) in order to choose the option under the target sentence. Reaction times were measured from the moment in which the two verb options appeared on the screen until the participants pressed the selected key.

## 5.6. Results

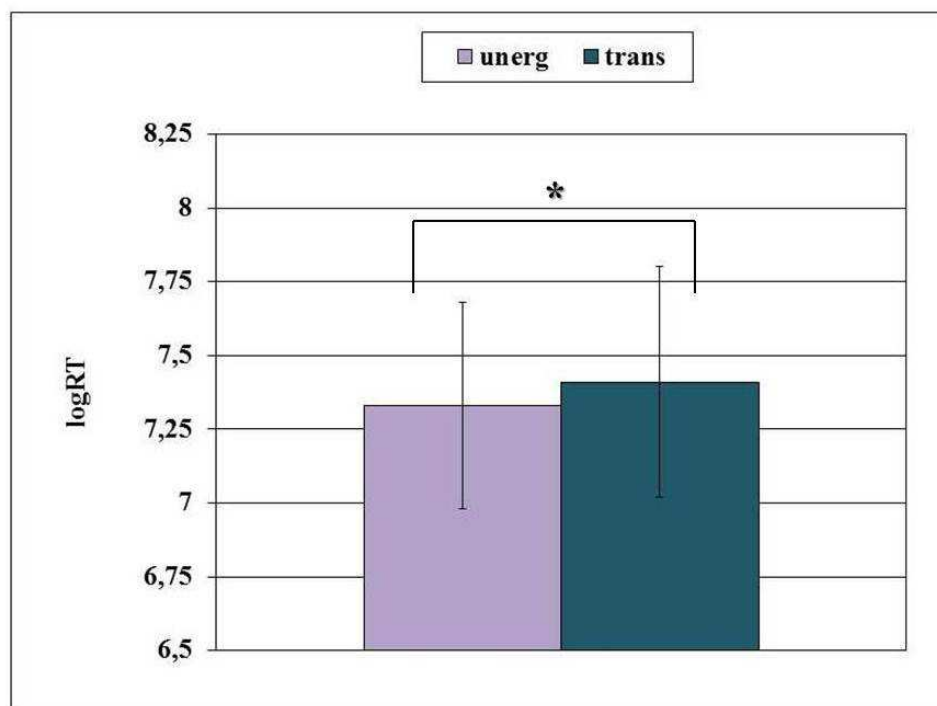
Accuracy data underwent a logistic regression analysis, whereas reaction times were analyzed by means of a multiple regression analysis. Analyses were performed following the statistical approach of mixed-effects models (Baayen, Davidson & Bates, 2008; Jaeger, 2009), i.e. with the introduction of random effects, in order to evaluate the effect of the variables of interest by partialling out item-related and subject-related variability. Continuous variables, i.e. frequency of



occurrence, imageability and length in letters, were transformed into their logarithms, so as to reduce skewness in the distribution .

Accuracy. Overall, participants performed well on the task (97% of correct responses). Accuracy was slightly better for unergative (97,7%) than for transitive (96%) options, but this difference was not statistically significant. ( $z=0.852$ ;  $p=n.s$ ). None of the lexical variables introduced in the analysis had a significant effect on accuracy, neither as single factors nor in the multivariate analyses.

Reaction times. The inspection of raw data revealed that participants responded faster when the correct option was an unergative verb than when it was a transitive verb (mean RT: 1575 ms for unergative verbs, 1691 ms for transitive verbs, see Figure 9).



**Figure 9.** Mean reaction times (RT) for the sentence completion task in Experiment 1. The white column represents RT to transitive options, whereas the grey column illustrates the mean RT for unergative verbs.

Before running the analysis, incorrect answers were deleted from the original dataset. Regression analyses were performed stepwise, by introducing one predictor at a time and by verifying the contribution of each predictor to the model by means of ANOVA comparisons between subsequent

models. *Item* and *participant* were introduced as random effects in each regression analysis. The model including only the predictor of interest, i.e. *verb type* (unergative, transitive), showed a highly significant effect of verb type on the participants' reaction times to the task ( $t=-2.92$ ,  $p=.004$ ). The effect resisted the introduction of *imageability* and *word frequency* as predictors in the multivariate analyses. The best fit model for reaction times data included *verb type*, *imageability*, *word frequency* and the interaction of the last two variables as predictors (Table 1). The effect of *verb type* proved to be statistically significant on participants' reaction times ( $t=-2.47$ ,  $p=.014$ ), whereas neither *imageability*, *word frequency* nor their interaction reached the threshold for statistical significance ( $p>.05$ ).

	Estimate	Std error	t-value	p(> t )
Intercept	7.35	0.29	24.85	<.001
Verb type	-0.05	0.02	-2.42	.016
Frequency	0.03	0.06	0.52	n.s.
Imageability	0.08	0.19	0.45	n.s.
Frequency * Imageability	-0.04	0.04	-0.89	n.s.

**Table 1.**

Performance of healthy Italian participants (N=20) in the sentence completion task. The Table illustrates the output of the best fit model resulting from the regression analysis. Results are reported for fixed effects only, with the exclusion of random effects

### 5.7. Discussion

The present study investigated one of the predictions made by the ASCH (Thompson, 2003), i.e. the higher complexity of transitive verbs when compared to unergative verbs, by testing healthy participants in a sentence completion task, where they were asked to fill the blank in the verb position by choosing the correct verb among two options. Since both verb options were semantically compatible with the sentence frame, and verb options were matched for all lexical variables, the task ensured that participants based their responses on VAS properties. Results

indicate that unimpaired speakers of Italian responded faster to the sentence completion task when the correct verb was the unergative option than when it was the transitive option. Thus, data offer further support to the ASCH, by demonstrating that the greater complexity of transitive vs. unergative verbs can account not only for the production impairment of nonfluent aphasic patients, but may also explain the performance of healthy participants. Given that participants had to access VAS information in order to perform the task, data indicate that access to VAS is somehow easier when verbs are unergative than when they are transitive. These data are interpreted as reflecting a different degree of complexity of unergative and transitive verb representations at the lemma level (see Levelt et al., 1999), with reference to the number of arguments taken by verbs. In detail, verb lemmas referring to transitive verbs are likely to contain a greater amount of information than unergative verbs, since transitive verbs always require at least two arguments. This interpretation is in line with data from neuroimaging studies (see for instance Ben-Shachar et al., 2003; Thompson et al., 2007, 2010; Shetreet et al., 2007), demonstrating a modulation of language brain areas by argument structure complexity in healthy participants, i.e. a greater amount of activation is found for verbs requiring more arguments or bearing multiple subcategorization options.

In the present study, the sentence completion task could be performed correctly only if participants relied on the VAS. The choice of this paradigm derived from the need to address the issue of argument structure complexity by teasing apart not only the possible influence of lexical variables like word frequency and imageability, but also the possibility that the verb semantic content could be responsible for the difference in the reaction times to transitive and unergative verbs. This is relevant in relation to the assumptions made by the constructional approach grammar (Goldberg, 1995; 2003, see 1.6.). Indeed, within this theoretical framework, argument structure information is assumed to be a property specific to the construction in which the verb occurs, and it also bears a specific semantic content. Following this approach, different constructions are likely to have different semantic or pragmatic function. In our study, the choice among the two verb options associated with a given sentence frame was not constrained by semantics, since verbs were either synonyms or semantically strictly related. Therefore, the present results indicate that VAS has an influence on lexical selection in normal participants, even when semantics does not play a role in it.

These data suggest a potential independence of semantic and VAS processing, in line with models from psycholinguistics (Levelt et al., 1999; Caramazza, 1997) and in contrast with the constructional approach of Goldberg (1995; 2003). The latter issue will be explicitly addressed in Experiment 2, by comparing access to semantic and VAS information within the same set of verbs.

## 6. Experiment 2: Accessing semantic and argument structure information while completing a sentence: data from English normal participants

### 6.1. Introduction

As described in the introduction to Experiment 1, many studies have demonstrated that verb argument structure (VAS) influences aphasic patients' performance in production tasks (e.g. Thompson et al., 1997; Luzzatti et al., 2002; Thompson, 2003) and – to a lesser extent – in tasks that do not require overt production (e.g. Shapiro & Levine, 1990; Shapiro et al, 1993; Kim & Thompson, 2000, 2004). In detail, transitive verbs have been shown to be less frequently produced than unergative verbs, and the latter have been reported to be less impaired than unaccusative verbs. An explanation for those data is offered by the Argument Structure Complexity Hypothesis (ASCH; Thompson, 2003), in terms of a more cognitively demanding processing of both transitive and unaccusative verbs as compared to unergative verbs (see 3.1.). With respect to normal language processing, evidence in favor of the ASCH mostly comes from neuroimaging studies (see Thompson et al., 2007; den Ouden et al, 2009, Shetreet et al., 2009). In Experiment 1, the performance of twenty Italian-speaking healthy participants in a sentence completion task was analyzed in light of the first prediction based on the ASCH, i.e. the more cognitively demanding processing of transitive verbs in comparison to unergative verbs. Reaction times to the sentence completion task have demonstrated that the performance of unimpaired participants is influenced by VAS complexity, i.e. transitive verbs elicited longer reaction times than unergative verbs.

An additional issue concerns the role of verb semantics in the determination of argument structure complexity. Indeed, most of the studies mentioned above were conducted by adopting a psycholinguistic-based approach according to which VAS is a feature coded at the lexical level. Within such models, VAS information is represented separately from conceptual information. For instance, VAS is assumed to be stored at the lemma level in the model of lexical production by Levelt and co-workers (Levelt, et al., 1999; see 1.5., Figure 3). According to Caramazza (1997), instead, VAS is represented as a lexical-syntactic information receiving activation from both the lexical-semantic level and from the phonological representation (P-lexeme, see 1.5., Figure 4).

Despite the differences between these two models of language production, both assume that semantic and VAS information correspond to separate levels of verb processing. However, not all the literature is in line with this assumption. A theoretical linguistics-based approach, i.e. the constructional approach to argument structure (Goldberg, 1995, 2003), holds a different position. Within this theoretical framework, verbs and VAS are stored as constructions, i.e. as 'stored pairings of form and function' (cit. Goldberg, 2003), each carrying a specific meaning. Following Pinker (1989), the constructional approach assumes that a sentence structure is predictable from the verb semantic representation, and therefore different sentence structures reflect differences in the verb meaning or in the discourse function (see 1.6.). According to this approach, argument structure is conceived as a piece of information carried by the construction (e.g. transitive, unaccusative, passive construction) and not by the verb, as stated by psycholinguistic approaches as well as by generative linguistic approaches. Moreover, semantic and argument structure information are supposed to be strictly tied to each other, and represented at the same level of processing, so that the construction's semantics determines the way the verb realizes its arguments.

## *6.2. Aim of the study*

This experiment had two main goals: the first was to test the same prediction concerning the ASCH that was investigated in Experiment 1, i.e. the higher degree of cognitive resources required to process transitive than unergative verbs. The task again was a sentence completion task, which was performed with the same paradigm as that used in Experiment 1 (see below, Condition 1). In detail, the aim was to test the generalization to English of the results obtained in Experiment 1 for Italian. It was again expected that, if transitive verbs require higher degree of cognitive resources than unergative verbs, normal participants are faster in selecting unergative verbs than transitive verbs. The second goal of the study was to test the assumption made by psycholinguistic models of lexical production (Caramazza, 1997; Levelt et al., 1999) in relation to the level of representation of VAS information. According to both Caramazza's and Levelt's models, a verb's argument structure is assumed to be stored at a subsequent and distinct level of representation than its semantic information, in contrast with the constructional approach (Goldberg, 1995, 2003), which

assumes that the main unit of representation is the construction, i.e. a stored pair of form and function. Within this framework, each construction corresponds to a particular way for the verb to realize its arguments, which is in turn associated with a specific verb meaning. Therefore, semantic and VAS information are assumed to be strictly tied to each other and possibly represented at the same level of processing. In order to contrast these two approaches, as well as to inform about the level of representation of VAS information, an additional condition in which the choice between the two verbs was based on semantics, i.e. on the verb meaning, was introduced (see below, Condition 2). The latter was designed so as to compare the participants' performance to the sentence completion task in this condition to the performance in Condition 1, and thus to test the hypothesis that access to different types of information (semantic, VAS information) would result in different reaction times, within the same set of verbs. In detail, our prediction was that, if the two levels of processing (semantic, VAS) are separable, we would find a difference in reaction times to the two different types of verb choices. In particular, following Levelt's (1999) and Caramazza's (1997) models of language production, semantic information should be accessed faster than VAS information.

### *6.3. Participants*

Eleven healthy participants (age range: 20-35) were enrolled at the Department of Communication Sciences and Disorders of Northwestern University. Participants were selected so as to have normal or corrected-to-normal vision, to have no previous history of language disorders and to be native speakers of American English only.

### *6.4. Materials and methods*

Twenty-eight verb pairs were selected for the sentence completion task. In each pair, one verb was strictly unergative (e.g. *to retreat*) and the other verb was a two-place transitive (e.g. *to abandon*). Verbs were preliminarily selected so as to belong to one argument structure class only (either unergative or two-place transitive); phrasal verbs, i.e. combinations of a verb and a preposition/adverb that modifies or changes the meaning of the verb, were excluded. A subsequent

formal classification was conducted by administering a questionnaire to 5 experts in linguistics, all native speakers of American English, in which they were asked to rate the group of verbs preliminarily selected by the authors as to their argument structure properties. Each verb was presented on a row, and participants were instructed to mark, for each verb, the box corresponding to the argument structure category/categories to which it belonged. Four categories were listed: unergative, unaccusative, obligatory transitive and optionally transitive. With respect to the distinction between unergative and unaccusative verbs, subjects were instructed to rely on the following tests (see Levin, 1993, for an extensive discussion): agentivity, the possibility of taking cognate objects, the insertion in the “expletive there” construction and the use of the past participle as an adjective qualifying the grammatical subject of a sentence with the same verb<sup>9</sup>. To determine the distinction between optional and obligatory transitive verbs, the raters were presented with a few examples and asked to imagine at least one situation in which the direct object was not necessary. Only verbs that were classified either as unergative or as obligatory transitive were included in the final set of stimuli.

#### 6.4.1. Argument structure choice (Condition 1)

Similarly to Experiment 1, verbs were paired so that both elements of each pair were either synonyms or semantically compatible with a given sentence frame (see example in (14) for the verb pair *retreats/abandons*). A total of 28 verb pairs were used for the argument structure choice condition. Verb pairs were matched for word frequency, as derived from the CELEX English database (Baayen, Piepenbrock, & van Rijn, 1993), and for length in letters ( $t=0.196$ ,  $p=n.s.$ ;  $t=1.081$ ,  $p=n.s.$ , respectively). Since it was impossible to match verb options for imageability, the latter was included in all regression analyses as a predictor. Imageability values were collected by asking 19 graduate students to express a judgment on the capability of each verb to elicit mental

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<sup>9</sup> The distinction between unergative and unaccusative verbs in English is more complicated than in Italian, since it is only based on a few linguistic tests. The three procedures used to select unergative verbs for the present experiment are the following: the first is the possibility of taking cognate objects, i.e. direct objects that are morphologically derived from the verb: the latter is a feature identifying unergative verbs (e.g. *John slept a peaceful sleep*), whereas unaccusative verbs cannot be used in a similar construction (e.g. *\*The vase fell a noisy fall*); another test concerns the possibility – for unaccusative verbs only – to be used in the so-called “expletive there” construction: for instance, an unaccusative verb like *to fall* can be used in the sentence *There fell the big vase in the kitchen*, whereas an unergative verb like *to sleep* would generate an ungrammatical sentence as shown by *\*There slept John in his bed*; the last test used for our classification referred to the possibility for the past participle of unaccusative verbs (e.g. *fallen*) to appear as an adjective qualifying the grammatical subject as shown by the following examples: *The fallen vase* is grammatical, whereas *\*The slept John* is not. A more extensive description of these tests and a complete list of all linguistic tests used for the discrimination between unergative and unaccusative verbs can be found in Levin (1993).



images, by ranking each verb on a range from 1 to 7. As for Experiment 1, sentence frames were created so that all had the same syntactic structure, with a NP playing the role of grammatical subject, a blank for the verb, and two post-verbal elements, the last of which was always a PP-adjunct. The first post-verbal element could either be a NP or a PP according to which of the two verb options fit the sentence frame. Three different sentence frames were associated to each verb pair, except for 4 verb pairs in which only two appropriate sentence frames were found to be semantically compatible with both verb options. Thus, a total of 80 sentence frames were included in the study, 39 of which fitting a transitive verb and 41 fitting the unergative option. The examples in (14) and (15) illustrate sentence frames associated to the verb pairs *retreat/abandon* and *cooperate/promote*, respectively. In order to ensure that an equal number of sentence frames fitting either the unergative or the transitive option was included in the experiment, in half of the verb pairs associated with three sentence frames, two fitted the transitive option and one the unergative option (see (14)), whereas in the other half, one sentence frame fitted the transitive verb and two fitted the unergative option (see (15)).

- (14) a. The soldier \_\_\_\_\_ the battlefield after the defeat  
b. The deputy \_\_\_\_\_ the council on the crisis  
c. The athlete \_\_\_\_\_ from the competition for the medal

- (15) a. The leaders \_\_\_\_\_ the rights of the minority  
b. The doctors \_\_\_\_\_ for the success of the clinic  
c. The merchants \_\_\_\_\_ for the increase in the exports

Sentences in (14) and (15) are examples of items included in the study. Sentence frames in (14) are associated with the verb pair *retreats/abandons*, with sentence frames in (a) e (b) fitting the transitive option, i.e. *abandons*, and the sentence frame in (c) fitting the unergative verb, i.e. *retreats*. Items in (15) illustrate the sentence frames associated with the verb pair

*cooperate/promote*, where the sentence in (a) fitted the transitive option, i.e. *promote*, and sentences in (b) and (c) fitted the unergative option, i.e. the verb *cooperate*.

#### 6.4.2. Semantic choice condition (Condition 2)

As to the semantic condition, 14 verb pairs were created by coupling the 28 transitive verbs used in Condition 1. Three distinct sentence frames (see (16)) were created for each verb pair, so that each of the sentence frames clearly fit only one of the two verb options as far as semantics was concerned, i.e. the selection of the incorrect verb would yield a semantic anomaly. Thus, 42 sentence frames were prepared in total, three of which were used as practice items, while the remaining 39 sentence frames were included in the experimental set of stimuli. An example of the experimental items is given in (15) for the verb pair *denounce/crave*:

- (16) a. The landlord \_\_\_\_\_ the theft in his apartment  
b. The customer \_\_\_\_\_ the sandwich in the restaurant  
c. The teenager \_\_\_\_\_ the pancake for her breakfast

Sentence in (16a) fits the verb *denounces* whereas sentences in (16b) and (16c) fit the other verb option, i.e. *craves*.

#### 6.5. Procedure

The same procedure adopted in Experiment 1 was used. Items were randomly ordered both within and between the two conditions, and presented on a computer screen running the script within E-prime (Psychology Software Tools, Inc.). Participants were not informed about the presence of two distinct conditions: they were instructed to fill in the blank in the sentence by choosing the correct verb as fast as possible. The task began with six practice items, half from Condition 1 and half from Condition 2. Accuracy and reaction times were recorded, with reaction times computed from the moment at which the two verb options appeared on the computer screen.

## 6.6. Results

Data analyses were again performed by adopting the mixed-effects approach for both accuracy data, which underwent logistic regression (see Jaeger, 2009), and reaction times data, on which a multiple regression was performed (see Baayen et al., 2008). A preliminary inspection of reaction times data revealed that one of the participants responded much slower than the average of the other participants (2 SD above the mean); therefore, final data analysis was performed on the dataset containing datapoints from ten subjects only.

Accuracy. The inspection of raw data revealed that overall accuracy was around 95,7%, with 96,7% in the AS-choice condition and 93,7% for the semantic choice. Within the AS-choice condition, accuracy was slightly better when the correct verb was the unergative (98,8%) than the transitive (94,6%) option. A regression analysis was performed on the dataset containing data deriving from both Condition 1 and Condition 2. The best fit model contained the following predictors: *verb type* (unergative or transitive), *condition* (AS-choice vs. semantic choice), and *imageability*. None of these proved to significantly influence the probability of responding correctly; despite the gap in accuracy between unergative and transitive verbs within Condition 1, the main effect of verb type did not reach significance ( $t=1.66$ ,  $p=.10$ ). Since none of the main effects were significant in the general model, we did not proceed with the accuracy analysis to test the two effects of interest (*verb type* and *condition*) separately.

Reaction times (RT). The inspection of the raw data – after the deletion of incorrect responses – showed similar reaction times to Condition 1 (mean RT = 2311 ms) and Condition 2 (mean RT = 2275 ms). However, within Condition 1, unergative verbs elicited faster reaction times (2178 ms) than transitive verbs (2458 ms). In addition, when considering reaction times to transitive verbs in the two conditions, reaction times to the semantic choice (2275 ms) were faster than to the AS choice (2458 ms). Analyses were initially performed on the database containing data from both conditions (see Table 2a).

The multiple regression analysis revealed that performance to the sentence completion task was significantly affected by *verb type*, with responses to unergative verbs being faster than responses to transitive verbs; a marginal effect of *condition* was found as well, with the semantic task being

performed faster than the AS-choice task. The effect of *verb type* resisted the introduction of *imageability*, which was not significant in predicting the participants' reaction times, and of *word frequency*, which was instead found to be significant (Table 2a). Since the interaction between *condition* and *verb type* could not be computed – due to the presence of only one level for the independent variable *verb type* in Condition 2 – separate analyses were also conducted in order to evaluate the two main effects of interest (*verb type*, *condition*).

**Table 2a.**

	Estimate	Std. Error	t-value	p(> t )
Intercept	7.87	0.14	55.82	<.001
Verb type	-0.15	0.05	-2.93	.003
Condition	-0.09	0.05	-1.88	.06
Frequency	-0.03	0.02	-2.16	.031
Imageability	0.04	0.07	0.68	n.s.

**Table 2b.**

	Estimate	Std. Error	t-value	p(> t )
Intercept	7.67	0.12	63.92	<.001
Verb type	-0.13	0.05	-2.59	.01
Imageability	0.03	0.08	0.43	n.s.

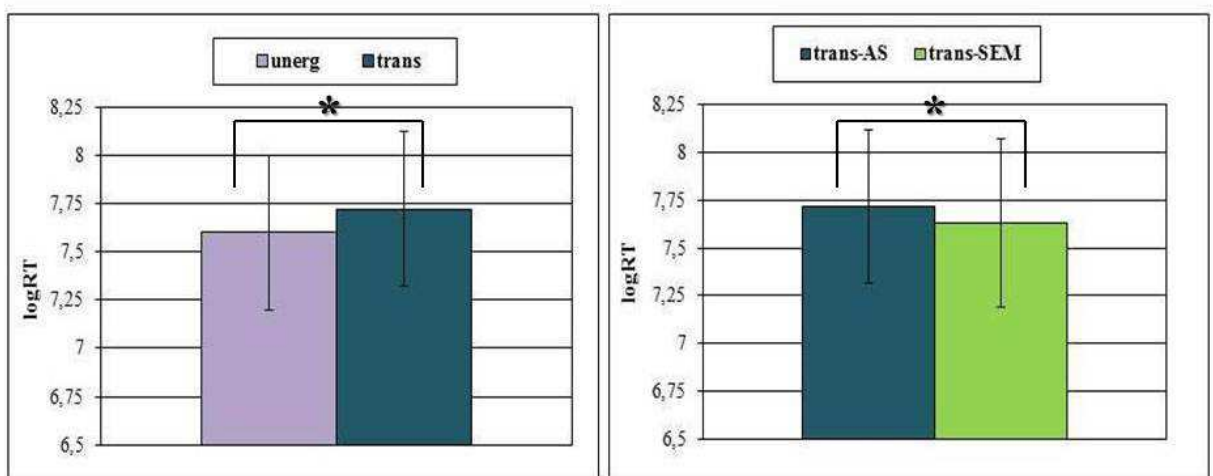
**Table 2c.**

	Estimate	Std. Error	t-value	p(> t )
Intercept	7.84	0.15	50.78	<.001
Condition	-0.09	0.04	-2.05	.04
Frequency	-0.05	0.02	-2.68	.007
Imageability	0.16	0.08	1.96	.05

**Table 2.**

Performance of healthy English participants (N=10) in the sentence completion task. Table 2a illustrates the best fit model for the whole dataset, including both Condition 1 and Condition 2. Table 2b refers to results referring to best fit model for the AS-choice (Condition 1), where RT to unergative and transitive verbs were compared within the participants' RT to Condition 1 only. Table 2c shows the best fit model for the performance in the sentence completion task (Condition 1 and Condition 2), for the transitive verbs.

The effect of *verb type* was thus analyzed by performing a multiple regression on the dataset containing data from Condition 1 only, whereas the effect of condition was evaluated by creating a dataset including transitive verbs only, since they were tested in both the AS-choice and the semantic choice task. As to data from Condition 1 (see Table 2b), the best fit model contained *verb type* and *imageability* as predictors. *Verb type* proved again to predict reaction times to the sentence completion task, with the same effect direction (RT unerg < RT trans; see Figure 10a) as in the previous analysis, and *imageability* was still non-significant.



**Figure 10.**

Mean reaction times (RT) for the sentence completion task in Experiment 2.

Figure 10a illustrates the mean RT to AS-choice (Condition 1), with the white bar representing RT for transitive options and the light grey bar depicting the RT to unergative verbs.

Figure 10b represents the mean RT for the group of transitive verbs: the white bar illustrates the mean RT for the AS-choice (same bar as in Figure 5a), whereas the dark grey bar depicts the RT to the semantic choice condition.

A third regression analysis (Table 2c) was performed on responses to transitive verbs, in order to evaluate the effect of condition on the reaction times to the sentence completion task. As illustrated in Table 2, the best fit model contained *condition*, *imageability* and *word frequency* as predictors. Results showed that *condition* significantly predicted participants' reaction times to the sentence completion task, with the semantic-based choice eliciting faster reaction times than the argument structure-based choice ( $t=-2.05$ ,  $p=.04$ , see Figure 10b). In addition, both the effect of *word frequency* and *imageability* proved to be statistically significant ( $t=-2.68$ ,  $p=.007$  and  $t=1.96$ ,  $p=.05$

respectively). In the latter analysis, despite the influence of lexical variables (*word frequency* and *imageability*) on the participants' performance to the task, the effect of *condition* was still significant also in the multivariate analyses.

### 6.7. Discussion

The aim of Experiment 2 was to investigate the influence of two factors on the reaction times of healthy participants to a sentence completion task, namely the type of VAS and the type of information guiding the choice between the two verb options. Experiment 2 adopted the same paradigm as Experiment 1, but differed from the latter in that the task was performed in two conditions.

Condition 1 (AS-choice) evaluated the influence of VAS on performing the choice between two verbs that are both semantically compatible with a given sentence, so as to investigate the prediction of the ASCH (Thompson, 2003) of a difference between verb types, due to the greater complexity of transitive verbs compared to unergative verbs. Results show that participants indeed responded faster when the correct choice was the unergative verb, in line with the gradient of complexity stated by the ASCH. These data confirm the results obtained on Italian healthy participants using the same task. Condition 2 (semantic choice) was introduced in order to test the participants' access to different types of information within the same set of verbs. In detail, participants were asked to fill the blank in the verb position by performing a choice between two verbs that differed in their meaning and, thus, in their appropriateness to the sentence frame. Both options were transitive verbs, and particularly the same transitive verbs used in the AS-choice, so as to test - within a given set of transitive verbs - the effect of condition on the participants' responses. Results demonstrated that, when the correct option was a transitive verb, subjects responded faster if the choice relied on semantic information than on argument structure information.

As far as the effect of argument structure is concerned, results demonstrate a pattern in line with the results obtained in Experiment 1 for the Italian participants and with the predictions of the ASCH. In detail, the present data indicate that lemma access is easier for unergative than for transitive

verbs, possibly because their representations contain a smaller amount of ‘information’ than transitive verbs. In fact, as in Experiment 1, participants could perform the task correctly only if they relied on argument structure information, which is assumed to be stored either at the lemma level (Levelt et al., 1999) or within the lexical-syntactic network (Caramazza, 1997). Following this psycholinguistic approach, lemma access (or access to the lexical-syntactic network) was necessary to perform the task. In addition, a difference in accessing the argument structure properties of different verb types must reflect different ease of access to verb lemmas (or the verb syntactic-lexical network).

With respect to the effect of condition, results demonstrate that the process of selecting the correct verb in the sentence completion task was faster when the choice was based on meaning, i.e. on semantic information, than on VAS. Notably, the difference in reaction times to the semantic and the AS-based choice did not reflect a difference in accuracy, thereby discouraging an interpretation of the data in terms of a disproportionately greater difficulty of the AS-based choice than of the semantic-based choice. Thus, data indicate that semantic and argument structure information – at least as an offline measure - can be accessed independently when required by the task. In particular, semantic information can be accessed faster than argument structure information. Since all the verbs included in the study had a specific argument structure construction, i.e. they were all two-place transitive verbs, and the comparison was made on the same set of verbs, i.e. excluding other potentially confounding factors, the comparison represents a pure measure of participants’ access to these two types of information.

The results of Experiment 2 are in line with psycholinguistic models like that developed by Levelt et al. (1999) or by Caramazza (1997), which both assume separate levels of representations for semantic and argument structure information. However, the present data represent a challenge for the constructional approach to argument structure (Goldberg, 1995, 2003). Indeed, according to that approach, argument structure information is coded at the semantic level, as a construction endowed with a specific verb meaning. Within this context, verb meaning is assumed to determine the type of verb construction, so that argument structure and semantic information are strictly tied to each other. The results from the present study, however, suggest an independent processing of

these two levels. Indeed, Condition 1 showed that elicited responses with different reaction times according to their argument structure (unergative vs. transitive). These data indicate that VAS influences normal participants' responses independently from the verb semantic content. However, this does not directly address the issue of a separate representation of the two types of information, which is showed instead by the comparison of reaction times to Condition 1 and Condition 2 within the same set of two-place transitive verbs. Moreover, given that transitive sentence frames in both the AS-based and the semantic-based choice had all the same syntactic construction, any difference related to the particular sentence construction can be excluded. The finding of a separability between semantic and argument structure information within the same verbs is at odds with the basics of the constructional approach. In fact, the present data are hard to explain by an approach where the verb semantic content and the VAS are represented at the same processing level and retrieved as a single construction. Rather, data seem more compatible with models assuming separate levels of representations for these two types of information. This does not imply that semantics does not play any role in determining argument structure; it is likely that semantic information increases or diminishes the probability that a particular argument structure – in case of verbs bearing more than one – is selected. However, in spite on this interplay between the two, our data demonstrate that argument structure information can be accessed independently and affect normal language processing even when semantics is kept under strict experimental control. Further research is necessary to determine the way semantic and argument structure information interact, and how semantics can pose restrictions on the way verbs realize their arguments in sentence production.



## 7. Experiment 3: Argument structure and lemma access in fluent and nonfluent aphasia

### *7.1. Introduction*

As described in 2.3., several studies reported a selective difficulty for agrammatic patients in producing verbs with respect to nouns. This feature has often been compared to the performance of anomia patients, who demonstrated a reverse pattern of difficulty, with nouns being more impaired than verb in picture naming (see Miceli et al., 1984; McCarthy & Warrington, 1985; Zingeser & Berndt, 1988). However, later studies pointed out that a disproportionate verb-impairment was not only restricted to agrammatic patients, but in some cases generalized to fluent aphasia (see Kohn et al., 1989; Berndt et al., 1997a, 1997b). Jonkers and Bastiaanse (1998) further extended this assumption by stating that all aphasic patients show a better retrieval of nouns than verbs, with the opposite pattern resulting from the influence of psycholinguistic variables affecting word retrieval. One of the features that characterizes verbs (and much less nouns) is the fact that verbs take arguments, i.e. obligatory elements required by verbs when implemented in sentences (see 1.1. and 1.2. for a description of the verb types). As widely discussed in chapter 3, argument structure properties has been found to influence agrammatic patients' performance in production in several languages (see Kegl, 1995; Thompson et al., 1997; Thompson, 2003; Kim & Thompson, 2000; 2004; Thompson et al., 2010, for English; Luzzatti et al., 2002, Barbieri et al., 2010, for Italian; De Bleser & Kauschke, 2003, for German; Jonkers, 2000, for Dutch; Kiss, 2000, for Hungarian; Dragoy & Bastiaanse, 2010, for Russian and Sanchez-Alonso et al., 2011, for Spanish). In order to account for those results, Thompson (2003) proposed the Argument Structure Complexity Hypothesis (ASCH), according to which agrammatic patients' production is as much difficult as more complex becomes the verb argument structure (VAS), both in terms of the number of arguments required by verbs and of the presence of syntactic movement (see 3.1.). Despite many studies provided data in favor of the predictions made by the ASCH, as shown also by data on neurologically unimpaired participants (see Thompson et al., 2007; den Ouden et al., 2009; Shetreet et al., 2009; Thompson et al., 2010), there are some exceptions (see Jonkers and Bastiaanse, 1998; Shetreet et al., 2007). In detail, Jonkers and Bastiaanse (1998) found intransitive

verbs to be more impaired than transitive verbs in agrammatic patients' production, whereas Shetreet and co-workers (2007) failed to find a modulation of brain activity in relation to the number of arguments required by verbs, in contrast with results obtained by Thompson and colleagues (Thompson et al., 2007; den Ouden et al., 2009; Thompson et al., 2010). Moreover, despite many studies focused on the performance of patients suffering from agrammatism, there are a few evidences in favor of a possible generalization of the principles illustrated by the ASCH to nonfluent aphasia in general (see Luzzatti et al., 2002), as well as to fluent aphasia (see McAllister, et al., 2009; Barbieri et al., 2010). In detail, McAllister and colleagues found better accuracy for both production and comprehension of sentences containing unergative verbs than for sentences with unaccusative verbs, for both the group of aphasic (mostly fluent) patients and of healthy participants. The finding of a better performance in producing and comprehending unergative sentences than unaccusative sentences in normal participants led the authors to hypothesize that the ASCH could more reflect a general principle of complexity underlying normal language processing than a specific account of agrammatic patients' production. In addition, in an earlier study, Barbieri and co-workers (2010) found that both fluent and nonfluent aphasic patients had difficulty in retrieving the appropriate argument structure for transitive verbs describing actions that required the use of an instrument (see 3.7. for a more detailed description).

Since the pioneer studies on the verb-noun dissociation typical of agrammatic production, several attempts have been made to account for the verb specific impairment characterizing agrammatism. Among those, the two main contrasting positions interpret the verb impairment either as a semantic deficit or as a grammatically driven effect. In detail, according to the semantic account, agrammatic patients are impaired in verb production because of a dysfunction of the semantic system, either in the type of semantic knowledge underlying verb representations, i.e. functional knowledge as opposed to the visual knowledge underlying noun retrieval (see McCarthy & Warrington, 1985), or as an effect of imageability, as suggested by some authors (Bird, Howard & Franklin, 2000, 2001, 2002). According to the latter hypothesis, the disproportionate verb impairment depends on the lower capability of verbs to elicit mental images, i.e. verbs are produced less accurately than nouns because they have lower imageability. Despite this account has received support in relation to the

influence of imageability on the production of aphasic patients (see e.g. Bates, Burani, D'Amico & Barca, 2001), it has been challenged by the findings of Rapp and Caramazza (2002). Moreover, Luzzatti and co-workers (2002) demonstrated that at least in some of the patients, the disproportionate verb impairment persisted even when imageability was partialled out by adding it as a predictor in a bivariate logistic regression analysis (see 2.3.). These results are therefore in favor of an interpretation of the verb specific impairment as a grammatical class effect. Even among authors supporting this assumption, however, the debate concerns the precise location of the deficit within models of lexical production. For instance, Caramazza and co-workers (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Rapp & Caramazza, 2002) assume that the deficit is located at a late lexical stage, i.e. either the phonological output lexicon or the orthographical output lexicon. Berndt and colleagues (1997a, 1997b; 2002) suggest instead that the deficit could arise at a lexical-syntactic level (*lemma level*), as proposed by Crepaldi et al. (2006). As discussed by Bastiaanse and van Zonneveld (2005), the deficit could consist either in a damage to lemma knowledge itself, or in a difficulty in accessing lemma information (see Kim & Thompson, 2000). Moreover, Bastiaanse & van Zonneveld discuss the hypothesis that the deficit could be located right after lemma retrieval, i.e. in mapping verb arguments onto the sentence syntactic structure. Within Levelt's theoretical framework (1989; Levelt et al., 1999), in this case the deficit would be located at the level of grammatical encoding (see 1.5., Figure 3), i.e. where the word's syntactic environment is created. In their study, Bastiaanse and van Zonneveld tested patients suffering from Broca's aphasia in two experiments using the same set of verbs in two conditions that differed for grammatical complexity. Since the authors found that the performance of agrammatic patients diminished in the most grammatically complex condition, i.e. the accuracy on the production of the same verbs was influenced by the sentence structure, they claimed that the locus of the deficit is subsequent to lemma retrieval and located at the stage of grammatical encoding.

As described in 3.7., in a previous study it has been proposed that the patients' deficit derived from a damage to the lemma information itself or to its access (Barbieri et al., 2010). This assumption has also been discussed by Bastiaanse and van Zonneveld, who claimed that an interpretation in terms of a damage to lemma knowledge is not in line with studies that report spared verb

comprehension (see Jonkers, 1998; Kim & Thompson, 2000). Since in their previous study Barbieri et al. did not test the performance of aphasic patients in input tasks, the aim of the present study is to investigate argument structure processing in fluent and nonfluent aphasia, by using a task that does not require overt production, but instead taps lemma access, in order to further inform about the locus of the verb production deficit in nonfluent aphasia.

## *7.2. Aim of the study*

In detail, the aim of the present experiment was to test the first prediction made by the ASCH, i.e. the greater difficulty in processing transitive verbs with respect to unergative verbs, in a sentence completion task, in order to (i) investigate the prediction of a more demanding cognitive processing of transitive vs. unergative verbs in a task that does not require overt production, (ii) test if the prediction is restricted to the performance of agrammatic patients or rather generalizes also to fluent aphasia, as suggested by previous studies (see Luzzatti et al., 2001; McAllister et al., 2009, Barbieri et al., 2010) and (iii) investigate the possibility for nonfluent aphasic patients of accessing verb lemmas, in relation to theories about the locus of the deficit (Kim & Thompson, 2000; Bastiaanse & van Zonneveld, 2005). The main prediction was that, if the ASCH accounted for patients' performance to the task, their accuracy in the selection of the correct verb would be higher when the correct option was the unergative verb than when it was the transitive verb. Moreover, if the prediction applied to the performance of fluent aphasic patients, a similar pattern would have been found in both groups, i.e. in nonfluent and in fluent aphasic patients. This task is assumed to inform about the possibility for patients to access lemma knowledge, because if patients were found to be sensitive to argument structure properties, i.e. to have a different ease of access for unergative verb lemmas vs. transitive verb lemmas, they should have at least partial access to lemma information. Indeed, following Levelt's model (1999), information about the number of arguments required by a verb is stored at the lemma level: thus, if patients do not have access to lemma knowledge, they should not demonstrated a different performance with unergative and transitive verbs.

### 7.3. Participants

The study was conducted on a group (N=10) of aphasic patients, selected with the following criteria: presence of mild-to-moderate language disorder, based on the administration of standard language examination, relatively spared written comprehension, in absence of severe reading deficit and/or severe articulation deficit. Following the administration of the Aachen Aphasia Test (AAT, Italian version, Luzzatti, Willmes & de Bleser, 1994), six patients were found to suffer from nonfluent aphasia, whereas four patients suffered from fluent language disorder (see Table 3).

Name	Age	YoE	Actiology	Type of aphasia
GR	34	13	heamorrhagic	agrammatic Broca
LZ	48	15	stroke	agrammatic Broca
NT	27	13	stroke	agrammatic Broca
SC	14	8	haemorrhagic	non-agrammatic Broca
RC	52	14	stroke	non-agrammatic Broca
GB	45	8	tumoral	non-agrammatic Broca
VL	61	8	stroke	anomic
MM	70	8	heamorrhagic	anomic
LG	56	18	heamorrhagic	Wernicke
SB	37	13	stroke	unclassified fluent

**Table 3.**  
Demographic data of the aphasic patients participating in the study.  
YoE= Years of education.

In detail, nonfluent aphasic patients were diagnosed as following: three suffered from agrammatic Broca's aphasia and three from non-agrammatic Broca's aphasia. The classification of nonfluent patients as agrammatic or non-agrammatic was based on the presence of "telegraphic" speech output, which characterizes agrammatic aphasia only: patients who showed slow rate of speech and

simplified syntactic structure, but no classic telegraphic output, were classified as non-agrammatic. As far as fluent aphasic patients are concerned, two were diagnosed as suffering from anomic aphasia, whereas the remaining two patients were diagnosed as suffering from Wernicke's aphasia and or from unclassified fluent aphasia.

Ten control participants, with age and educational level similar to those of aphasic participants (mean age:  $55.8 \pm 4.4$ ; mean education:  $8.9 \pm 2.6$ ), were also included in the study. Control participants were selected so as to have no previous history of language disorders, nor of neurological/psychiatric illness, and to have normal or corrected-to-normal vision.

#### *7.4. Materials and methods*

The stimuli were the same as those described in Experiment 1. The procedure was adapted from Experiment 1, as follows: participants listened to the instructions given by the experimenter and were shown 6 practice items in order to become familiar with the task. After the practice trials, instructions were repeated once and then participants were presented with the experimental trials. Each trial (see 5.5., Figure 8) began with a fixation cross (+), which remained on the screen for 1500 milliseconds (ms) and was followed by a sentence with a blank on the verb position. Participants were instructed to read the sentence aloud, and were corrected by the experimenter in case of error. Once the reading of the sentence frame was completed, the experimenter pressed the spacebar and the two verb options appeared on the screen, one above and one under the sentence frame. Subjects were then instructed to choose the correct option by indicating the selected verb on the screen. Given the difficulty of the task, participants were instructed to be accurate, and no particular attention was paid to the time needed for the response. Therefore, reaction times to the task were not considered, and accuracy was the only dependent variable introduced in the regression analysis.

#### *7.5. Results*

Items eliciting a mean accuracy that was more than 2 SD below the mean of the whole group of aphasic patients were deleted. Therefore, the final analyses for both the group of aphasic patients

and of age-matched control participants were performed on a total of 30 verb pairs. Analyses were conducted by using logistic regression within the approach of mixed-effects models (Jaeger, 2009). In all analyses, the dependent variable was item accuracy, and the main predictor of interest was *verb type* (unergative, transitive). Lexical variables (*lemma frequency*, *imageability*) and *length* (in letters) were considered as predictors in the analyses as well. In all analyses, *subject*, *item*, *age* and *years of education* were included as random factors. All analyses were performed by introducing first the predictor of interest, i.e. verb type, and then the other predictors one by one. The contribution of each predictor to the model was evaluated by performing ANOVAs between the model containing the predictor under scrutiny and the model without that predictor.

Control participants. Healthy participants performed overall well on the task (89,3% of correct responses), and errors were equally distributed among unergative and transitive verbs (10% and 11,3% of incorrect responses). The slight difference in accuracy between unergative and transitive verbs was not found to be significant, as shown by the output of the logistic regression (*verb type*:  $z=-0.352$ ,  $p=n.s.$ ).

Aphasic patients. The performance of aphasic patients is illustrated in Table 4. A preliminary analysis was conducted on the dataset of all participants in order to compare the overall performance to the task of the group of aphasic patients to control participants. This analysis revealed that aphasic patients performed worse than the group of age-matched control participants ( $z=-3.898$ ,  $p<.001$ ). Similar results were obtained from the two groups of nonfluent and fluent aphasic patients: patients' accuracy to the sentence completion task was lower than accuracy of control subjects for both groups (nonfluent:  $z=-3.384$ ,  $p<.001$ ; fluent:  $z=-2.310$ ,  $p=.021$ ).

A regression analysis was conducted on the whole group of aphasic patients (Table 5a) and the model that revealed to best fit of the data contained *verb type* (unergative, transitive), *fluency* (nonfluent, fluent aphasia), *imageability*, *word frequency* and the interaction between the latter two factors as predictors. Among them, only *verb type* ( $z=2.893$ ,  $p=.004$ ) and *imageability* ( $z=1.991$ ,  $p=.046$ ) were found to be statistically significant, with unergative verbs eliciting accurate responses more often than transitive verbs. *Word frequency* and the interaction between frequency and imageability were only marginally significant. (Table 5a). On the contrary, verbal *fluency* was not

found to have an effect on patients' accuracy, i.e. there was no significant difference in the overall performance between fluent and nonfluent aphasic patients. As to the effect of *verb type*, mean accuracy was better when the correct option was an unergative verb (75,2%) than a transitive verb (64%, Table 4).

Name	Fluency	% Correct transitive	% Correct unergative
GR	NF	53	57
LZ	NF	63	70
NT	NF	50	67
SC	NF	53	67
RC	NF	60	77
GB	NF	73	93
<b>mean accuracy NF</b>		<b>58,7</b>	<b>71,8</b>
VL	F	67	77
MM	F	70	90
LG	F	73	90
SB	F	67	57
<b>mean accuracy F</b>		<b>69,3</b>	<b>78,5</b>
<b>overall mean accuracy</b>		<b>64,0</b>	<b>75,2</b>

**Table 4.**

Results obtained by the whole group of aphasic patients (N=10) in the sentence completion task.

A subsequent analysis was performed on the two groups of patients (fluent vs. nonfluent type of aphasia), in order to evaluate the effect of verb type within each group. The logistic regression on the dataset of the nonfluent aphasic patients demonstrated again that the statistical model that best fitted the data contained *verb type*, *frequency*, *imageability* and the interaction between the two as predictors (see Table 5b). *Verb type* was found to be significant in this group ( $z=2.421$ ,  $p=.015$ ), with the same direction of the effect found in the entire patient sample, i.e. with better accuracy for



unergative than for transitive verbs (71,8% vs. 58,7% of accuracy respectively, see Table 4). In this group, *imageability* was also marginally significant ( $z=1.918$ ,  $p=.055$ ). The analysis conducted on the group of patients suffering from fluent aphasia (see Table 5c) revealed that the effect of *verb type* was not significant neither as a single predictor ( $z=1.625$ ,  $p=n.s.$ ), nor in conjunction with the other lexical variables that were significant in the previous regression analyses (see Table 5c).

**Table 5a**

Predictor	Estimate	Std. Error	z-value	p(> z )
Verb type	0.53	0.18	2.89	.004
Fluency	-0.37	0.26	-1.46	n.s.
Frequency	0.96	0.51	1.89	.058
Imageability	2.99	1.50	1.99	.046
Frequency*Imageability	-0.60	0.33	-1.83	.067

**Table 5b**

Predictor	Estimate	Std. Error	z-value	p(> z )
Verb type	0.56	0.23	2.42	.015
Frequency	1.11	0.65	1.71	n.s.
Imageability	3.71	1.93	1.92	.055
Frequency*Imageability	-0.73	0.42	-1.74	n.s.

**Table 5c**

Predictor	Estimate	Std. Error	z-value	p(> z )
Verb type	0.48	0.30	1.59	n.s.
Frequency	0.48	0.44	1.08	n.s.
Imageability	0.45	0.51	0.88	n.s.
Frequency*Imageability	-0.09	0.11	-0.84	n.s.

**Table 5.**

Results from the logistic regression analyses performed on the following groups: all patients (Table 5a), nonfluent aphasic patients (Table 5b) and fluent aphasic patients (Table 5c).

Given the aforementioned results, additional single-case analyses were performed for each participant within the group of aphasic patients, so as to evaluate individual differences among participants in each group (fluent and nonfluent patients). As far as overall accuracy to the task is concerned, 8 out of 10 patients showed lower accuracy than the age-matched control participants:

all comparisons elicited high  $\chi^2$  values ( $p < .001$ ), except the comparison between M.M. and controls showing  $\chi^2 = 4.7$ ,  $p = .03$ . Two patients (G.B. and L.G.) showed an overall performance that did not differ from control participants when considering responses to both unergative and transitive verbs altogether ( $\chi^2 = 2.0$ ,  $p = .16$  and  $\chi^2 = 3.2$ ,  $p = .07$  respectively). However, when considering the accuracy in responding to transitive verbs only, both patients showed lower accuracy than control participants ( $\chi^2 = 5.77$ ,  $p = .02$  for both). The pattern of accuracy was also analyzed in each patient in relation to the type of verb required to complete the sentence. Results are shown in Table 6.

name	fluency	unergative accuracy (N=30)	transitive accuracy (N=30)	$\chi^2$	p
GR	NF	17	16	0.07	n.s.
LZ	NF	21	19	0.3	n.s.
NT	NF	20	15	1.71	n.s.
SC	NF	20	16	1.11	n.s.
RC	NF	23	18	1.92	n.s.
GB	NF	28	22	4.32	.04
VL	F	23	20	0.74	n.s.
MM	F	27	21	3.75	.05
SB	F	17	20	0.63	n.s.
LG	F	27	22	2.78	.09

**Table 6.**

Single-case analysis depicting the accuracy score of aphasic patients to the sentence completion task, with respect to the type of verb (unergative, transitive) required by the sentence.

The majority of aphasic patients showed different accuracy values for unergative and transitive verbs (unergative verbs being more correct than transitive verbs), which resulted to be significant only in two of them (G.B. and M.M.). One patient showed a pattern of accuracy that was close to statistical significance, with the same direction of the effect (L.G.). With respect to fluency, two of those patients were suffering from fluent aphasia (M.M. and L.G.) whereas one was classified as suffering from nonfluent language disorder (G.B.).

## 7.6. Discussion

The present study was led by the aim of investigating the first prediction made by the ASCH (Thompson, 2003), according to which agrammatic patients are more impaired in producing transitive than unergative verbs, in relation to the difference in the number of arguments they require. In detail, our goals were: first, to investigate the prediction of a more demanding processing of transitive than unergative verbs in a task requiring lemma access and bypassing overt production; secondly, to test the possibility of generalizing this prediction to the performance of fluent aphasic patients, as suggested by previous studies (McAllister et al., 2009; Barbieri et al., 2010; see Luzzatti et al., 2001 for results on the comprehension of passive reversible sentences). An additional goal was, by testing the patients' access to lemma knowledge, to inform about the locus of the deficit in nonfluent aphasia, particularly in relation to the hypothesis of a deficit in lemma access (Kim & Thompson, 2000), a hypothesis that has been challenged by Bastiaanse and van Zonneveld (2005), who suggested instead a post-lemma deficit, i.e. a dysfunction of the grammatical encoding process.

Nonfluent and fluent aphasic patients, as well as a group of healthy participants with comparable age and educational level, underwent a sentence completion task in which they were asked to choose the correct verb among two alternatives that were very similar as to their semantic content, but had different argument structure, i.e. one was unergative and one was a two-place transitive verb. The performance of control participants was not influenced by the verb type, in contrast with McAllister and colleagues' (2009) data, who found an advantage for unergative verbs (in comparison to unaccusative verbs) also in neurologically unimpaired subjects. Despite accuracy was slightly below the ceiling level, control participants made an equal amount of errors when the correct option was either the unergative or the transitive verb. This finding is line with data from young healthy participants, who performed the same task showing no differences in accuracy between the two verb types, but obtained faster reaction times in selecting unergative than transitive verbs (Experiment 1). Results from the group of aphasic patients show instead a different level of accuracy in selecting unergative vs. transitive options. In detail, accuracy in performing the sentence completion task was significantly higher when the correct option was an unergative vs. a

transitive verb for the whole group of aphasic patients. Verb type was indeed found to be a significant predictor of the performance of aphasic patients both as a single factor and in the multivariate analyses, i.e. when considering the other lexical variables often influencing the patients' accuracy in a variety of tasks. In particular, the effect of verb type resisted the introduction of imageability, a factor referring to the verb semantic content that has often been claimed to account for the verb-specific deficit in nonfluent aphasia (Bird et al., 2000, 2001, 2002). However, this variable has always been found to interact with grammatical class (Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Rapp & Caramazza, 2002; Luzzatti et al., 2002, Crepaldi et al., 2006). Imageability cannot be matched across nouns and verbs in a picture naming task (Luzzatti et al., 2002). In the present study, verbs with different argument structure, could be perfectly matched for imageability. The item selection was made in order to ensure that patients based their choice solely on the verb grammatical properties, i.e. on the VAS. Therefore, the present results indicate a truly grammatical class effect elicited at the lemma level. In detail, these data are accounted for by the prediction of the ASCH regarding a more cognitively demanding processing of verbs according to argument structure complexity.

As to the comparison between the performance of fluent and nonfluent aphasic patients, overall accuracy did not differ between the two groups. However, the two groups behaved differently with respect to the effect of verb type. In detail, the results revealed that nonfluent aphasic patients were more accurate in choosing the correct verb when the target option was an unergative verb than a transitive verb, whereas the effect of verb type did not reach significance in the fluent aphasic patients. The single-case analysis conducted for each participant demonstrated that, despite all nonfluent patients showed a better performance on unergative than on transitive verbs, this effect reached the significance level only in one patient (G.B.). This patient was classified as suffering from non-agrammatic Broca's aphasia. Furthermore, the remaining two patients in which transitive verbs were more impaired than unergative verbs suffered from fluent aphasia. The data thus suggest that the predictions of the ASCH may apply to the performance of non-agrammatic nonfluent aphasic patients as well as to fluent aphasic patients. The latter claim is – at least in part – in line with data from Luzzatti and co-workers (2002), who found an influence of the type of VAS

on the performance of the whole group of nonfluent aphasic patients in a picture naming task of verbs. As to the different outcome of single-case analyses in comparison to group analyses, in this case the lack of an effect of verb type may be due either to variability related to the co-existence of different subtypes of fluent aphasia, or to inter-individual variability, as suggested by the analysis of single-case profiles.

The analysis of the performance of each patient in isolation, outlined that the effect may characterize the performance of either fluent or nonfluent aphasic patients. In detail, if considering the cases of the patients that clearly demonstrated an effect of verb type in line with the predictions of the ASCH, it is noticeable that their general performance was closest to control participants. Therefore, the finding of an effect of verb type at an individual level may be related to the level of language severity, i.e. the effect arises more easily in patients with better preserved language abilities.

The third objective of the present study was to test theories that explain the verb-specific deficit in aphasia. As to this issue, group analyses suggest that nonfluent patients may have access to lemma information. Indeed, the results obtained from the group of nonfluent aphasic participants indicate that they still may distinguish between unergative and transitive verbs. Their accuracy pattern replicates the pattern found for reaction times to the same task in young control participants (Experiment 1). Moreover, data are in line with the neuroimaging evidence attesting a modulation of brain activity in language areas according to argument structure complexity (see den Ouden et al., 2009; Thompson et al., 2010). However young controls, as well as the control group tested in the present Experiment, were not found to differ in accuracy. Therefore, it can be assumed that, since aphasic patients show greater ease in retrieving the argument structure of unergative verbs, they must have access to the processing level where this information is stored, i.e. the lemma level. If lemma knowledge may be accessed, then the deficit in producing verbs with more complex argument structure (see e.g. Thompson et al., 1997; Luzzatti et al., 2002) must be located after the lemma has been retrieved, e.g. at the level of grammatical encoding, as suggested by Bastiaanse and van Zonneveld (2005). This hypothesis could also explain data from a previous study (Barbieri et al., 2010), where patients showed errors in using lexically appropriate verbs with a correct

argument structure. In that study, both nonfluent agrammatic (4) and fluent (1) patients were found to have difficulty in realizing transitive verbs' arguments when performing a picture description task. Despite in that study we offered an explanation in terms of damage to the lemma level, those data may also be accounted by a deficit in mapping spared VAS knowledge and the sentence syntactic structure.

## 8. Experiment 4: A test of the ASCH in a word naming task

### 8.1. Introduction

The verb argument structure (VAS), defined as a verb feature indicating the number and type of participants in the event described by a verb, has been shown to influence aphasic patients' accuracy in several studies and in different languages (see 3.2, 3.3. and 3.6.). In detail, transitive verbs (e.g. *to chase*) have been reported to elicit lower accuracy in production, in comparison to unergative verbs (e.g. *to sleep*). On the other side, unaccusative verbs (e.g. *to disappear*) were found to be more difficult to produce than unergative verbs. As described in 1.1. and 1.2., transitive verbs differ from unergative verbs in the number of arguments taken by a verb, i.e. transitive verbs require at least two arguments, whereas unergative verbs usually require only one argument. Unergative and unaccusative verbs instead differ as to the underlying syntactic structure: according to the Unaccusative Hypothesis (Perlmutter, 1978; Burzio, 1986), the grammatical subject of unaccusative verbs generates in the VP-internal position, i.e. the position usually occupied by the direct object in transitive sentences, but moves to the subject position (SpecIP) leaving a trace behind (see 1.1., Figure 1a). Thus, unaccusative sentences are subject to a syntactic movement (Argument-movement, or A-movement<sup>10</sup>) analogous to the movement underlying passive sentences. As a consequence of this, the grammatical subjects of unaccusative verbs receive the role of Theme, whereas unergative verbs assign the role of Agent to their grammatical subjects. An additional difference between Italian unaccusative and unergative verbs relies in type of auxiliary selected by verbs at the composite past forms, i.e. unaccusative verbs require *essere* (e.g. *Il ragazzo è scomparso* [The boy disappeared, lit. The boy is disappeared]) and unergative verbs require *avere* (e.g. *Gianni ha dormito* [Gianni slept, lit. Gianni has slept]).

As earlier mentioned, several studies on agrammatic patients across different languages reported an increasing difficulty in processing verbs as the number of their arguments increases. This has been shown for English by Thompson and co-workers (Thompson et al., 1997; Kim & Thompson, 2000, Thompson, 2003; Kim & Thompson, 2004). A difficulty in naming transitive vs. unergative was also reported by Luzzatti and coworkers (2002) for Italian agrammatic patients. In addition, the

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<sup>10</sup> A-movement is defined as the movement of a verb argument from one position to a different one within the syntactic tree (see Chomsky, 1995).

authors found the whole group of nonfluent aphasic patients to be impaired on unaccusative verbs as later reported by Thompson (2003). In order to account for the data described so far, Thompson proposed the Argument Structure Complexity Hypothesis (ASCH), which explains the pattern of impairment of the agrammatic patients' verb production as a function of the argument structure complexity, i.e. both in terms of the number of arguments taken by a verb and of the presence of syntactic movement.

Evidence for an influence of argument structure complexity on verb processing also comes from neuroimaging studies on normal participants, which report a greater amount of brain activation for two- and three-place transitive verbs than for unergative verbs (see Thompson et al., 2007; den Ouden et al., 2009), even though with some exceptions (Shetreet et al., 2007), and for unaccusative vs. unergative verbs (Shetreet et al., 2009).

To summarize, evidences for an effect of the number of arguments taken by verbs on aphasic and normal participants come from a variety of tasks, among which some not requiring overt production (e.g. verb categorization in Kim & Thompson, 2000, 2004; lexical decision in Shapiro et al., 1987; Shapiro & Levine, 1990; Shapiro et al., 1993; Thompson et al., 2007; Thompson et al., 2010). On the contrary, vis-à-vis the issue of unaccusativity, almost all data derive from studies on the aphasic patients' production, either in picture naming tasks (Luzzatti et al., 2002; Thompson, 2003) or in sentence production tasks (see Lee and Thompson, 2004), with only a few evidences coming from tasks that did not require overt production (see McAllister et al., 2009, Shetreet et al., 2009).

#### *8.1.1. Why studying deep dyslexia?*

As described in 2.4., deep dyslexia (DD) (Marshall & Newcombe, 1973; Coltheart et al., 1980), is an acquired reading disorder characterized by an impossibility in reading non-words, as well as by the occurrence of semantic (*night* vs. *sleep*), visual (*white* vs. *while*) and morphological errors (*class* vs. *classify*) when reading words. The patients' reading performance is also characterized by an imageability effect, i.e. concrete nouns are read better than abstract nouns, and by an effect of grammatical class, i.e. nouns are read better than verbs and function words. Within the dual-route model of reading (Coltheart et al., 1993; Coltheart et al., 2001, see 2.4, Figure 5), DD is assumed to result from damage to the sub-lexical route and concomitant disruption of the direct lexical route



(“multiple-deficit account”, see Nolan and Caramazza, 1982), which forces the retrieval of the phonological representation to follow the access of conceptual knowledge. An additional fragility of either the semantic system itself or of the connection between semantics and the phonological output lexicon would account for the occurrence of semantic errors (Shallice & Warrington, 1980). Another account of DD that has received wide support is the so-called “Right Hemisphere Hypothesis” (RHH; Coltheart, 1980, 2000; Saffran et al., 1980), according to which DD reflects the emerging linguistic abilities of the right hemisphere (RH), which are supposed to be limited to high-frequency concrete nouns (see 2.4). A further account of DD arises from the “Failure of Inhibition Theory” (FIT) proposed by Buchanan and colleagues (2003; see also Colangelo & Buchanan, 2005), according to which the massive presence of semantic substitutions in DD would derive from a defective inhibition of semantically related competitors within the phonological output lexicon. The investigation of deep dyslexia has often provided the opportunity to test models of lexical processing. For instance, Luzzatti, Mondini & Semenza (2001) analyzed the performance of an Italian agrammatic patient with phonological/deep dyslexia in reading morphologically complex words, in order to test Baayen and colleagues’ (1997a, 1997b) dual-route model of complex words processing<sup>11</sup>. This theory assumes an interaction between word frequency and decompositional processes and predicts that frequent forms are stored as a whole and thus retrieved faster than infrequent forms, which are instead subject to on-line (de)composition. The results reported by Luzzatti and coworkers supported the aforementioned prediction, by showing a significantly better reading performance of singular forms vs. plural forms for singular-dominant nouns, i.e. for nouns whose singular form is more frequent than the plural one (e.g. *nose* vs. *noses*). Another example comes from Buchanan et al. (2003), who tested a deep dyslexic patient (JO) with respect to her ability to implicitly and explicitly access semantic information and to use this information in a naming task. By showing an influence of semantics on JO’s ability to read non-words as novel compounds, the results support an implicit access of semantic information and are

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<sup>11</sup> *Dual route* models were introduced as a compromise solution within the debate between supporters of the *full-listing* and 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 and independently from 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 on-line.

interpreted as an evidence in favor of a model of lexical processing named PEIR<sup>12</sup>. Moreover, the investigation of patients with DD has informed about cognitive models of processing of other types of stimuli, such as numbers (see for instance Cohen, Dehaene & Verstichel, 1994). Aim of the present study is to investigate the influence of argument structure complexity while reading verbs as singletons, by testing a patient suffering from agrammatism and DD. The aforementioned studies on agrammatic patients (see Thompson et al., 1997; Luzzatti et al., 2002; Thompson, 2003) revealed a difficulty in producing both unaccusative and transitive verbs when compared to unergative verbs. These data are accounted by the ASCH (Thompson, 2003), which explains the dissociation among verb categories in terms of a higher complexity (either due to the number of arguments or to the presence of syntactic movement of constituents) of transitive and unaccusative verbs vs. unergative verbs. Since agrammatism and deep dyslexia share several features and they also often co-occur in a same patient, the present study was led by the idea that a similar set of effects could be found in deep dyslexic patients too. Indeed, in light of the “multiple-deficit account”, the DD reading disorder would follow an extensive left perisylvian lesion causing complete disruption of both the sub-lexical and of the direct route of reading: therefore, patients have to rely on the lexical-semantic route, thus accessing each word lexical entry. The assumption implies therefore an access to the word lemma, where information about verb argument structure is stored (Levelt et al., 1999, see 1.5., Figure 3). Assuming that the argument structure properties are spared in DD patients, the fact that they are forced to read via the lexical-semantic route predicts that their reading performance shall reflect an ASCH complexity effect also in a reading task.

## 8.2. *Aim of the study*

In detail, main goals of the study are: 1) to outline 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 deep dyslexic patients; 2) to test the hypothesis of a dissociation among verb categories based on their underlying argument structure, in line with the

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<sup>12</sup> According to the PEIR, Production is based on Explicit access, which follows Implicit access, which in turn depends on intact Representation. This model of lexical processing is the theoretical framework in which the FIT (see above) was conceived.

predictions of the ASCH, and particularly: a) testing the effect of the argument number, by comparing unergative to transitive verbs, and b) testing the influence of A-movement by comparing unergative to unaccusative verbs. As far as the first issue is concerned, we predict verbs to be more impaired than nouns, as part of the grammatical class effect usually arising in DD. As to the second objective, we predict the number of arguments effect to be elicited even in a simple word naming task, in line with neuroimaging studies that showed a modulation of language areas already in a lexical decision task. These data actually indicate an effect of the number of arguments taken by the verb as soon as the lexical entry is accessed. Therefore, we expect DD patients to be more accurate in reading unergative than transitive verbs. With respect to the unaccusativity issue, our expectations are less clear. Indeed, similarly to the effect of the number of arguments, almost all evidences of a greater complexity of unaccusative vs. unergative verbs come from studies on verb production in aphasic participants. Furthermore, unlike for the number of arguments issue, the only neuroimaging study reporting an effect of unaccusativity used a semantic plausibility judgment on sentences. The same holds for the study on normal participants conducted by Friedmann et al. (2008), who analyzed the processing of sentences containing unaccusative verbs. Therefore, we aimed at testing whether the syntactic complexity underlying the processing of unaccusative verbs would also arise in a word naming task.

### *8.3. Participant*

GR is a 34-years-old employee (GR) with 13 years of education, who suffered from a left fronto-parietal haematoma three years prior to the present study. GR's language and cognitive abilities were assessed before and after intensive language training at the Villa Beretta Rehabilitation Unit. The administration of the Italian version of the Aachen Aphasia Test (Luzzatti et al., 1994) revealed a moderate Broca's aphasia with agrammatism. Her speech was reduced to short agrammatic utterances with rare production of verbs and almost complete omission of function words. Her naming ability was further investigated by administering 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 of this test indicate a significantly better performance on nouns than on verbs, and a difference in accuracy among the different verb types (unergative > transitive verbs).

	N=	naming accuracy	
		N	%
natural	25	18	72
artificial	25	17	68
<b>total nouns</b>	<b>50</b>	<b>35</b>	<b>70</b>
unergative	17	6	35
unaccusative	13	2	15
transitive	20	2	10
<b>total verbs</b>	<b>50</b>	<b>10</b>	<b>20</b>

**Table 7.**  
GR's accuracy in the picture naming task of nouns and verbs.

GR's reading performance was assessed by means of two additional tasks: a standard task assessing the patient's ability to read words and non-words, and a test specifically designed to investigate the emergence of semantic errors in reading. The first (Toraldo, Cattani, Zonca, Saletta & Luzzatti, 2006) included 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 known to be necessary for reading non-words. The second task investigated the emergence of semantic errors in reading: the reading list was composed of pairs of semantically related words, each pair being made of a highly frequent and a low frequent word (e.g. *gatto - miccio* [cat - kitten]). Based on the results on both tasks, GR was classified as suffering from deep dyslexia. Indeed, GR was unable to read non-words and the analysis of her errors in the reading tasks revealed a significant grammatical class and imageability effect, many semantic errors as well

as morphological and visual errors (see Marelli, Aggujaro, Scola, Molteni & Luzzatti, 2009, for a more detailed description of the tasks and of GR's reading performance).

#### 8.4. Materials and methods

Seventy-eight verbs and thirty-one nouns were included in the experimental task. Verbs included in the word naming task had to belong to only one of the following categories: *unaccusative* verbs, *unergative* verbs, two-place *transitive* verbs (see 1.1.). 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, i.e. verbs in which the grammatical subject receives the role of Theme were considered as unaccusatives, whereas when the grammatical subject identifies the performer of the action (Agent) the verb was classified as unergative. An additional criterion used to identify unaccusative verbs was the type of auxiliary taken in the compound past form (e.g. the verb *esistere* [to exist] was classified as unaccusative, whereas the verb *tremare* [to tremble] was classified as unergative, since the first requires the auxiliary verb *essere* in the past tense, whereas the second takes *avere* as auxiliary verb in the past form). With reference to the issue of transitivity, all the verbs included in the study were classified as strictly transitive. Alternating unaccusative verbs as *affondare* [to sink] (see 1.3.) and verbs that may subcategorize both an unergative and a transitive sentence structure like *mangiare* [to eat] (see 1.1.) were not included in the reading list. Verbs in the three categories were matched for lemma frequency, length and imageability, whose 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 seventy-eight verbs, 26 per category. All verbs were presented in the infinitive form (e.g. *parlare* [to talk]), which is in Italian the citation form of verbs and is the easiest verb form to produce for agrammatic patients<sup>13</sup>. Thirty-one

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<sup>13</sup> Italian is a language with very rich morphology, in which both verbs and nouns are always inflected. Unlike English, the deletion of a verb or noun suffix would result in a non-word. Not all inflections are equally difficult for Italian agrammatic patients. Indeed, 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*).

nouns, all in the singular form (half of them bearing the masculine and half the feminine grammatical gender) were also included in the reading list.

The stimuli were randomly presented on a computer screen after a fixation cross lasting 1500 msec. The participant 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 the patient was unable to read a word, she was encouraged to go on, by pressing the spacebar and to move to the following word. The whole patient's production – pauses included - was manually transcribed. The task was administered in two sessions, with a time interval of a month. Since the number of correct responses given by GR in each session was relatively low, the final scoring was computed using the following criterium: items that were read correctly (including repairs) 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".

### *8.5. Results*

The first arising remark is GR's overall low reading performance on verbs (13 correct responses out of 78, see Table 7), which is in contrast with her good accuracy on nouns (27 correct responses out of 31). The better performance in reading nouns vs. verbs parallels the results obtained in the picture naming task, where GR named 35 out of 50 objects and only 10 out of 50 actions. A better reading accuracy in reading nouns than verbs emerged in both sessions, whereas the patient's ability of reading verbs improved in the second session (6 vs. 12 correct responses out of 78 verbs respectively).

With respect to our primary interest, i.e. to investigate the possibility that the verb category (unergative, unaccusative, transitive) has influenced GR's ability of reading verbs in isolation, data indicate that GR read unergative verbs significantly better than unaccusative verbs, which were read in turn more easily than two-place transitive verbs (see Table 8). A similar pattern was also found in the picture naming task (see Table 7).

	N=	Correct
Unergative	26	8
Unaccusative	26	4
Transitive	26	1
Total Verbs	78	13
Nouns	31	27

**Table 8.**  
GR's accuracy in the word naming task.

	First session		Second session	
	Nouns (N=31)	Verbs (N=78)	Nouns (N=31)	Verbs (N=78)
Correct	23	6	24	12
Visual	3	5	1	8
Morphological	0	4	0	5
Semantic	1	4	1	1
Mixed	0	2	0	2
Unrelated	0	0	1	6
No response	4	57	4	44

**Table 9.**  
Qualitative analysis of GR's performance over the two sessions. The label "mixed errors" illustrates those errors that were classified as belonging at the same time to two of the following categories: "visual errors", "morphological errors" or "semantic errors".

The analysis of GR's errors in the reading task indicates that, in case of difficulty, the patient tended to give up and move to the following item without producing any response (see Table 9). This type of behavior was the most frequent in verb reading. Among the types of error usually characterizing DD, visual errors (e.g. *accedere*, to access → *accendere*, to light) were overall more

frequent than both morphological (e.g. *badare*, to look after → *badante*, care giver) and semantic errors (e.g. *arrestare*, to arrest → *prigione*, jail<sub>Noun</sub>), whereas morphological and semantic errors appeared with almost equal frequency. Unrelated responses and mixed errors, e.g. errors that were classified as being both visual and morphological (e.g. *ipotizzare*, to hypothesize → *ipnotico*, hypnotic, via *ipnotizzare*, to hypnotize) also emerged in GR's production (see Table 9).

### 8.5.1. Quantitative data analysis

The first aspect that was investigated is the grammatical class effect. A logistic regression – conducted using the approach of mixed-effects models (see Jaeger, 2009) - was performed on GR's accuracy data, with the dependent variable being the probability of a given item to be read correctly in at least one of the two sessions. *Verb regularity* (for verbs) and *grammatical gender* (for nouns) were introduced as random factors in the analyses. Grammatical class and all remaining lexical variables (word frequency, length, 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 their logarithms. The regression was performed by introducing one predictor at time and by comparing each model with the model including the newly introduced variable by means of an analysis of variance (ANOVA). The effect of *grammatical class* was found to be highly significant both as a single predictor ( $z=3.773$ ,  $p<.001$ ) and following the addition of *imageability* (grammatical class:  $z=3.071$ ,  $p=.002$ ; imageability:  $z=3.478$ ,  $p<.001$ ) as well as of the other lexical variables. The model that best fitted the data contained *grammatical class*, as well as *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 ( $z=1.920$ ,  $p=.055$ ), all other factors significantly predicted the patients' accuracy to the reading task (grammatical class:  $z=2.312$ ,  $p=.021$ ; imageability:  $z=3.677$ ,  $p<.001$ ; length:  $z=-2.092$ ,  $p=.036$ ). Data show a persistence of the grammatical class even after partialling out the effect of imageability.

Secondly, we performed an additional logistic regression analysis on GR's accuracy for verbs only, in order to investigate the effect of argument structure complexity. In this case, *verb type* replaced grammatical category as a predictor in the regression analysis. The model that proved to be the best



to fit our data contained *verb type*, *imageability* and *length* as predictors. Despite length was not significant ( $z=-1.659$ ,  $p=.097$ ), both imageability and verb type were found to significantly influence the patient's response to the task. Accuracy in naming verbs was highest for unergative verbs and progressively less inaccurate for unaccusative and for transitive verbs, but the contrast between unergative and transitive verbs ( $z=-2.286$ ,  $p=.022$ ) proved to be statistically significant, and the comparison between unaccusative and transitive verbs was found to be marginally significant ( $z=-1.923$ ,  $p=.054$ ). On the contrary, the comparison between unergative and unaccusative verbs ( $z=-0.604$ ,  $p= n.s.$ ) did not approach significance.

### 8.6. Discussion

The present study investigated the effect of grammaticality in the reading performance of a deep dyslexic patient, with respect to two main issues: 1) the dissociation between nouns and verbs and its relationship to imageability; 2) the effect of verb type as outlined by the Argument Structure Complexity Hypothesis (Thompson, 2003). In detail, aim of the present study was to investigate the prediction that verbs that have a more complex argument structure, either because they require 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 more simple argument structure. An agrammatic patient suffering from deep dyslexia (GR) performed a word naming task on both nouns and verbs. The verbs included in the task belonged to the unergative, unaccusative or transitive category. As to the type of errors found in GR's production, visual, morphological, semantic and mixed (visual and semantic) errors were all represented. The analysis of GR's performance in the word naming task revealed a very impaired ability of reading verbs, whereas reading of nouns was only slightly impaired. The pattern of impairment found in GR's word reading ability replicates the data reported by Marelli and coworkers (2009), who tested the same patient in multiple tasks reporting an effect of grammatical class and concreteness on her production. These findings are in line with the literature reporting a grammaticality effect in deep dyslexia, as outlined by Coltheart (1980) and supported by further research (see for instance Friedman & Perlman, 1982). The main finding of the study is a dissociated pattern of impairment

among verb types, i.e. a disproportionate impairment of transitive verbs, which replicates the effect of argument structure complexity found in the agrammatic patients' production in several languages (see Luzzatti et al., 2002 for Italian, Thompson, 2003; Lee & Thompson, 2004 for English, Jonkers, 2000; Jonkers & Bastiaanse, 1996, 1998 for Dutch; de Bleser & Kauschke, 2003 for German). Data are discussed 1) in light of the debate on the relation between imageability and grammatical effects, 2) with reference to the theories on the mental representation of argument structure at the lemma level and 3) in light of the several accounts of deep dyslexia.

#### *8.6.1. Grammatical class effects and imageability*

Part-of-speech and imageability effects on reading accuracy are typical symptoms of deep dyslexia. They have often been interpreted as strongly interconnected, specifically in relation to the impairment shown by deep dyslexic patients in reading function words. Function words are indeed less imageable than nouns; therefore the grammatical class effect has often been considered as a consequence of the semantic impairment typical of deep dyslexia (see for instance Nolan & Caramazza, 1982). A similar position has been assumed by some authors in attempting to account for the pattern of verb and noun processing shown by agrammatic patients (Bird et al., 2000, 2001, 2002). In detail, Bird and colleagues hold that the effect of grammatical class results from the different imageability underlying nouns and verbs. This assumption is in contrast with the position of other authors (Caramazza & Hillis, 1991; Berndt et al., 2002; Rapp & Caramazza, 2002) who assumed a separate representation of nouns and verbs within the mental lexicon. Moreover, the imageability account of the grammatical class effect is challenged by some studies (Luzzatti et al., 2002; Aggujaro et al., 2006) reporting a persistence of the noun/verb superiority even after partialling out the effect of imageability in the logistic regression analysis.

The present experiment outlines a highly significant grammatical class effect, which is in line with the data obtained in the picture naming task, demonstrating a much better production of nouns than of verbs. Even if nouns and verbs were initially not matched for length, frequency and imageability these variables as well as their interactions were included as predictors in the logistic regression. The results show persistent grammatical class effects despite the introduction of imageability,

indicating that the dissociated performance between nouns and verbs was not accounted for by imageability, in contrast with Bird and coworkers' (2000, 2001, 2002) hypothesis.

However, the main finding of this study concerns the dissociation among verb categories (unergative, transitive and unaccusative verbs). In this case, the three lists of verbs were matched for imageability, as well as for the other variables. Moreover, imageability was included as a predictor in the logistic regression analysis, so as to evaluate the effect of argument structure taking into account the influence of this variable. Similarly to the noun-verb dissociation, the effect of verb type persisted even after partialling out the effect of imageability. Taken together, the present results are in line with data from Luzzatti et al. (2002) and Aggujaro et al. (2006), in that all studies report grammaticality effects that cannot be accounted for by differences in imageability, in contrast with Bird and colleagues' account (2000, 2001, 2002).

#### *8.6.2. Word naming and argument structure complexity*

As far as the issue of verb argument structure complexity is concerned, data show that the patient's performance followed the gradient of complexity indicated by the ASCH: indeed, unergative verbs elicited the highest number of correct responses, and accuracy was progressively lower for unaccusative and transitive verbs; however, only the contrast 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 conceives the issue of complexity considering two aspects: the number of arguments taken by verbs and an underlying syntactic movement. According to the prediction based on argument structure complexity, verbs taking more than one argument, as for instance transitive verbs, should be more difficult to retrieve than unergative verbs, which require only one argument. According to the prediction based on syntactic movement, unaccusative verbs should be more complex than unergative verbs in that their construction entails a movement of one of the constituents which is similar to the movement occurring in passive sentences (Perlmutter, 1978; Burzio, 1986). The results obtained in the present study are in line only with the first of these two predictions, since syntactic movement did not elicit a significantly worse accuracy on unaccusative verbs in our patient. On the contrary, the number of arguments required by verbs had an influence on GR's

production, as shown by the highly significant contrast between unergative and transitive verbs, as well as by the comparison between unaccusative and transitive verbs, which was very close to the threshold for statistical significance. The absence of an effect of A-movement in our data could be due to the limited number of correct responses given by our patient. However, an alternative account of this result can be put forward, i.e. these two effects (number of arguments and syntactic movement) arise at different levels of lexical processing. In detail, we assume that the number of arguments is a feature that becomes available as soon as the lemma is accessed, since it is lexical in nature. As far as the issue of unaccusativity is concerned, a further step – in terms of language processing – is necessary. Indeed, unaccusative and unergative verbs do not differ in the number of required arguments, but in the syntactic structure of the subcategorized sentences: therefore, the higher complexity of unaccusative with respect to unergative verbs arises when the a minimal syntactic activation is required.

As already mentioned, the influence of the **number of arguments** taken by verbs has been reported in studies assessing the aphasic patients' verb production 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 single verbs and of verbs implemented in sentences (Ben-Shachar et al., 2003; Shetreet et al., 2007; Thompson et al., 2007, den Ouden et al., 2009). 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; Thompson, Bonakdarpour & Fix, 2010), i.e. in absence of a syntactic context.

On the contrary, as far as the **effect of syntactic movement** is concerned, evidences of a more demanding processing of unaccusative than unergative verbs mainly come from studies on the aphasic patients' verb production both in isolation (Luzzatti et al., 2002, Thompson, 2003) and in a sentence context (Thompson, 2003, Lee & Thompson, 2004). A more recent study (McAllister et al., 2009) also reported an effect of A-movement on both aphasic and normal participants' accuracy, by showing better accuracy in producing and comprehending sentences that contained unaccusative verbs when compared to unergative sentences. Neuroimaging studies so far conducted

have shown an effect of unaccusativity only when processing sentences (see Shetreet et al., 2009). In conclusion, there is no evidence of an effect of unaccusativity in tasks beyond picture naming for verbs as singletons. Picture naming, when designed to elicit verb production, entails the depiction of the participants to the action, thus enhancing the probability that a (minimal) sentence structure is prepared. Thus, it can be assumed that the effect of unaccusativity, i.e. the effect of syntactic movement, arises in an action naming task, but not necessarily when participants are asked to perform a lexical decision or a word naming task on verbs, since syntax is unlikely to be activated in the last two conditions. Therefore, it can be assumed that the representation of the number of arguments required by verbs is contained at lemma level, whereas the effect of unaccusativity is likely to arise at a post-lemma level (i.e. the stage of *grammatical encoding*<sup>14</sup>). In our study, picture naming data were collected on a different pool of verbs from those used in the word reading task, this preventing a real comparison between the results from the two tasks. GR's performance in the picture naming task demonstrates a tendency that is in line with the aforementioned hypothesis. Indeed, out of the few verbs correctly retrieved by the patient, the majority of them were unergative (35%), whereas only 15% of unaccusative and 10% of transitive verbs were named correctly, thus suggesting a better lexical retrieval when an action is described by an unergative verb than by either an unaccusative or a transitive verb.

### 8.6.3. Lemma access and theories of deep dyslexia

The present study indicates that GR has access to the word lexical-syntactic features, i.e. the *lemma*, where information about verb argument structure is stored. These data are also in line with previous research demonstrating a dissociation based on grammatical class, since this information is part of the lemma as well. The fact that GR may access lemma stored information is consistent with an interpretation of deep dyslexia in light of a dual-route model of reading: indeed, assuming a damage to both the GPC and the direct lexical route ("multiple-deficits account"; Newcombe & Marshall, 1980; Shallice & Warrington, 1980; Nolan & Caramazza, 1982), reading can proceed only through the lexical-semantic route, thus implying access to the semantic and lexical features of the word. Therefore, the possibility of accessing lemma information, which is assumed to be

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<sup>14</sup> In Levelt's model of lexical selection (Levelt et al., 1999; Levelt, 2001), *grammatical encoding* is the stage in which the creation of the "syntactic environment", i.e. the realization of phrases and clauses, begins.

located between semantics and the phonological output lexicon (Levelt, 1989, 1999), is in line with this model. Another interpretation of deep dyslexia outlined in the introduction is the Right Hemisphere Hypothesis (RHH; Coltheart, 1980, 2000; Saffran et al. 1980), which considers the symptoms of deep dyslexia as resulting from the emerging linguistic abilities of the right hemisphere (RH), limited to frequent, concrete nouns. Within this theoretical framework, if lemma information is retrieved before the phonological word form, two alternative options need to be considered: 1) lemma information is stored in both hemispheres and thus deep dyslexic patients may access it in the RH; 2) lemmas are represented only in the LH and deep dyslexic patients shall still be able to access this information. The first option is in contrast with the assumption of limited linguistic competence of the RH: information stored at the lemma level is abstract in nature; moreover, even assuming that lemma information is stored in the RH as well, it is unlikely that such information may concern verbs. Therefore, the second option seems to be more likely, as long as processing of written words is assumed to shift to the left hemisphere immediately after retrieval of the underlying semantic features.

A third account of deep dyslexia is the failure-of-inhibition theory (FIT; Buchanan et al., 2003), according to which both semantic paralexias and the impossibility of reading non-words are explainable as a defective inhibition, respectively, of the semantic competitors within the semantic system and of the co-activated real words within the phonological output lexicon. This theory has a relevant advantage, i.e. the possibility of explaining the complexity of symptoms appearing in deep dyslexia in terms of a single mechanism: a defective inhibition of active competitors. However, it does not offer an explanation for the grammatical class dissociation that is often observed in deep dyslexia. The FIT is based on a model of lexical production labeled PEIR, which posits a distinction between implicit and explicit access to phonological, semantic and morphological information. Following this model, deep dyslexia is caused by an impairment in explicit access to phonological representation, in spite of a preserved implicit access. Our results are consistent with a spared implicit access to word lexical information, given the possibility for GR to access VAS information at the lemma level. However, Buchanan et al.'s (2003) theory does not offer an

explanation for the grammatical class effects, and is therefore little suitable to explain the finding of a greater impairment in reading transitive vs. unergative verbs in terms of competitors inhibition. To conclude, the results of the present study demonstrate a pattern of verb reading that follows the predictions of the ASCH, as far as the number of arguments (unergative vs. transitive, unaccusative vs. transitive) is concerned. On the contrary, the absence of a clear difference in accuracy between unergative and unaccusative verbs suggests that the more demanding processing of unaccusative verbs may arise at a post-lexical level, i.e. at the level of grammatical encoding. The sensitivity to VAS is in favor of a spared access to the word lexical-syntactic properties (lemma) in our patient. The possibility for deep dyslexic patients to access lemma information is in line with both the multiple-deficit account of deep dyslexia and the RHH; on the contrary, the interpretation in light of the FIT only partly accounts for our data.

## 9. General discussion

The study was conducted so as to test the mental organization of VAS and the generalization of the predictions of the ASCH, with respect to both the comparison between transitive and unergative verbs and between unergative and unaccusative verbs. In detail, the aims were the following: i) to test the effect of the number of verb arguments in a task that does not require overt production but instead requires explicit access to information about the VAS in Italian-speaking healthy participants (Experiment 1) as well as in fluent and nonfluent aphasic patients (Experiment 3); ii) to test both the effect of the number of arguments and of the presence of syntactic movement in a word naming task by testing a patient suffering from deep dyslexia (Experiment 4). A second goal is to inform about the deficit underlying the verb-specific deficit that characterizes nonfluent aphasia (Experiment 3), by testing the hypothesis of a defective lemma access (Kim & Thompson, 2000) as compared to a post-lemma deficit at the level of grammatical encoding (see Bastiaanse & van Zonneveld, 2005). An additional goal was to investigate the independent access to semantic and to VAS information, as suggested by models of contemporary psycholinguistics, by testing healthy participants in a sentence completion task while manipulating the type of information required to perform the task (Experiment 2).

As far as the first goal is concerned, Experiment 1 investigated the hypothesis of a greater processing complexity of transitive verbs - as compared to unergative verbs - in a sentence completion task where Italian healthy participants were asked to complete a sentence by choosing among two verb options with similar semantic content but with different argument structure, i.e. by choosing between an unergative and a transitive verb. The results outline that reaction times were significantly faster in selecting unergative verbs as compared to transitive verbs, whereas no differences were observed in accuracy. Analogous results were found in Experiment 2 for English-speaking participants: in this Experiment, native speakers of American English were tested by using the same paradigm, i.e. a sentence completion task, and by manipulating the type of information required to complete the sentence. In detail, Condition 1 was identical to Experiment 1, with participants performing a choice based on VAS information. On the contrary, in Condition 2 participants performed a choice based on the verb semantic content: in this case, the two verb



options were both two-place transitive verbs (the same transitive verbs used in Condition 1), with only one of them fitting the sentence as far as semantics is concerned. As far as reaction times data in Condition 1, results confirm those obtained on Italian healthy participants, i.e. responses were faster when the correct verb option was an unergative vs. a transitive verb. Moreover, the comparison between reaction times to transitive verbs in Condition 1 and Condition 2 reveals that – among the same set of transitive verbs – responses were faster when performing a choice based on semantic than on VAS information. In Experiment 3, the same task and stimuli of Experiment 1 were administered to a group of aphasic patients, six of which were suffering from nonfluent and four from fluent aphasia. The results demonstrate a significantly better accuracy – for the group of nonfluent aphasic patients only – when responding to unergative than to transitive verbs. However, when considering individual patterns of accuracy, only two out of ten patients showed a significant effect of the number of arguments taken by verbs (one patient suffered from nonfluent aphasia and one from fluent aphasia). Finally, in Experiment 4 a nonfluent agrammatic patient (GR) suffering from deep dyslexia was tested as to her ability in reading verbs with different VAS (unergative, unaccusative, two-place transitive verbs). Results outline that GR performed overall better on unergative than on transitive verbs, whereas the difference between unergative and unaccusative verbs failed to reach significance.

Considering the results of each Experiment in relation to the goals stated above, an arising remark is that the first prediction made by the ASCH, i.e. the more cognitively demanding processing of transitive verbs as compared to unergative verbs, is confirmed by two source of evidence: accuracy data obtained from aphasic patients and the analysis of reaction times in healthy participants. In detail, Experiment 3 has confirmed that the accuracy of nonfluent aphasic patients, at least at a group level, is better for unergative verbs than for transitive verbs, even in a task that taps access to VAS information without requiring overt production. However, the analysis of the individual profiles also suggest that in some cases fluent aphasic patients may show the same pattern: therefore, the present data suggest that the predictions of the ASCH may generalize to fluent aphasia as well. Moreover, Experiment 4 has shown that this prediction can generalize also to a word naming task, i.e. it can account for the pattern of performance of patients suffering from deep

dyslexia. Finally, the analysis of reaction times data of healthy participants (Experiment 1, Experiment 2 – Condition 1) demonstrate that transitive verbs elicit longer reaction times than unergative verbs, thus indicating that the ASCH could reflect a more general process regulating normal language processing, as previously suggested by McAllister and colleagues (2009).

As far as the second goal of the study is concerned, i.e. testing the more cognitively demanding processing of unaccusative verbs as compared to unergative verbs, the analysis of the accuracy pattern shown by our deep dyslexic patient (GR) failed in outlining an effect of syntactic movement. Therefore, the second prediction of the ASCH is not confirmed by data from Experiment 4, as opposed of earlier evidence (Luzzatti et al., 2002) attesting a less frequent production of unaccusative than of unergative verbs in nonfluent aphasic patients. The absence of an effect of syntactic movement on GR's production could depend either on the limited number of correct responses given by the patient or on the type of task used in this Experiment. Indeed, GR underwent a word naming task, where verbs were presented as singletons, in absence of any additional syntactic context. This particular condition could have prevented the effect of syntactic movement to arise, given that the more cognitively demanding processing of unaccusative verbs is assumed to be related to a purely syntactic factor, i.e. the movement of the NP grammatical subject from a post-verbal position to the subject position.

Considering the third objective of the study, i.e. informing about the locus of the verb production deficit in nonfluent aphasia, Experiment 3 indicates that nonfluent aphasic patients, at least at a group level, can differentiate between unergative and transitive verbs, thus having at least partial access to VAS information, i.e. to the lemma level. Therefore, the greater difficulty in producing transitive than unergative verbs reported in the literature may be due to a deficit in mapping arguments onto the sentence syntactic structure, i.e. at the level of grammatical encoding as suggested by Bastiaanse and van Zonneveld (2005).

Finally, with respect to the fourth goal of the study, results obtained in Experiment 2 inform about the role of semantic and VAS information in sentence processing. In detail, the finding of faster reaction times – within the same set of transitive verbs – in responding to semantic information than to VAS information is interpreted as indicating a faster access to semantic than to lemma

knowledge. Therefore, data support an independent access to semantic and VAS information. Further research is necessary to determine the way semantic and argument structure information interact, and how semantics can pose restrictions on the way verbs realize their arguments in sentence production.

To conclude, the present research offers evidence in favor of the role of VAS information in determining the normal and aphasic subjects' performance to verb and sentence processing. The present data demonstrate that access to VAS information is faster (for healthy subjects) and easier (for aphasic patients) for unergative than for transitive verbs, in line with the first hypothesis made by the ASCH. This suggests a more cognitively demanding processing of transitive verbs as compared to unergative verbs, possibly in relation to the different number of arguments required by the two verb types. Moreover, the present data suggest that the ASCH could not only account for the pattern of verb production in agrammatic patients, but could reflect a more general process underlying normal language processing in a variety of tasks, among which written word naming. In addition, the results indicate that the greater complexity of unaccusative verbs as compared to unergative verbs may arise at a post-lemma level, i.e. the level of grammatical encoding. The latter level is also considered to be the stage – within models of lexical production - at which the deficit characterizing the production of verbs in nonfluent aphasia is located. Finally, VAS and semantic information can be accessed independently, thus suggesting a representation of semantic and VAS information at separate and subsequent levels of language processing.

## 10. Acknowledgments

First of all, I want to thank my mentor, Prof. Claudio Luzzatti, who first inspired my interest in aphasia as well as in the mysterious process underlying language production. Since there are so many reasons to thank him, I will just say that without him I would have not ended up with writing a PhD dissertation. Wherever this will take me, I feel it like a huge accomplishment which would have not been possible if I had not met him. Secondly, I am very grateful to Prof. Cynthia Thompson, whose work widely inspired my research in the last four years and who gave me the opportunity to collect data (as well as to spend nine wonderful months) in her lab at Northwestern University. I am also thankful to Prof. Dirk den Ouden, who always gives me great advices and answers to my questions, and who taught me how to find something good about myself every day.

I would like to thank Dr. Carlo Geraci for his comments on the stimuli used in this study, as well as Dr. Davide Crepaldi and my colleague Marco Marelli, who both introduced me to the ‘magic’ world of R and to mixed-effects models while eating kebab at lunchtime. A special thank goes also to Dr. Mirta Vernice for listening to me when I used to stop by her office and to ask her big unsolved questions about language and argument structure processing.

I am grateful to the professionals who helped me with data collection by allowing me to test their patients: Dr. Silvia Aggujaro from Villa Beretta Rehabilitation Clinic in Costamasnaga (LC), and Ruggero Verga, Paola Saletta, Graziella Ghirardi, Mirella Frustaci from the Rehabilitation Unit of G. Salvini Hospital in Passirana (MI).

I also need to say “thank you” to all the people who allowed me to survive the past four years by rendering all this work much more pleasant than it would have been without them. Among people based in the University of Milano-Bicocca, I thank my office-mates, and in particular Maria, Katia, Alice, Alessandra and Marco M., who gave me the opportunity to openly talk about whatever came to my mind, and to express all my frustration as much as I needed. Among people settled at Northwestern University, I want to thank my ex-colleague and present friend Sladjana, who introduced me to the beauty of Chicago, as well as to Serbian music, to which I am now addicted. Thank you, for having encouraged me through the several e-mails, chats and skype talks we had during the past months and for the great time we had together when we shared the same office! I

am also grateful to Jim for the patience he demonstrated both in proofreading part of this manuscript and in listening to me even when I needed 5 minutes to produce a quite meaningful sentence, but most importantly for being my friend. A special “thank you” goes also to Mary Cosic, who made some of my American bad days much better: thanks for being such a nice person!

Now it is time to thank all my friends who had a big part in my life in the past four years. First, I want to thank my best friend, Laura: there are so many reasons why I should thank you that I do not know where to start, really. I am so happy that you are part of my life. You are the one I can always count on, the one who always knows what to do with me, the one who knows me the best. Thank you for always being there. I am also thankful to my dear friend Silvia, with whom I always learn something new about myself and who always makes me feel fully understood. Then, thanks to all my other dear friends: Simona, Elisa, Dario, Pietro, Marco Z., Selena, Carola, and all the other people with whom I spent nice moments in the past four years.

I could not forget to mention all the people who participated in this study. Therefore, I would like to thank all the patients who kindly gave their permission to be tested, as well as the control participants, among which some members of my family. One of them, Martina, is not only an experimental subject but also a very supportive aunt, who was able to give me the right advice at the right moment. Thank you a lot.

Finally, and most importantly, I would like to say “thank you” to the two people who – more than anyone else – made all this possible: my parents, Augusta and Giuseppe. Thanks for all you know I should be thankful. Thank you for always being on my side in any decisions I make, thank you for supporting and encouraging me. I will always be grateful for that. I love you.

## 11. References

- Aggujaro, S., Crepaldi, D., Pistarini, C., Taricco, M. & Luzzatti, C. (2006). Neuro-anatomical correlates of impaired retrieval of verbs and nouns: Interaction of grammatical class, imageability and actionality. *Journal of Neurolinguistics*, 19: 175-194.
- Baayen, R. H., Burani, C., & Schreuder, R. (1997a). Effects of semantic markedness in the processing of regular nominal singulars and plurals in Italian. In G. E. Booij and J. van Marle (Eds.), *Yearbook of morphology 1996*. Dordrecht: Kluwer Academic.
- Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997b). Singulars and plurals in Dutch: Evidence for a parallel dual route model. *Journal of Memory and Language*, 37: 94–117.
- Baayen, R.H., Davidson, D.J. & Bates, D.M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, 59: 390-412.
- Barbieri, E., Basso, A., Frustaci, M., & Luzzatti, C. (2010). Argument structure deficits in aphasia: New perspective on models of lexical production. *Aphasiology*, 24: 1400-1423.
- Bastiaanse, R. & van Zonneveld, R. (2005). Sentence production with verbs of alternating transitivity in agrammatic Broca's aphasia. *Journal of Neurolinguistics*, 18: 57-66.
- Bates, E., Burani, C., D'Amico, S. & Barca, L. (2001). Word reading and picture naming in Italian. *Memory and Cognition*, 29: 986-999.
- Ben-Shachar, M., Hendler, T., Kahn, I., Ben-Bashat, D., & Grodzinsky, Y. (2003). The neural reality of syntactic transformations: evidence from functional magnetic resonance imaging. *Psychological Science*, 14: 433-440.
- Benson, F. & Ardila, A. (1996). *Aphasia. A clinical perspective*. New York: Oxford University Press.
- Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997a). Verb retrieval in aphasia. 1. Characterizing single word impairments. *Brain and Language*, 56: 68–106.
- Berndt, R. S., Mitchum, C. C., Haendiges, A. N., & Sandson, J. (1997b). Verb retrieval in aphasia. 2. Relationship to sentence processing. *Brain and Language*, 56: 107–137.
- Berndt, R. S., Haendiges, A. N., Burton, M. W., & Mitchum, C. C. (2002). Grammatical class and imageability in aphasic word production: Their effects are independent. *Journal of Neurolinguistics*, 15: 353–371.
- Bird, H., Howard, D. & Franklin, S. (2000). Why is a verb like an inanimate object? Grammatical category and semantic category deficits. *Brain and Language*, 72: 246-309.

- Bird, H., Howard, D. & Franklin, S. (2001). Noun-verb differences? A question of semantics: A response to Shapiro and Caramazza. *Brain and Language*, 76: 213-222.
- Bird, H., Howard, D. & Franklin, S. (2002). "Little words" not really: Function and content words in normal and aphasic speech. *Journal of Neurolinguistics*, 15: 209-237.
- Bock, K. & Levelt, W.J.M. (1994). Language production: grammatical encoding. In M.A. Gernsbacher (Eds.). *Handbook of psycholinguistics*. San Diego: Academy Press.
- Buchanan, L., McEwen, S., Westbury, C. & Libben, G. (2003). Semantic and semantic error: Implicit access to semantic information from words and nonwords in deep dyslexia. *Brain & Language. Special Issue: Meaning in language*, 84: 65-83.
- Burzio, L. (1986). *Italian Syntax*. Dordrecht: Reidel.
- Butterworth, B. & Howard, D. (1987). Paragrammatisms. *Cognition*, 26: 1-37.
- Byng, S. & Black, M. (1989). Some aspects of sentence production in aphasia. *Aphasiology*, 3: 241-263.
- Canseco-Gonzalez, E., Shapiro, L. P., Zurif, E. B., & Baker, E. (1990). Predicate-argument structure as a link between linguistic and nonlinguistic representations. *Brain and Language*, 39: 391-404
- Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, 14: 177-208.
- Caramazza, A. & Zurif, E.B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, 3: 572-582.
- Caramazza, A., & Hillis, A. (1991). Lexical organization of nouns and verbs in the brain. *Nature*, 349: 788-790.
- Chomsky, N. (1981). *Lectures on Government and Binding*. Dordrecht: Foris Publications.
- Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA: MIT Press.
- Chomsky, N. & Lasnik, H. (1991). Principles and parameters theory. In Jacobs, J., von Stechow, A., Sternefeld, W. & Venneman, T. (Eds) *Syntax: An international handbook of contemporary research*. Berlin: de Gruyter.
- Cohen, L. , Dehaene, S. and Verstichel, P. (1994). Number words and number non-words: A case of deep dyslexia extending to arabic numerals. *Brain*, 117:267-279.
- Colangelo, A. & Buchanan, L. (2005). Semantic ambiguity and the failure of inhibition hypothesis as an explanation for reading errors in deep dyslexia. *Brain and Cognition*, 57: 39-42.
- Coltheart, M. (2000). Deep dyslexia is right-hemisphere reading. *Brain and Language*, 71: 299-309.

- Coltheart, M., Patterson, K. & Marshall, J.C. (1980). *Deep Dyslexia*. London: Routledge & Kegan Paul.
- Coltheart, M., Patterson, K., & Marshall, J. C. (1987). Deep dyslexia since 1980. In M. Coltheart & K. Patterson (Eds.), *Deep dyslexia* (2nd ed.). London: Routledge & Kegan Paul.
- Coltheart M, Curtis B, Atkins P & Haller P. (1993). Models of reading aloud: dual-route and parallel-distributed-processing approaches. *Psychological Review*, 100: 589-608.
- Coltheart, M., Rastle, K., Perry, C., Langdon, R. & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, 108: 204-256.
- Crepaldi, D., Aggujaro, S., Arduino, L.S., Zonca, G., Ghirardi, G., Inzaghi, M.I., et al. (2006). Noun-verb dissociation in aphasia: The role of imageability and the functional locus of the lesion. *Neuropsychologia*, 44: 73-89.
- Crepaldi, D., Berlingeri, M., Paulesu, E. & Luzzatti, C. (2011). A place for nouns and a place for verbs? A critical review of neurocognitive data on grammatical-class effects. *Brain and Language*, 116: 33-49.
- Damasio, A.R. & Tranel, D. (1993). Nouns and verbs are retrieved with differently distributed neural systems. *Proceeding of the National Academy of Science*, 90: 4957-4960.
- De Bleser, R., & Kauschke, C. (2003). Acquisition and loss of nouns and verbs: parallel or divergent patterns? *Journal of Neurolinguistics*, 16, 213-229.
- Den Ouden, D-B., Fix, S., Parrish, T.B. & Thompson, C.K. (2009). Argument structure effects in action verb naming in static and dynamic conditions. *Journal of Neurolinguistics*, 22: 196-215.
- Dragoy, O., & Bastiaanse, R. (2010). Verb production and word order in Russian agrammatic speakers. *Aphasiology*, 24: 28-55.
- Fodor, J.A. (1983). *Modularity of Mind: An Essay on Faculty Psychology*. Cambridge, Mass.: MIT Press.
- Friedman, R.B. & Perlman, M.B. (1982). On the underlying causes of semantic paralexias in a patient with deep dyslexia. *Neuropsychologia*, 20: 559-568.
- Friedmann, N. (2000). Moving verbs in agrammatic production. In R. Bastiaanse & Y. Grodzinsky (Eds.), *Grammatical disorders in aphasia: A neurolinguistic perspective*. London: Whurr.
- Friedmann, N., Taranto, G., Shapiro, L.P. & Swinney, D.(2008). The leaf fell (the leaf): The online processing of unaccusatives. *Linguistic Inquiry*, 39: 355-377.
- Garrett, M.F. (1980). Levels of processing in sentence production. In Butterworth, B. (Eds). *Language production* (vol.1). New York: Academic Press.
- Gentner, D. (1981). Some interesting differences between nouns and verbs. *Cognition and Brain Theory*, 4: 161-178.



- Geschwind, N. (1965). Disconnection syndromes in animals and man. *Brain*, 88: 237-294, 585-644.
- Goldberg, A.E. (1995) *Constructions: A construction grammar approach to argument structure*. Chicago University Press, Chicago.
- Goldberg, A.E. (2003). Constructions: A new theoretical approach to language. *Trends in Cognitive Sciences*, 7: 219-224.
- Grimshaw, J. (1990). *Argument structure*. Cambridge, MA: The MIT press.
- Grodzinsky, Y. (2000). The neurology of syntax: Language use without Broca's area. *Behavioral and Brain Sciences*, 23: 1-71.
- Hillis, A., & Caramazza, A. (1995). Representation of grammatical knowledge in the brain. *Journal of Cognitive Neuroscience*, 7: 369-407.
- Jackendoff, R. (1977). *X-bar syntax*. Cambridge, MA: MIT Press.
- Jaeger, T.F. (2009). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, 59: 434-446.
- Jonkers, R. (1998). *Comprehension and production of verbs in aphasic speakers*. Groningen, GRODIL (Groningen Dissertations in Linguistics)
- Jonkers, R. (2000). Verb-finding problems in Broca's aphasics. In R. Bastiaanse, & Y. Grodzinsky (Eds.), *Grammatical disorders in aphasia: A neurolinguistic perspective*. London: Whurr.
- Jonkers, R., & Bastiaanse, R. (1996). The influence of instrumentality and transitivity on action naming in Broca's and anomic aphasia. *Brain and Language*, 55: 37-39.
- Jonkers, R., & Bastiaanse, R. (1998). How selective are selective word class deficits?: Two case studies of action and object naming. *Aphasiology*, 12: 193-206.
- Kegl, J. (1995). Levels of representation and units of access relevant to agrammatism. *Brain and Language*, 50: 151-200.
- Kemmerer, D., & Tranel, D. (2000). Verb retrieval in brain-damaged subjects: 1. Analysis of stimulus, lexical, and conceptual factors. *Brain and Language*, 73: 347-392.
- Kim, M., & Thompson, C. K. (2000). Patterns of comprehension and production of nouns and verbs in agrammatism: implications for lexical organization. *Brain and Language*, 74: 1-25.
- Kim, M., & Thompson, C. K. (2004). Verb deficits in Alzheimer's disease and agrammatism: implications for lexical organization. *Brain and Language*, 88: 1-20.

- Kiss, K. (2000). Effect of verb complexity on agrammatic aphasics' sentence production. In R. Bastiaanse, & Y. Grodzinsky (Eds.), *Grammatical disorders in aphasia: A neurolinguistic perspective*. London: Whurr
- Kohn, S. E., Lorch, M. P., & Pearson, D. M. (1989). Verb finding in aphasia. *Cortex*, 25, 57–69.
- Laudanna, A: & Voghera, M. (2002). Nouns and verbs as grammatical classes in the lexicon. *Rivista di Linguistica*, 14.1: 9-26.
- Lee, J. & Thompson, C.K. (2011). Real-time production of arguments and adjunct in normal and agrammatic speakers. *Language and Cognitive Processes*, 26: 985-1021.
- Lee, M. & Thompson, C.K. (2004). Agrammatic aphasic production and comprehension of unaccusative verbs in sentence contexts. *Journal of Neurolinguistics*, 17: 315-330.
- Levelt, W.J.M. (1989). *Speaking: From intention to articulation*. MIT Press.
- Levelt, W.J.M. (2001). Spoken word production: A theory of lexical access. *Proceedings of the National Academy of Sciences*, 98: 13464–13471.
- Levelt, W. J. M., Roelofs, A. & Meyer, A. S. (1999) A theory of lexical access in speech production. *Behavioral and Brain Sciences*, 22, 1–38.
- Levin, B. (1993). *English verb classes and alternations: A preliminary investigation*. Chicago: The University of Chicago Press.
- Lichtheim, L. (1885). On aphasia. *Brain*, 7: 433-484.
- Linebarger, M.C., Schwartz, M.F. & Saffran, E.M. (1983). Sensitivity to grammatical structure in so-called agrammatic aphasics. *Cognition*, 13: 361-392.
- Lonzi, L., & Luzzatti, C. (1995). Omissions of prepositions in agrammatism and the Universal Grammar constraint of recoverability. *Brain and Language*, 51, 129–132.
- Lukatela, K., Shankweiler, D. & Crain, S. (1995). Syntactic processing in agrammatic aphasia by speakers of a Slavic language. *Brain and Language*, 49: 50-76.
- Luzzatti, C. (2005). La riabilitazione dei deficit morfo-sintattici. In Mazzucchi, A. (Eds). *La riabilitazione neuropsicologica*. Milano: Masson.
- Luzzatti, C., Willmes, K., & De Bleser, R. (1994). *Aachener Aphasie Test – Versione Italiana*. Firenze: Organizzazioni Speciali.
- Luzzatti, C., & De Bleser, R. (1996). Morphological processing in Italian agrammatic speakers: Eight experiments in lexical morphology. *Brain and Language*, 54, 26–74.

- Luzzatti, C., Mondini, S. & Semenza, C. (2001). Lexical representation and processing of morphologically complex words: Evidence from the reading performance of an Italian agrammatic patient. *Brain and Language*, 79: 345-359.
- Luzzatti, C., Toraldo, A., Guasti, M.T., Ghirardi, G., Lorenzi, L. & Guarnaschelli, C. (2001). Comprehension of reversible active and passive sentences in agrammatism. *Aphasiology*, 15: 419-441.
- Luzzatti, C., Raggi, R., Zonca, G., Pistarini, C., Contardi, A. & Pinna, G.D. (2002). Verb–Noun Double Dissociation in Aphasic Lexical Impairments: The Role of Word Frequency and Imageability. *Brain and Language*, 81: 432-444.
- Marelli, M., Aggujaro, S., Scola, I., Molteni, F. & Luzzatti, C. (2009). Semantic and morphological effects in deep dyslexia. *Europa Medicophysica*, 45.
- Marshall, J. C., & Newcombe, F. (1973). Patterns of paralexia: A psycholinguistic approach. *Journal of Psycholinguistic Research*, 2, 175–199.
- McAllister, T., Bachrach, A., Waters, G., Michaud, J. & Caplan, D. (2009). Production and comprehension of unaccusatives in aphasia. *Aphasiology*, 23: 989-1004.
- McCarthy, R. & Warrington, E.K. (1985). Category specificity in an agrammatic patient: The relative impairment of verb retrieval and comprehension. *Neuropsychologia*, 23: 709-727.
- Miceli, G., Silveri, M.C., Villa, G. & Caramazza, A. (1984). On the basis for the agrammatic's difficulty in producing main verbs. *Cortex*, 20, 207-240.
- Newcombe, F. & Marshall, J.C. (1980). Response monitoring and response blocking in deep dyslexia, in M. Coltheart, K. Patterson, J.C. Marshall (Eds.). *Deep dyslexia*. London: Routledge & Kegan Paul.
- Nolan, K.A. & Caramazza, A. (1982). Modality-independent impairments in word-processing in a deep dyslexic patient. *Brain and Language*, 16: 237-264.
- Patterson, K.E. & Marcel, A.J. (1977). Aphasia, dyslexia and the phonological coding of written words. *Quarterly Journal of Experimental Psychology*. 29: 307-318.
- Perlmutter, D. (1978). *Impersonal Passive and the Unaccusative Hypothesis*. Proceedings of the Berkeley Linguistics Society 4.
- Pinker, S. (1989). *Learnability and cognition: The acquisition of argument structure*. Cambridge, MA: MIT Press.
- Plaut, D.C. & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology*, 10: 377-500.
- Rapp, B. & Caramazza, A. (2002). Selective difficulties with spoken spoken nouns and written verbs: A single case study. *Journal of Neurolinguistics*, 15: 373-402.

- Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition*, 64: 249-284.
- Rosenbeck, J.C., Kent, D.R. & La Pointe, L.L. (1989). Apraxia of speech : An overview and some and some perspectives. In Rosenbeck, J.C., McNeil, M.R. & Aronson, A.E. (eds.). *Apraxia of speech*. College Hill Press: San Diego, CA.
- Saffran, E. M., Boygo, L. C., Schwartz, M. F., & Marin, O. S. M. (1980). Does deep dyslexia reflect right hemisphere reading? In M. Coltheart, K. E. Patterson, & J. C. Marshall (Eds.) *Deep dyslexia*. London: Routledge & Kegan Paul.
- Sánchez-Alonso, S., Martínez-Ferreiro, S. & Bastiaanse, R. (2011). *Deciphering unaccusativity in agrammatic Spanish monolinguals and Spanish-Catalan bilinguals*. Poster presented at the 12<sup>th</sup> International Science of Aphasia Conference, Barcelona.
- Schwartz, M.F., Saffran, E.M. & Marin, O.S.M. (1980a). The word order problem in agrammatism. I. Comprehension. *Brain and Language*, 10: 249-62.
- Schwartz, M.F., Saffran, E.M. & Marin, O.S.M. (1980b). Fractionating the reading process in dementia: Evidence for word-specific print-to-sound associations. In: M. Coltheart, K. Patterson and J.C. Marshall (Eds.) *Deep Dyslexia*, London: Routledge & Kegan Paul.
- Shallice, T., & Warrington, E. (1980). Single and multiple component central dyslexic syndromes. In M. Coltheart, K. E. Patterson, & J. C. Marshall (Eds.) *Deep dyslexia*. London: Routledge & Kegan Paul.
- Shapiro, L. P., Zurif, E., & Grimshaw, J. (1987). Sentence processing and the mental representation of verbs. *Cognition*, 27: 219-246.
- Shapiro, L.P. & Levine, B.A. (1990). Verb processing during sentence comprehension in aphasia. *Brain and Language*, 38: 21-47.
- Shapiro, L.P., McNamara, P., Zurif, E., Lanzoni, S., & Cermak, L. (1992). Processing complexity and sentence memory: Evidence from amnesia. *Brain and Language*, 42: 431-453.
- Shapiro, L.P., Gordon, B., Hack, N. & Killackey, J. (1993). Verb-argument structure processing in complex sentences in Broca's and Wernicke's aphasia. *Brain and Language*, 45: 423-447.
- Shetreet, E., Palti, D., Friedmann, N., & Hadar, U. (2007). Cortical representation of verb processing in sentence comprehension: number of complements, subcategorization and thematic frames. *Cerebral Cortex*, 17: 1958-1969.
- Shetreet, E., Friedmann, N. & Hadar, U. (2009). The neural correlates of linguistic distinctions: Unaccusative and unergative verbs. *Journal of Cognitive Neuroscience*, 22: 2306-2315.

- Thompson, C. K. (2003). Unaccusative verb production in agrammatic aphasia: the argument structure complexity hypothesis. *Journal of Neurolinguistics*, *16*, 151-167.
- Thompson, C., Lange, K., Schneider, S., & Shapiro, L. (1997). Agrammatic and non-brain-damaged subjects' verb and verb argument structure production. *Aphasiology*, *11*, 473-490.
- Thompson, C. K., Bonakdarpour, B., Fix, S., Blumenfeld, H., Parrish, T., Gitelman, D., et al. (2007). Neural correlates of verb argument structure processing: an fMRI study. *Journal of Cognitive Neuroscience*, *19*, 1753-1767.
- Thompson, C.K., & Lee, M. (2009). Psych verb production and comprehension in agrammatic Broca's aphasia. *Journal of Neurolinguistics*, *22*: 354-369.
- Thompson, C.K., Bonakdarpour, B. & Fix, S.F. (2010). Neural mechanisms of verb argument structure processing in agrammatic aphasic and healthy age-matched listeners. *Journal of Cognitive Neuroscience* *22*, 1993–2011.
- Toraldo, A., Cattani, B., Zonca, G., Saletta, P., & Luzzatti, C. (2006). Reading disorders in a language with shallow orthography: A multiple single-case study in Italian. *Aphasiology*, *20*: 823-850.
- Tranel, D., Manzel, K., Asp, E. & Kemmerer, D. (2008). Naming dynamic and static actions: neuropsychological evidence. *Journal of Physiology – Paris*, *102*: 80-94.
- Wernicke, C. (1874). *Der aphasische Symptomenkomplex*. Cohn & Weigart: Breslau, Germany.
- Zingeser, L.B. & Berndt, R.S. (1988). Grammatical class and context effects in a case of pure anomia: Implications for model of language processing. *Cognitive Neuropsychology*, *5*: 473-516.